SPECTRAL SIGNATURES USED IN REMOTE SENSING

Introduction

Various remote sensors are used to record the emitted and reflected EMR of various components of the test sites. The ground investigations with respect to remote sensing involve two kinds of observations depending upon the objective to be achieved. These are (a) Visual and (b) spectral measurements. The visual observations involves observation such as colour, shape, size, texture, and temperature of the object of interest. The spectral observation involves measurements of spectral reflectance of a particular objects, in-situ using specially designed equipment for this purpose.

Signature

Any remotely sensed parameter, which directly or indirectly characterizes the nature and/or condition of the object under observation, is defined as its signature. We actually use the spectral signature of the object in remote sensing. This can be defined as a unique pattern of wavelengths radiated by an object. These can be categorised as

a) **Spectral Variation:** Variation in reflectivity and emissivity as a function of wavelength.

b) **Spatial Variation:** Variation of reflectivity and emissivity with spatial position (i.e. shape, texture and size of the object).

c) **Temporal variation:** Variation of emissivity and reflectivity like that in diurnal and seasonal cycle.

d) **Polarization variation:** are introduced by the material in the radiation reