Chapter 2

LITERATURE SURVEY

CHAPTER - 2

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2.1 Introduction

This chapter begins with a brief discussion on RS technology, the LU/LC analysis, followed by change detection studies, land surface temperature variation and UHI phenomenon. A brief introduction about the modern tools like GIS, GPS, and application software are also discussed.

2.2 Remote sensing

Remote sensing technology is used to acquire and interpret geospatial data to derive information about earth features, objects, oceans, and atmosphere. Exploration of earth's natural resources is essential for the socio-economic development of any country. The state-of-the-art technology of space based earth observation systems offers timely and accurate information on various natural resources such as land, water, forests, mineral resources etc. The remote sensing is a powerful tool for mapping/ inventorying, monitoring and managing of natural resources due to the inherent advantages of synoptic viewing, repetitive imaging, capability to study inaccessible areas, relatively at low cost and real time/near real time availability of data. Remote sensing is mainly concerned with the measurement or acquisition of information about an object without being in physical contact with the object under study. The term remote sensing is restricted to methods, which employ electromagnetic waves as the means for collection of information about the object. Depending on its physical features and properties, the earth surface reflects or reradiates or emits different kinds and amounts of electromagnetic energy in various wavelengths. The measurement of reflected or radiated or emitted electromagnetic radiation forms the basis for understanding the characteristic of earth's surface features (Lillesand and Kiefer, 2003; Sabins, 1997). Remote sensed data of the land surface is possible across a wide range of wavebands, from the visible (VIS), near infrared (NIR), short wave infrared (SWIR), mid-infrared (MIR), thermal infrared (TIR), and microwave (MW) regions of the electromagnetic spectrum.

2.3 Stages in remote sensing

The process of remote sensing involves a number of processes like energy emission from source, data analysis, and information extraction. The remote sensing stages are described in following steps.

2.3.1 Source of energy

The source of energy is a prerequisite for the process of remote sensing. Two types of energy sources exists indirect (example the Sun) and direct (RADAR). These sources emit electromagnetic radiations (EMRs) which can be sensed by the sensors.

2.3.2 EMR interaction with the atmosphere

The interaction of EMR with the atmosphere while traveling from the source to earth features and from earth features to the sensor often leads to atmospheric noise and as such undergoes changes in intensity and wavelength, which affects the sensing of the EMR by the sensor.

2.3.3 EMR interaction with earth features

The incident EMR on the earth features may be reflected, absorbed, transmitted, emitted by the ground objects, this depends upon the properties of the material in contact and also EMR itself.

2.3.4 EMR detection by the remote sensing sensor

The remote sensing device records the EMR after its interaction with the earth features which depends upon the amount of EMR and sensor's capabilities.

2.4 Types of remote sensing

2.4.1 Based on source of energy

The Sun is the main source of energy for remote sensing. The Sun's energy is either reflected (for visible wavelength) or absorbed and then re-emitted (for thermal infrared wavelength). The naturally available energy is measured by sensors of remote sensing systems are called passive sensors**.** This takes place when the Sun is illuminating the earth but during night there is no reflected energy available from the Sun. The active sensors in the remote sensing systems use their own source of energy for illumination. The data at any time of day or season can be obtained using these sensors. The examples for passive energy sources are solar energy and radiant heat while Synthetic Aperture Radar (SAR) is an example of active sensor.

2.4.2 Based on range of electromagnetic spectrum

2.4.2.1 Optical remote sensing

The visible, near infrared and short wave infrared portion of the electromagnetic spectrum is used by the optical remote sensing devices. These devices record EMR in the range of wavelengths from 300nm to 3000nm. Example of optical remote sensing device is bands of IRS P6 LISS IV sensor.

2.4.2.2 Thermal remote sensing

The thermal remote sensing devices operate in thermal range of electromagnetic spectrum these sensors record the energy emitted from the various earth features in the wavelength range of 3000nm to 5000nm (high temperature phenomenon like forest fire) and 8000nm to 14000nm (general earth features-lower temperature). Thus fire detection and thermal pollution studies uses thermal remote sensing. Example for this type of sensor is band 6 of LANDSAT ETM+.

2.4.2.3 Microwave remote sensing

The backscattered microwaves in the wavelength range of 1mm to 1m of electromagnetic spectrum recorded by a microwave remote sensor. Most of these sensors are active sensors like RADARSAT which are independent of weather and solar radiations.

2.4.3 Spectral reflectance

Reflectance of a surface is the measure of energy reflected and is defined as the ratio of energy reflected to energy incident. Reflectance is the function of wavelength and is called spectral reflectance.

The spectral reflectance, $R(\lambda) = E_R(\lambda)/E_I(\lambda)$

Where E_R - reflected energy and E_I - incident energy.

2.4.3.1 Spectral reflectance of vegetation

The spectral characteristics of vegetation depend on wavelength. The chlorophyll in the leaves reflect green wavelength, but strongly absorbs radiation in the red and blue wavelengths. The healthy leaves internal structure act as diffuse reflector of near-infrared wavelengths. Thus measuring and monitoring the infrared reflectance may be used to determine how healthy particular vegetation.

2.4.3.2 Spectral reflectance of water

Major portion of the radiation incident upon water is absorbed or transmitted not reflected. Water absorbs longer visible wavelengths and near-infrared radiations more than the shorter visible wavelengths. Thus water appears blue or blue-green due to stronger reflectance at shorter wavelengths and darker if viewed at red or near-infrared wavelengths. The factors influences the variability in reflectance of a water body are materials within water, depth of water and surface roughness of water.

2.4.3.3 Spectral reflectance of soil

The majority of radiation incident on a surface is either reflected or absorbed and small fraction is transmitted. The characteristics of soil are its moisture-content, texture, structure, iron-oxide content that determines its reflectance properties. The soil curve shows valley variations and fewer peaks. The presence of moisture content in soil decreases its reflectance.

2.4.4 Satellite sensor resolutions

2.4.4.1 Spatial resolution

Spatial resolution is the measure of smallest object that can be detected by a satellite sensor which represents area covered by a pixel on the ground. For example, spatial resolution of CARTOSAT-1 sensor is 2.5m x 2.5m, while IRS P6 LISS IV sensor has a spatial resolution of 5.6m x 5.6m for its multispectral bands and spatial resolution of LISS III is 23.5m x 23.5m in its first three bands.

2.4.4.2 Spectral resolution

Spectral resolution refers to the specific wavelength intervals in the electromagnetic spectrum for which a satellite sensor can record the data. It can also be defined as the number and dimension of specific wavelength intervals in the electromagnetic spectrum to which a remote sensing instrument is sensitive. For example, band 1 of the LANDSAT TM sensor records energy in the visible part of the spectrum in the range 0.45-0.52µm.

2.4.4.3 Radiometric resolution

Radiometric resolution defined as the sensitivity of a remote sensing detector to differentiate in signal strength as it records the radiant flux reflected or emitted from the terrain. For example, radiometric resolution is 7-bit for LISS III, the data file values for each pixel ranges from 0 to 128.

2.4.4.4 Temporal Resolution

The temporal resolution refers to how frequently it records imagery of a particular area. For example, the images of the same area of the globe acquired by CARTOSAT-1 for every 5 days, while IRS-1C/ID/Resourcesat LISS III does it for every 24 days. This is very much helpful in change detection studies.

2.5 Satellites and sensors

Earth Resources Technology Satellite (ERTS) also known as LANDSAT-1 was the first remote sensing satellite launched by NASA, USA for surveying, mapping and monitoring of earth resources. Realizing the potentials of this emerging technology many other countries like France (satellite series named SPOT), India (satellite series named IRS) have entered into this venture. So far, eight satellites in the series of LANDSAT have been launched of which first three carried Return Beam Vidicon (RBV) and Multispectral Scanner (MSS) imaging sensors and latest series satellites carried apart from MSS, advanced imaging sensor called Thematic Mapper (TM) with 30m spatial resolution and seven spectral bands (including short wave, mid infra red and thermal bands). The LANDSAT-7 satellite consists of Enhanced Thematic Mapper (ETM) sensor with 15m spatial resolution. Unlike geostationary satellites, the remote sensing satellites are Sun synchronous (same local equatorial crossing time of the descending node enabling the study of natural resources at various seasons under the same illumination condition), and polar orbiting type with a repetitively cycle of 16 to 26 days enabling repeated collection of data of the same place at the same local time for continuous monitoring of the earth's resources. The imaging payloads of these satellites operate in different spectral bands (parts of electromagnetic spectrum), spatial resolution (the smallest area on the ground being sensed by the sensors), and radiometric resolution (number of grey/reflectance levels which is distinguishable).

Remote sensing surveys carried out till date use data from remote sensing satellites such as LANDSAT, IRS and SPOT etc. Sometimes information is supplemented by aerial photos/airborne sensors. The resolutions offered by these satellites broadly fall in four categories low, medium, high and very high. Low resolution (70-80m pixel size) is offered by LANDSAT-MSS and IRS-LISS I sensors. Medium resolution (20-40m) is offered by LANDSAT-TM, IRS-LISS II, LISS III and SPOT HRV MLA sensors, high resolution (5-10m) is available from SPOT-HRV-PLA, IRS-1C/1D-PAN and Resourcesat-LISS-IV sensors. IKONOS, Quick Bird and Worldview satellites offer very high resolution of 4m, 1m and 2.4m and 0.61m (Lillesand and Kiefer, 2003).

2.5.1 Indian remote sensing satellites (IRS)

India's first operational indigenously developed Remote Sensing Satellite IRS-1A in the IRS series was successfully launched on March 17, 1988. IRS-1A was placed in the Sun-synchronous orbit of 904km with equatorial crossing time of the descending node being at 10.25AM, which enables the study of natural resources at various seasons under the same illumination condition. The repetitivity cycle of IRS-1A was 22 days. The major payloads of IRS-1A consisted of two types of imaging sensors, which operated in push broom scanning mode using Linear Imaging Self Scanning Sensor (LISS). In this mode of operation, each line of the image is electronically scanned by a linear array of detectors called Charge Coupled Devices (CCD) consisting 2048 elements. The first type of imaging sensor provided a spatial resolution of 72.5m and designated as LISS-I and the other type consisted of two separate imaging sensors providing spatial resolution of 36.25m and designated as LISS-IIA and LISS-IIB. LISS-I provided a swath of 148km on ground while LISS-IIA and LISS-IIB provided a composite swath of 145km on ground.

The spectral bands selected for the IRS-1A are almost similar to that of first four bands of LANDSAT TM sensor. As follow-on to IRS-1A, the second operational Remote Sensing Satellite, IRS-1B in the IRS series was launched successfully on August 29, 1991. IRS-1B is functionally identical to that of IRS-1A and phased in such a way as to provide a combined repetitivity cycle of 11 days, as against 22 days provided by each of them. The IRS-1A and IRS-1B data products are being used extensively in various application projects like geological mapping, ground water potential zone mapping, drought management, water resources management, LU/LC mapping, etc. IRS- 1C/1D launched in 1995/1997 have sensors such as (i) LISS-III (with spatial resolution of 23.5m and SWIR- Short Wave Infrared band) (ii) PAN (Panchromatic band with 5.8m spatial resolution) and (iii) WiFS (Wide Field Sensor- with 188m spatial resolution). The data from these sensors are being extensively utilized for various application projects. IRS-P6 (RESOURCESAT) launched in October 2003 has sensors like LISS-IV (5.8m spatial resolution in multi-spectral mode), AWiFS (Advanced Wide Field Sensor - with spatial resolution of 56m) and LISS-III (identical to one in IRS-1C/1D). CARTOSAT-1 launched in May 2005 provides panchromatic data with 2.5m spatial resolution and stereo products. IRS-1C/1D launched in 1995/1997 have sensors such as (i) LISS-III (with spatial resolution of 23.5m and SWIR- Short Wave Infrared band) (ii) PAN (Panchromatic band with 5.8m spatial resolution) and (iii) WiFS (Wide Field Sensor- with 188m spatial resolution). The data from these sensors are being extensively utilized for various application projects. IRS-P6 (RESOURCESAT) launched in October 2003 has sensors like LISS-IV (5.8m spatial resolution in multi-spectral mode), AWiFS (Advanced Wide Field Sensor - with spatial resolution of 56m) and LISS-III (identical to one in IRS-1C/1D). CARTOSAT-1 launched in May 2005 provides panchromatic data with 2.5m spatial resolution and stereo products.

2.5.2 LANDSAT Systems

Most popular remote sensing systems are LANDSAT satellites sensors the imagery acquired from these are widely used across the globe. NASA’s LANDSAT satellite programme was started in 1972 (Figure 2.1). It was formerly known as ERTS (Earth Resource Technology Satellite) programme. The first satellite in the LANDSAT series LANDSAT -1 (formerly ERTS-1) was launched on July 23, 1972. The sensors used in the

LANDSAT series are Return Beam Vidicon (RBV), Thematic Mapper (TM), Enhanced Thematic Mapper (ETM), Enhanced Thematic Mapper plus (ETM+) and the Multispectral Scanner (MSS). LANDSAT ETM+ (LANDSAT-7) was successfully launched in 1999. LANDSAT ETM+ contains four bands in Near Infrared-visible (NIR-VIS) region with 30m x 30m spatial resolution, two bands in Short Wave Infrared (SWIR) region with same resolution, one in Thermal Infrared (TIR) region (10.5-12.5μm) with spatial resolution of 60m x 60m and one panchromatic band of 15m resolution with revisit period of 16 days.

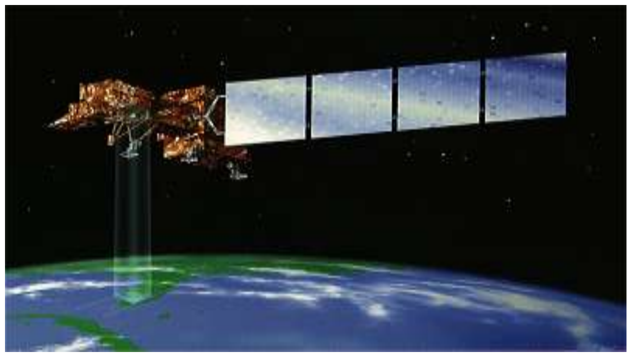

Figure 2.1: LANDSAT-7 ETM+ satellite imagery

LANDSAT-8 with operational land imager (OLI) and thermal infrared sensor (TIRS) launched on February 11, 2013 and it is the recent one in the series. OLI and TIRS images consist of 9 spectral bands with 30m spatial resolution for Bands 1 to 7 and 9. The resolution of panchromatic Band 8 is 15m. Thermal bands 10 and 11 provide more accurate surface temperatures at 100m resolution.

2.5.3 MODIS

MODIS (Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM). These satellites are imaging the entire earth's surface every 1 to 2 days in 36 bands, 1 in SWIR, 6 in Mid IR, 10 in Thermal-IR. Used for measurements of surface/cloud temperature, atmospheric temperature, cirrus clouds and water vapor and also of ozone with cloud top altitude.

2.5.4 ASTER sensor

ASTER is the acronym for Advanced Space borne Thermal Emission and Reflection Radiometer (Figure 2.2). It is a Japanese multispectral sensor carried on the TERRA satellite, which was launched on December 18, 1999. TERRA orbits the earth with a period of 98.1 minutes at a height of 720km. ASTER is a narrow-field of view sensor (the swath angle of the sensor is ±2.4°), which scans a swath of 60km on the ground every 16 days. The sensor has nine (9) reflective bands and five (5) bands in the thermal infrared (Figure 2.3), providing a wealth of spectral information to map earth surfaces. In the TIR region, ASTER has 12-bit quantization with 15m spatial resolution.

Figure 2.2: ASTER sensor

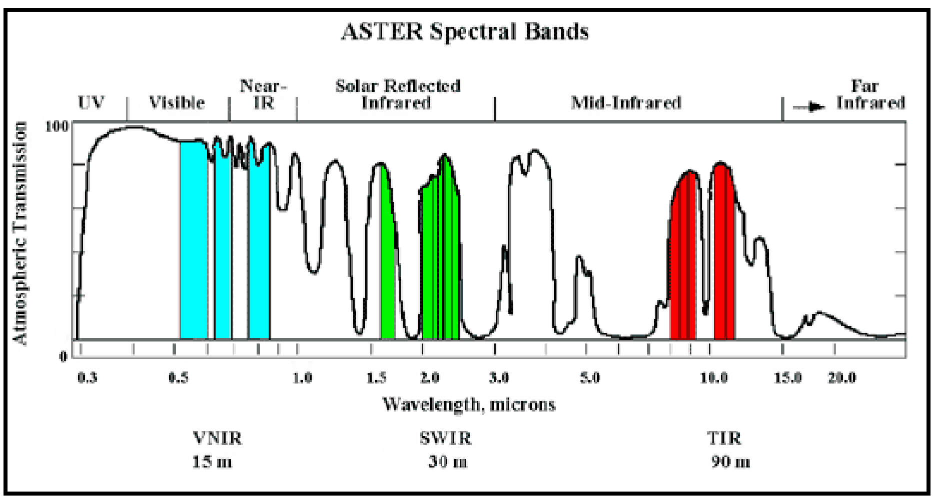

Figure 2.3: ASTER spectral bands

2.6 Digital image processing

2.6.1 Introduction

Digital Image Processing (DIP) is a technique which involves manipulation of digital image to extract information by means of digital computers; this technique is also referred to as satellite image processing. It involves combination of software-based image processing tools. The digital image processing process can be classified into three parts.

- Digital image pre-processing
- Digital image enhancement
- Digital image classification

2.6.2 Digital image pre-processing

The raw satellite images may contain errors in their geometry and radiometry. Hence before starting their interpretation it is important to rectify these images. This typically involves the initial processing of raw satellite image for correcting radiometric corrections, geometric distortions, calibration and also noise removal from the data which is also referred as image rectification. Thus image pre-processing is done before enhancement, manipulation, interpretation and classification of satellite images.

2.6.3 Digital image enhancement

Some image enhancement techniques are applied before visual interpretation of satellite images to improve, enhance features and segregating one feature type to the other. Image enhancement techniques consists of a number of statistical and image manipulation functions mainly contrast enhancement, density slicing, histogram equalization, spatial filtering, principal components analysis (PCA), colour transformations, image ratio (like NDVI), image fusion, image stacking etc.

2.6.4 Digital image classification

It is software–based image classification technique which involves automated information extraction and subsequent classification of multispectral satellite images with statistical decision rules, which groups pixels in different feature classes. Digital classification techniques are less time consuming than visual techniques. Digital satellite images can be classified digitally using unsupervised, supervised or hybrid type of image classification.

2.6.5 Information extraction

Unlike analog image processing, digital image processing uses the elements of image analysis, which relies mostly on the primary elements of tone and color of image pixels. There has been some success with expert systems and neural networks which attempt to enable the computer to mimic the ways in which humans interpret images. Expert systems accomplish this through the compilation of a large database of human knowledge gained from analog image interpretation which the computer draws upon in its interpretations. Neural networks attempt to 'teach' the computer what decisions to make based upon a training data set. Once it has 'learned' how to classify the training data successfully, it is used to interpret and classify new data sets.

2.6.6 Information output

The processed remotely sensed data must be placed into a format that can effectively transmit the information it was intended to. This can be done in a variety of ways including a printout of the enhanced image itself, and image map, a thematic map, a spatial database, summary statistics and graphs. There are number of ways in which the output can be displayed, knowledge not only of remote sensing, but of such fields GIS, cartography, and spatial statistics are a necessity. Thus with an understanding of these areas and how they interact one with another, it is possible to produce output that give the user the information needed without confusion. However, without such knowledge it is more probable that output will be poor and difficult to use properly, thus wasting the time and effort expended in processing the remotely sensed data.

2.7 Significance of remote sensing for the present study

Remote Sensing is the science and art of acquiring information (spatial, spectral and temporal) about material objects, area, or phenomenon, without coming into physical contact with the objects, or area, or phenomenon under investigation. In remote sensing, information transfer is accomplished by use of electromagnetic radiation (EMR). EMR is a form of energy that reveals its presence by the observable effects it produces when it strikes the matter. Remote Sensing provides spatial coverage by measurement of reflected, emitted and backscattered radiation, across a wide range of wavebands, from the earth’s surface and surrounding atmosphere.

- The reflectance characteristics of earth surface features can be quantified by measuring the portion of incident energy that is reflected which is termed as spectral reflectance.

- The graph of spectral reflectance (Figure 2.4) object as a function of wavelength is called a spectral reflectance curve.
- Spectral reflectance curves are commonly collected in advance of any remote sensing study.
- Survey in order to aid both the identification of different surfaces and to decide which remote sensor should be used to observe them.

2.8 Spectral signatures of natural surfaces

- The Reflectance (%): The ratio of energy reflected by a surface at a given wavelength.
- Rocks and soils: Reflectance is affected by minerals, surface alteration, texture, structure and water content.
- Vegetation: Related to photosynthetic activity (plant phenology), plant morphology, leaf shape and water content.
- The greater the photosynthesis, lower the reflectance in visible and higher the reflectance in the NIR.
- Water: Low reflectance and most of the radiation is absorbed or transmitted.

The reflective portion of the Electromagnetic Spectrum (EMS) ranges nominally from 0.4 to 3.75µm. Light of wavelength shorter than this is termed as ultraviolet (UV). The reflective portion of the EMS can be further subdivided into visible (0.4-0.7µm), near infrared (NIR) (0.7-1.1µm) and shortwave infrared (SWIR) (1.1-3.75µm).

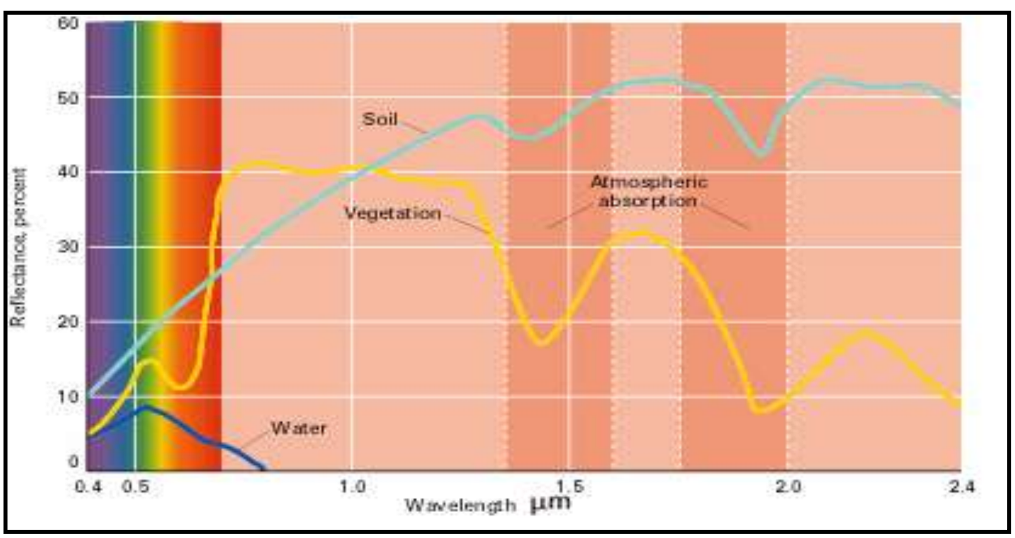

Figure 2.4: Spectral signatures of various cover types

Remote sensing converts an analogue photon flux to digital images, where the number of quantization levels is a function of the number of bits used to represent the photon flux. The number of quantization levels equals two to the power of the number of bits. The 7-bit data provide 128 (2^7) levels of quantization, 8-bit data 256 (2^8), 10-bit data 1024 (2^{10}) and 12-bit data 4096 (2^{12}). The ability of remote sensing measurements to distinguish different properties of the earth's surface in the EMS is partly determined by the level of quantization. Most remote sensing sensors have channels in the Red and NIR wavelength of the spectrum. The normalized difference vegetation index (NDVI), is derived from the ratio (NIR-Red)/(NIR+Red).

2.9 Thermal imaging

Thermal infrared radiations are electromagnetic waves with 3-20µm wavelength range. Most thermal sensors operate in the 3-5µm and 8-14µm range. The thermal infrared remote sensing system uses emitted energy, whereas the near infrared uses reflected energy, similar to visible light. The temperature effects are studied by sensing radiation emitted from the target in the thermal infrared region of the spectrum. There are two atmospheric windows with minimum absorption, shown in Figure 2.5 (Sabins, 1997). The water vapor and carbon dioxide absorb some of the energy across the spectrum and ozone absorbs energy in the 10.5-12.5µm intervals. During daylight hours solar reflectance contaminate the 3-4µm windows to some extent, so for earth studies measurements are made at night.

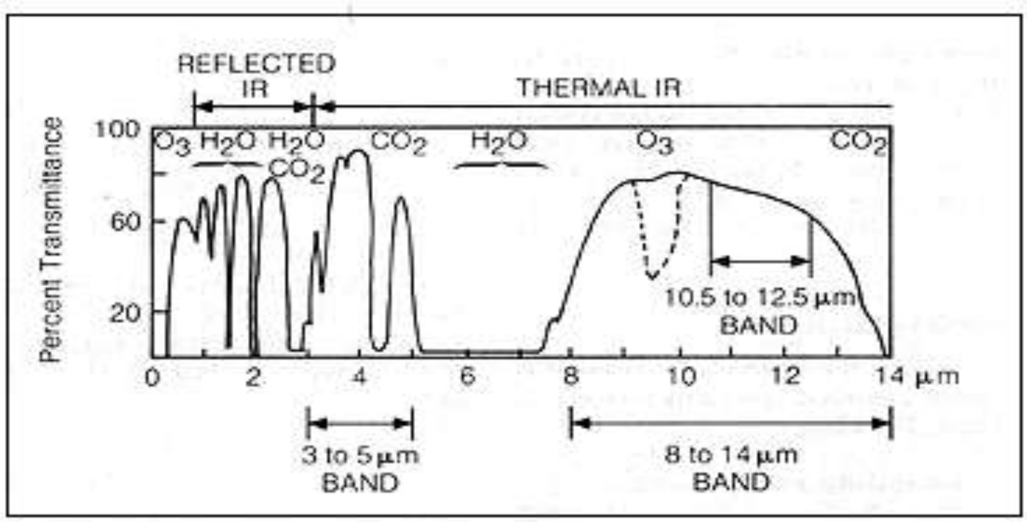

Figure 2.5: Thermal transmittance curve

2.9.1 The concept of emission of radiation

- Each radiator or energy source emits a characteristic wavelength of EM spectrum.
- The concept of a black body is widely used in such studies.
- A black body is defined as an object that absorbs the entire energy incident upon it, and emits the maximum amount of radiation at all wavelengths.
- There are various laws which relate radiators to those of a black-body.

2.9.1.1 Planck radiation (black body) law

The perfect black body (BB) is an ideal material that completely absorbs all incident radiation, converts it to internal energy leads to characteristic temperature profile. There is no transmittance or reflectance by BB only emission process. The amount of radiant energy depends on temperature and wavelength. Planck's radiation law gives the rate at which BB objects radiate thermal energy (http://fas.org/irp/imint/docs/rst/Sect9/Sect9_1.html).

$$E(\lambda, T) = \frac{2\pi hc^2}{\lambda^5 (e^{hc/\lambda kT} - 1)}$$

where [E] = W/m²/m

- λ … Wavelength
- c … Speed of light
- k … Boltzmann's constant
- h … Planck's constant
- e = 2.718 … Base of Natural Logarithms

- [T] = Kelvin
- [λ] = meter
- $h = 6.626 \times 10^{-34}$ Js
- $c = 2.998 \times 10^{8}$ m/s
- $k = 1.381 \times 10^{-23}$ J/K

Planck equation often used in remote sensing calculations, in differential form is given below

$$P_\lambda d\lambda = \frac{c_1 \lambda^{-5}}{e^{c_2/\lambda T} - 1} d\lambda \qquad \begin{aligned} c_1 &= 2\pi hc^2 = 3.74183 \times 10^{-16}\,\mathrm{W\,m^2}, \\ c_2 &= hc/k = 1.4388 \times 10^{-2}\,\mathrm{m\,K}. \end{aligned}$$

Where $P_\lambda = E_\lambda$ = spectral emission in $W/m^2/m$ at a wavelength λ.

2.9.1.2 Stefan-Boltzmann law

All matter at temperatures above absolute zero (-273°C) continually emit EM radiation. Terrestrial objects are also sources of radiation, though of a different magnitude and spectral composition than that of the Sun. The amount of energy that an object radiates can be expressed as follows: $E = sT^4$

E - Total radiant exitance from the surface of a material (Wm^{-2})

s - Stefan-Boltzmann constant, ($5.6697 \times 10^{-8}\ W\ m^{-2}\ K^{-4}$)

T - Absolute temperature (K) of the emitting material

Total energy emitted from an object (varies as T^4) increases rapidly with increase in temperature. Here energy source behaves like a blackbody.

2.9.1.3 Kirchhoff's law

No real body is a perfect emitter; its exitance is less than that of a black-body. It is important to know how the real exitance (M) compares with the black-body exitance (M_b). The emissivity (e) of the real body; $M = eM_b$.

The Figure 2.6 shows spectral wavelength versus emitted radiance from thermal radiators at various peak radiant temperatures ranging from that of the Sun to the earth's surface. Wien's displacement law gives the relationship between radiant body temperature and peak wavelength; $\lambda_m T = 2898$,Where T is the absolute temperature expressed in kelvin, λ_m is the wavelength at maximum radiant emittance and the constant 2898 is in units of µmK. The photospheric radiant temperature of about 6000K for the Sun, this peak is in the visible (centered on 0.58µm). A forest fire peaks around 5.0µm and for the earth's surface, as observed from space, peaks within 8-14µm intervals.

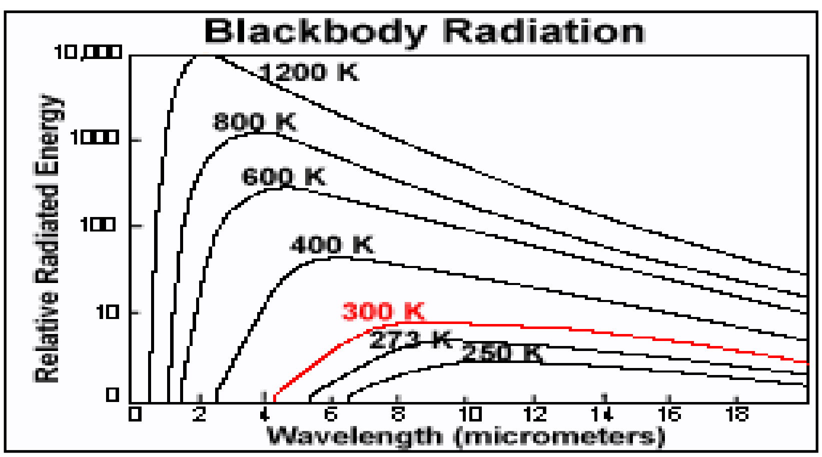

Figure 2.6: Wien Displacement law and emissivity effects

2.9.2 Heat capacity; thermal conductivity; thermal inertia

A primary objective of temperature measurements and related thermal responses (http://fas.org/irp/imint/docs/rst/Sect9/Sect9_3.html) is to infer something about the nature of the composition and other physical attributes of materials at the earth's surface and in its atmosphere.

Table 2.1

Shows the values of thermal properties for some surface materials

	Water	Sandy Soil	Basalt	Stainless Steel
K	0.0014	0.0014	0.0050	0.030
C	1.0	0.24	0.20	0.12
P	1.0	1.82	2.80	7.83
P	0.038	0.024	0.053	0.168

The internal properties also contribute for the temperature of a body (Table 2.1). The properties are as follows:

- Heat capacity (c): It is a measure of the increase in thermal energy content (Q) per degree of temperature rise which denotes the capacity of a material to store heat. Specific heat, $C = c/\rho$ (expressed in the units calories/gram/degree Centigrade) where ρ (rho) = density. Thus specific heat capacity is the heat capacity required to raise temperature of one gram mass of water through one degree Centigrade.
- Thermal conductivity (K): The rate at which heat passes through a specific thickness of a substance, conducted in one second across a one centimeter square area through a thickness of one cm at one degree Centigrade temperature gradient.
- Thermal inertia (P): The resistance of a material to temperature change, indicated by the time dependent variations in temperature during a full heating/cooling cycle for earth 24-hour day; $P = (Kc\rho)^{1/2}$.
- The internal temperature and emissivity determines the amount of radiation emitted by an object.
- The real objects absorption and emission properties described by emissivity (ε).
- $\varepsilon(\lambda)$ = Radiant flux of an object at given temperature/radiant flux of a blackbody at same temperature (ε depends on wavelength and temperature).
- The object is said to be a selective radiant if the emissivity of an object depends on wavelength.
- A gray body has $\varepsilon<1$ but is constant at all wavelengths.
- At any given wavelength, the radiant flux from a gray body is a constant fraction of that of a blackbody.

- Thermal imaging is performed in the wavelength region 8-14µm, not only because it includes an atmospheric window, which also contains the peak energy emissions for most surface features.
- For any given material type, emissivity is often considered constant in 8-14µm range (gray bodies).
- The emissivity values vary considerably with wavelength and material condition (Figure 2.7).

2.9.3 Blackbody/gray body/selective radiator

A black body has $\varepsilon_\lambda = 1$; A gray body has ε_λ = constant; A selective radiator $\varepsilon_\lambda = fn(\lambda)$. Emissivity of earth materials (http://www.icess.ucsb.edu/modis).

- Generally water, ice, and snow have a high emissivity, 0.94 to 0.99, in the thermal infrared region and green vegetation is structured and contains water so it has very high emissivity.

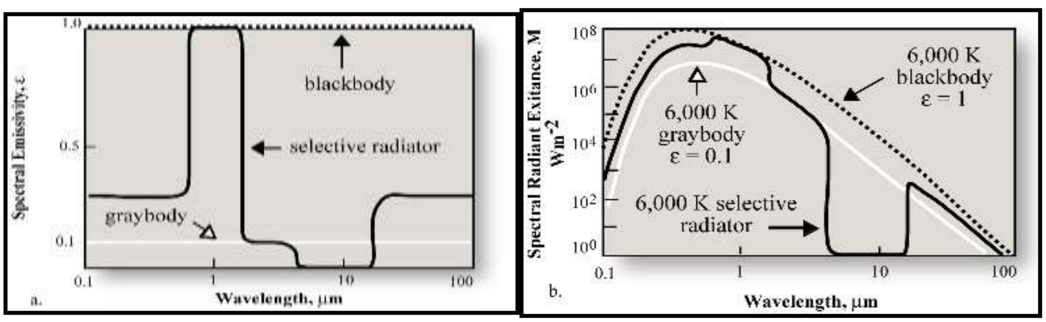

Figure 2.7: Spectral emissivity of a blackbody, a gray body, and a hypothetical selective radiator

- Soil and Minerals exhibit strong spectral features. The signature in the 3 to 5µm region depends strongly on the water and organic content. But dryer and purer soils have lower emissivity in this region.
- Senescent (dry) vegetation has a more variable emissivity, in the 3 to 5µm range, which depends on the type and structure of the cover type, the dryness etc.
- Refined, polished metals and manmade materials have lowest emissivity values.
- Rough dielectric materials such as asphalt and brick have emissivity values are in the same range as natural materials, approximately 0.90 to 0.98. Comparative studies of emissivities of various earth features are shown in Figure 2.8, 2.9 and 2.10.

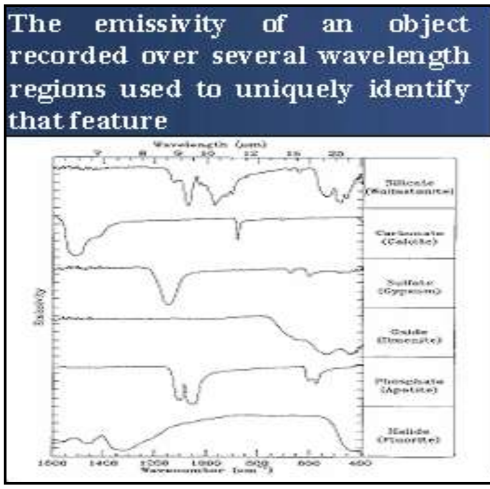

TABLE 5.2 Typical Emissivities of Various Common Materials Over the Range of 8 to 14 μm

Material	Typical Average Emissivity ε over 8–14 μm*
Clear water	0.98–0.99
Wet snow	0.98–0.99
Human skin	0.97–0.99
Rough ice	0.97–0.98
Healthy green vegetation	0.96–0.99
Wet soil	0.95–0.98
Asphaltic concrete	0.94–0.97
Brick	0.93–0.94
Wood	0.93–0.94
Basaltic rock	0.92–0.96
Dry mineral soil	0.92–0.94
Portland cement concrete	0.92–0.94
Paint	0.90–0.96
Dry vegetation	0.88–0.94
Dry snow	0.85–0.90
Granitic rock	0.83–0.87
Glass	0.77–0.81
Sheet iron (rusted)	0.63–0.70
Polished metals	0.16–0.21
Aluminum foil	0.03–0.07
Highly polished gold	0.02–0.03

Figure 2.8: Emissivities of minerals and of various common materials

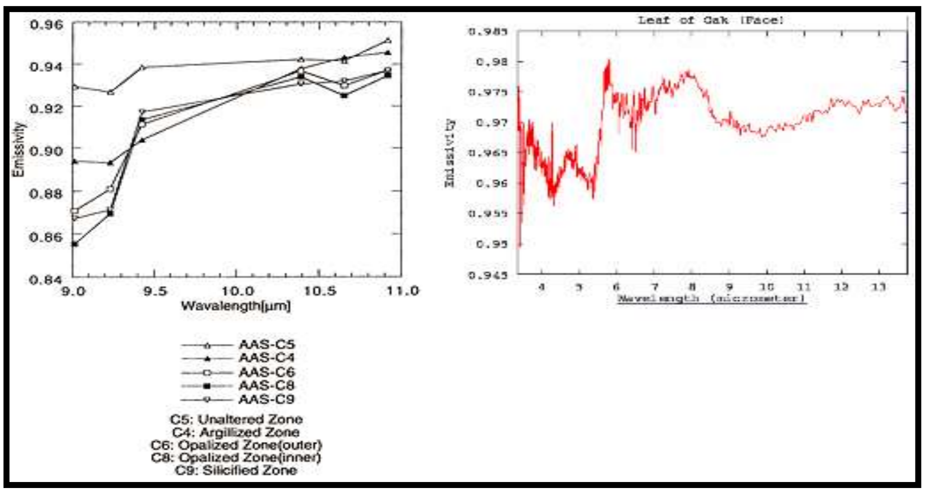

Figure 2.9: Selective radiator minerals

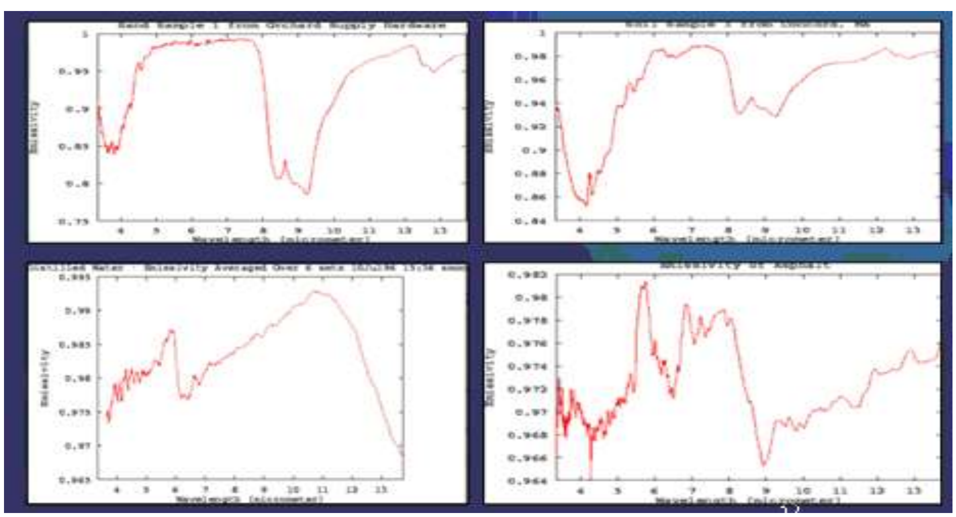

Figure 2.10: Emissivities of sand, soil, water and asphalt

2.9.4 Remote sensing and its applications

Satellite remote sensing techniques can provide information on land surface characteristics and also on the biophysical processes over the earth surfaces. As compared to the conventional techniques that provide such information, remote sensing techniques are having specific advantages. Their ability to provide spatial data at different spatial and temporal scales eliminate the problem of the availability of data for most of the time series studies even for the sites that are not in accessibility for the researcher. With the progress of remote sensing techniques during the past decade, they are now being used in a wide range of disciplines. Remote sensing systems are commonly used to survey, map and monitor the resources and environment of the earth, and also to explore planets. Global, regional and local natural resource survey and assessment strategies are now increasingly incorporating remotely sensed imagery to monitor current and historical vegetation dynamics.

2.9.5 Spatial information collection with satellite data

Most advanced method of remote sensing available today is the satellite remote sensing. These satellites based remote sensing techniques can be used in a wide range of applications such as communication, weather monitoring, navigation, military purpose and earth observation etc. Weather satellites carry cameras and other instruments pointed toward earth's atmosphere. Earth orbiting satellites have increasingly been used as data sources for better formulation of issues related to climatology. The spectral data in the regions of red and near Infrared of the electromagnetic spectrum have been extensively used in monitoring vegetation dynamics over the land. Data obtained in the thermal bands of the electromagnetic spectrum have been extensively used for the retrieval of LST.

2.10 GPS (Global Positioning System)

Global positioning system has revolutionized positioning concepts; though it is started primarily as a navigation system. It works on the principle of space resection. It has wide range of geodetic, geophysical, navigational, marine, military and social applications. The NAVASTAR GPS (Navigation Satellite Timing and Ranging Global Positioning System) is a satellite-based radio navigation system providing precise three-dimensional position, navigation and time information to suitably equipped users everywhere on a continuous basis (Goodchild, 1992). It is primarily a military system with limited access to civilian users. GPS receivers have been developed which observe signals transmitted by satellites and achieve sub-meter accuracy in point positioning. It has the following advantages over the classical methods. The inter-visibility between points is not required. It can be operated in all weather and day-and-night conditions. Distances up to thousands of kilometers can be measured, and is fast and economical.

2.11 GIS (Geographic Information System)

A geographic information system is a computer-based tool for capturing, managing, integrating, manipulating, analyzing and displaying data which is spatially referenced to the earth. GIS technology integrates common database operations such as query and statistical analysis with the geographic analysis and unique visualization using maps (David, *et al.*, 1991). These abilities distinguish GIS from other information systems and make it valuable in different fields for explaining events, predicting outcomes, and planning strategies. GIS performs these tasks better and faster than the old manual methods. Areas of GIS application can range from natural resources management to crime control and near real-time applications like flood warning and war theatre operations. Geologists use them to record locations of rock formations and for use in resource prospecting operations (Healy, 1991). GIS can build three dimensional models, where the topography of a geographical location can be represented with an x, y, z such data model is known as Digital Terrain (or Elevation) Model (DTM/DEM). The x and y dimensions of a DTM represent the horizontal plane, and z represents spot heights for the respective x, y coordinates. The data are represented by a DEM array (grid cells) or a Triangulated Irregular Network (TIN). The data sets derived from a DTM can be used to analyze environmental phenomena in forestry and stream sedimentation studies which are influenced by elevation, aspect or slope (Demers, 1999).

2.12 LU/LC analysis

Land use and land cover is related to factors like human activities, vegetation, soil types and topography. Although land-use is generally inferred based on the cover, yet both the terms being closely related are interchangeable. Land cover is an essential attribute in the surface of the earth that is shaped by geologic, hydrologic, climatic, atmospheric, and land use processes that occur at a range of spatial and temporal scales. In recent decades, the anthropogenic impact on land cover changes has unprecedentedly accelerated due to technological development and increase in human population. The information gained like land-use/land-cover permits a better understanding of the land utilization aspects on cropping patterns, fallow lands, forest, wastelands and surface water bodies, which is essential for developmental planning. Viewing the earth from space is now crucial to the understanding of the influence of man's activities on his natural resource base over time. In situations of rapid and often unrecorded land use change, observations of the earth from space provide objective information of human utilization of the landscape. Over the past years, data from earth sensing satellites has become vital in mapping the earth's features and infrastructures, managing natural resources and studying environmental change.

Conventional ground methods of land use mapping are labour intensive, time consuming and are done relatively infrequently. These maps will soon become outdated with the passage of time, particularly in a rapid changing environment. In fact, monitoring changes and time series analysis is quite difficult with traditional method of surveying. In recent years, satellite remote sensing techniques have been developed, which have proved to be of immense value for preparing accurate land use /land cover maps and monitoring changes at regular intervals of time.

2.13 LU/LC change detection analysis

Detection of changes in the land-use/land-cover involves use of data sets for at least two periods (Jensen, 1986); with the availability of multi-sensor satellite data at very high spatial, spectral and temporal resolutions, it is now possible to prepare updated and accurate land-use/land-cover map in less time, at lower cost and with better accuracy (Jensen and Patterson, 2001). This information not only provides a better understanding of land utilization aspects but also plays a vital role in the formulation of policies and program required for developmental planning. Remote sensing techniques offer benefits in the field of land-use/land-cover mapping and their change analysis. One of the major advantages of remote sensing systems is their capability for repetitive coverage, which is necessary for change detection studies at global and regional scales. The LU/LC changes have effects on a broad range of landscape and environmental parameters as well as the quality of water, land and air resources, eco-system process and function, biotic diversity, soil quality, run-off, and the climate system itself through greenhouse gas emission and resultant effects. In a particular region, the land use or land cover pattern is a result of natural and socio-economic factors which is used by human beings in different time and space. Nowadays, the massive agricultural and population pressure is gradually increasing the scarcity of land resource. The land use change occurs through natural processes even in the lack of human activities whereas land use change is the handling of land cover by people for numerous purposes like food, fodder, timber, fuel wood, leaf, waste, medicine, raw materials etc. Therefore, numbers of socio-economic and environmental factors are engaged for the transformation in land use and land cover. From different standpoints land use and land cover change has been studied in order to identify the diversity, factors, process and consequences of this land use and land cover change. Generally, urban growth is the movement and expansion of commercial and residential land towards periphery of an urban centre. This movement has long been considered as a symbol of regional economic strength for this particular urban centre. But, the benefits from it are progressively more balanced against the impacts on eco-system, including deterioration of water and air quality, rising the land surface temperature and loss of vegetation coverage, social fragmentation, socio-economic disparities, and infrastructure costs.

Remote sensing and GIS are well-established information technologies, which are broadly recognized in managing land and natural resources. Recently, some researchers have acknowledged that some diverse approaches for data gaining, land-use classification and analysis operate remote sensing satellite imagery as a source data in the origin of spatial data sets with high spatial and temporal resolution. To understand landscape dynamics, remote sensing and GIS is a cost effective and perfect alternative tool. It has been accepted that combination of remote sensing and geographic information systems (GIS), has been extensively applied as an influential and useful tool in determining land use and land cover change. On the basis of multi-spectral and multi-temporal remotely sensed data, digital change detection techniques and land surface temperature estimation techniques have demonstrated a great possibility as a means to understand landscape dynamics to perceive, map identification, and monitor temporal differences in land use types. In the natural science communities satellite imagery has been utilized perfectly for measuring quantitative and qualitative changes of terrestrial land cover. LANDSAT data are most extensively used for measuring the surface temperature and changing scenario of land use and land cover. By assessing physical or environmental condition of the study area, our objectives of this present study are to analyze temporal changes of land use land cover and the causes behind this. Another objective of this study is to analyze the effects of urban expansion with temporal extension of built-up area and population growth of Udupi taluk.

2.14 Normalized difference vegetation index (NDVI)

Status of the vegetation cover is a good indicator of the prevailing climatic conditions of a particular area. Satellite remote sensing facilitates the identification of vegetation cover and the changes over time very effectively compared to the conventional field surveying techniques. The NDVI is a vegetation sensitive indicator that reflects the pattern of spectral responses of ground objects in the visible and near-infrared regions of the electromagnetic spectrum. It is found to be a good indicator of the vegetation characteristics over the land surface. Rouse *et al*., (1974) defined the NDVI as (NIR-R)/ (NIR+R) where, NIR and R are the radiances or reflectances in the near- infrared and red spectral channels respectively.

Chlorophyll in plant leaves causes considerable absorption in the red light region of the electromagnetic spectrum in the incoming light while plant spongy mesophyll leaf structure creates considerable reflectance in the near infra-red region of the spectrum (Tucker, 1980; Jackson *et al.*, 1983). As a result, vigorously growing healthy vegetation has lower reflectance in the red light region and a higher reflectance in the near infra red region of the spectrum. This ultimately results in higher NDVI values for the vigorously growing healthy vegetations and it tends to become lower as the greenness of the vegetation decreases. The algorithm produces output values in the range of -1.0 to 1.0. Increasing positive NDVI values indicates increasing amounts of healthy and vigorous green vegetations. The values closer to zero and decreasing negative values indicate non vegetated features such as barren surfaces and water, snow, ice and clouds. Reed *et al*., (1994) and

Yang *et al*., (1998) have shown that the satellite derived NDVI data have the potential to provide temporal indicators of the onset, end, peak and duration of vegetation greenness as well as the rate of growth, senescence and periodicity of photosynthetic activity. Through long term data analysis, trends in such ecological indicators can also be assessed. Such analyses will then be helpful in improving our forecasting capabilities and could be used in making inferences about climate and drought conditions. Bayarjargal *et al*., (2000) have used the NOAA/AVHRR data for the detection of drought-affected regions by calculating the NDVI and the LST values for the drought and wet years separately. They also have developed a NDVI-LST space based drought indicator that can be used to detect and monitor drought distribution over Mongolia. The drought conditions of the central Asian zone mapped by Adyasuren and Bayarjargal (1995) based on the multi-temporal global vegetation index data from 1982-1987. They noticed that when drought events occur in the Mongolian Gobi Desert zone, the NDVI values reduce to low values which are same as the extra-arid land values.

Vegetation cover over the land surface is a good indicator of the occurrence of rainfall over an area. Therefore, NDVI values can also be used in monitoring the occurrences of rainfall at different spatio-temporal scales. Natural Resources and Animal Affairs Research centre researchers have studied the vegetation responses and rainfall relationship for the period from 1995 to 1997 for the south western part of Iran using NOAA/AVHRR Images. Their findings showed a higher dependence of NDVI on the rainfall in the previous month. Dayawansa *et al*., (2002) reported strong correlations among NDVI and the one month lag rainfall for the semiarid, dry and intermediate zones of Sri Lanka for the year 2002. The comparison between the AVHRR derived NDVI values and rainfall data shows dependence of the NDVI values on the sum of the amount of rainfall during the concurrent month and the two previous months during the two years period from 1996-1997 in two types of semi arid environments; sand dune and rocky located in the Negev Desert of Israel (Schmidt and Karnieli, 2000). The NDVI values could also be used in prediction of the changes of climatic parameters such as LST. In the Split Window Algorithm developed by Price (1984), the NDVI values are used to approximate the mean pixel emissivity of each pixel of the images. The combination of NDVI and LST was also proposed as a method for assessing the surface moisture status and fractional vegetation cover over non uniform land surfaces (Carlson *et al.*, 1994; Nemani *et al*., 1993).

2.15 Land surface temperature (LST)

The land surface temperature (LST) is a fundamental factor that regulates most physical, chemical and biological processes of the earth and is controlled by the surface energy balance, atmospheric state, thermal properties of the surface, and subsurface mediums. The physical properties of different types of surfaces, such as color, sky view factor, street geometry, and anthropogenic activities are important factors that determine LSTs in the surface of the earth. Therefore, the LST corresponds closely to the land cover characteristics and their distribution Land surface temperature (LST), controlled by the surface energy balance, atmospheric state, thermal properties of the surface, and subsurface media, is an important factor controlling most physical, chemical, and biological processes of the earth. In remote sensing, LST could be explained as the temperature of the surfaces of any object recorded by the sensor and is determined by the varying patterns of spectral responses of each object. Considering the spatial resolution of satellite remote sensing data, the LST in remote sensing can be defined as the average surface temperature of the ground under the pixel scale mixed with different fractions of surface types. In spite of the great importance in modeling and application of LST, confusions exits in both the use of the term and its determination with satellite thermal data. Numerous factors need to be quantified in order to estimate the LST accurately from satellite thermal data and therefore algorithms must be developed by taking all these factors into account.

In the estimation of LST from satellite thermal data, the digital number (DN) of image pixels first needs to be converted into spectral radiance or top of atmosphere reflectance using the sensor calibration data (Markham and Barker, 1986). However, the radiance converted from digital number does not represent a true surface temperature but a mixed signal or the sum of different fractions of energy. These fractions include the energy emitted from the ground, up welling radiance from the atmosphere, as well as the down welling radiance from the sky integrated over the hemisphere above the surface. Therefore, the effects of both surface emissivity and atmosphere must be corrected in the accurate estimation of LST (Qin *et al*., 2001). The Split Window Algorithm developed by Price (1984) is found to be the most extensively used algorithm for the retrieval of LST from satellite information. The algorithm performs the atmospheric and emissivity correction of LST. In this algorithm NDVI information of each pixel is used to approximate the mean pixel emissivity using the algorithm developed by Cihlar *et al.,* (1997). The algorithm also takes the advantage of the differential absorption in the two close infrared bands (Channel 4 and 5 of NOAA AVHRR/2 sensor) to account for the effects of absorption by atmospheric gasses. This avoids the error introduced by poorly constrained atmospheric molecular absorption coefficients, aerosol absorption/scattering coefficients, and atmospheric profiles (Kerr *et al*., 1992). They concluded that the estimated surface temperature values are found to be within error limits of less than 1°C. Uliveri *et al*., (1994) have also been used the same algorithm and have been able to retrieve the LST values under the conditions of India at higher accuracy.

2.16 Urban heat island (UHI)

Before human development, disturbance began of natural habitats, soils, and vegetation constituted part of a balanced ecosystem that managed precipitation and solar energy effectively (Getter and Rowe, 2006). The losses of these features have been replaced with impervious areas. In the United States, it is estimated that 10% of residential developments and 71% to 95% of industrial areas and shopping centers are covered with impervious areas. Today, two-thirds of all impervious area is in the form of parking lots, driveways, roads, and highways (Getter and Rowe, 2006). These increasing impervious areas consist of cities, towns, and suburbs. It is documented that urbanization can have significant effects on local weather and climate. Of these effects one of the most familiar is the UHI (Streuker, 2002). The increase of urbanization has greatly increased over the last century. Though it may seem the study of the UHI is fairly new, it actually was noticed and documented as far back as 1820. The UHI is a metropolitan area that is significantly warmer than its rural surroundings (Figure 2.11). The thermal characteristics of materials used in the city (asphalt, brick, concrete, glass, etc.) differ greatly from those found in the countryside (trees, grass, water bodies, bare soil, etc.). In addition, the canyon structure created by tall buildings enhances warming by the Sun. During the day the energy is trapped by multiple reflections and absorption by the buildings (Chapman and David, 2005). This stored energy in urban areas is then reradiated as long-wave radiation less efficiently than in rural areas during the night (Solecki *et al*., 2005) keeping the urban areas warmer than the surrounding rural areas, while the buildings play a role in reducing wind speed. The combination of reducing wind speed and cloud cover aid in the UHI becoming magnified. Heat island magnitudes are largest under calm and clear weather conditions. Increasing winds mix the air and reduce the heat island.

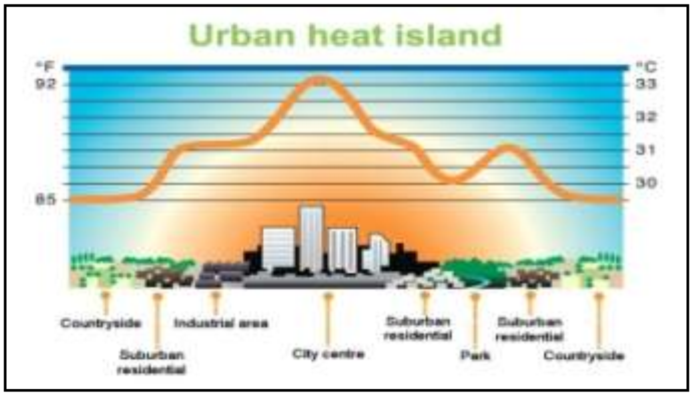

Figure 2.11: Urban heat island phenomenon

2.17 International scenario

In recent studies, quantitative approaches for urban thermal environment and related factors are widely seen. The earliest UHI study was conducted in 1965 in the urban southern Singapore. Subsequently, significant research has been done to study the diurnal, seasonal and spatio-temporal characteristics of urban thermal environment and identification of appropriate indices to quantify the bio-physical and demographic characteristics of urban landscape to explain the LST variations. Studies have established that UHI intensity is related to patterns of land use/cover changes, e.g., the composition of vegetation, water and built-up and their changes over a specific period. Various vegetation indices obtained from remote sensing images can be used in the assessment of vegetation cover qualitatively and quantitatively. Qualitative and quantitative studies on the relationship between and use/cover pattern and LST are imperative for effective urban land use planning. Increasing clouds reduce radiative cooling at night and also reduce the heat island (Voogt and Oke, 2003). Another component that adds to the creation of an UHI is from waste heat. Waste heat is emitted from a range of human activities-automobiles, air conditioning equipment, industrial facilities, and a variety of other sources, including human metabolism (Sailor and Dietsch, 2005). Air temperature also is reduced through evapotranspiration. Evapotranspiration occurs when plants secrete, or transpire, water vapor through pores in their leaves. The water draws heat as it evaporates, thus cooling the air surrounding the leaves in the process. Trees can transpire up to 100 gallons of water in a day. In a hot dry climate, this cooling effect equals that of five air conditioners running for 20 hours per day (Gray and Finster, 1999). In contrast to the natural landscape cities tend to have little vegetation, and due to large fractional cover of impervious surfaces there also tends to be less surface moisture in urban areas (Sailor and Dietsch, 2005). The increase in urban temperatures can affect public health, the environment, and the amount of energy that consumers use in the summertime cooling. Summertime heat islands increase energy demand for air conditioning, raising power plant emission of harmful pollutants. Higher temperatures also accelerate the chemical reaction that produces ground level ozone and smog (http://cfpub.epa.gov/ncea/risk). Over the next century, human induced warming is projected to raise global temperatures by an additional 3 to 7^{o}F (Chicago Climate Task Force, 2007) adding to the Global Warming Effect. In response to the increase in temperature, the Environmental Protection Agency (EPA) created the Heat Island Reduction Initiative (HIRI). Through its HIRI, established in 1997, the EPA is working with stakeholders to mitigate the heat island effect by promoting heat island reduction strategies which included planting shade trees, increasing urban vegetation cover, and installing cool roofing and paving materials that were reflective and emissive (Wong, 2008). Green roofs are one of the promoting strategies taking hold that helps reduce the UHI effect. A study was conducted by Kent State University in which 31 years of temperature data were studied for Toledo, Ohio. In this study an electronic remote reading thermometer was used with a thermograph that was maintained as a back-up system and was used occasionally when personnel were not available to read thermometers on weekends prior to 1983 (Schmidlin, 1989). The study utilized two stations, one downtown and one at a rural site (airport). The study found the average annual temperature was 2.0^{o}C warmer at the urban site than the rural site. The heat island was most intense during the summer months and least evident during winter and spring (Schmidlin, 1989). The freeze-free season, when corrected for the local effect of Lake Erie, was approximately 24 days longer at the urban site. In another study conducted on

Singapore to determine the remediation effects of green roofs on the UHI, researchers determined that gardens reduced roof ambient temperature by $4^{o}C$ and that heat transfers into the rooms below were lower. The team analyzed climatic data collected from various regions of Singapore and historical climatic data obtained from meteorological services. The researchers found that commercial- and business-district areas were hotter than the green areas by $2^{o}C$ (Hein, 2002).

NASA scientists presented a new research (http://www.nasa.gov) recently and concluded that over a three year period summer LST of cities in the northeast of America on an average of 7 - 9°C warmer than surrounding rural areas. Inference drawn about cities land surface temperatures, particularly densely-developed cities, tend to be elevated in comparison to surrounding areas and for the largest cities, analysis showed, the strongest heat islands. The forested regions surrounding cities have stronger heat islands compared to cities situated in grassy or desert environments. High temperatures at night time can have significant health related problems such as increase in the mortality of elderly people with pre-existing respiratory and cardiovascular illness. The lack of cooling at nighttime, rather than high daytime temperatures, that poses a health risk. Thus there is an urgent need to study temperature variation of developing cities so that a proper developmental planning in the formulation of policies could be implemented in future.

2.18 Indian scenario

All cities of India have witnessed rapid urbanization, which causes the natural landscape having predominantly vegetation cover and pervious areas, converted into built up and impervious area. This impervious area is largely contributed by use of materials like concrete, bricks, tiles etc for buildings and bitumen etc. for roads and parking lots. The introduction of new surface materials coupled with emission of heat, moisture and pollutants dramatically change radiative, thermal, moisture, roughness and emission properties of the surface and the atmosphere above. In addition, urbanization also causes generation of large amount of heat by vehicular traffic, industries and domestic buildings. The recent climate change and changes in temperature trends are due to natural and anthropogenic forcing. Recent studies have shown that the anthropogenic forcing due to land-use and land-cover changes may also significantly modify the temperature trends. The changes in LU/LC modify the underlying land surface conditions which in turn change the interaction, i.e. the exchange of energy and moisture between land surface and the atmosphere. LU/LC can influence climate variables such as maximum, minimum and diurnal temperature range. The LU/LC change is mainly due to urbanization, deforestation and changes in agricultural pattern. In recent years, the impact/contribution of LU/LC changes on regional climate has been studied. Currently available satellite thermal infrared sensors provide different spatial resolution and temporal coverage data that can be used to estimate LST. These LST data can be used to derive UHI effect and analysis of spatial variations of LST using LANDSAT ETM+ thermal measurements with the urban vegetation abundance and to investigate their relationship. The advent of satellite remote sensing technology has made it possible to study UHI both remotely and on continental or global scales. In India UHI studies have been carried out for Gujarat state (Parida, 2008), Jaipur City and Bangalore etc. Results reveal that Jaipur city has witnessed considerable growth in built up area at the cost of greener patches over the last decade, which has had clear impact on variation in LST. There has been an average rise of 2.99 ºC in overall summer temperature. New suburbs of the city record 2º to 4º C increase in LST. LST change is inversely related to change in vegetation cover and positively related to extent of built up area. However, no such study has been conducted over Indian coastal region except for Mangalore city (Usha *et al*., 2014) and hence it is important to do research on the impact/contribution of LU/LC change on temperature trends over this region. Hence, in the present study an attempt has been made to understand the impact of LU/LC change on temperature trends of Udupi, costal region of Karnataka state. The study of (Ramachandra T V, 2009) identified that there has been a growth of 63% in urban areas of Greater Bangalore across 37 years (1973 to 2009). Also, increased urbanisation has resulted in higher population densities in certain wards, which incidentally have higher LST due to high level of anthropogenic activities. Urban heat island phenomenon is evident from large number of localities with higher local temperatures. The study unravels the pattern of growth in Greater Bangalore and its implication on local climate (an increase of ~2 to 2.5 ºC during the last decade) and also on the natural resources (76% decline in vegetation cover and 79% decline in water bodies), necessitating appropriate strategies for the sustainable management.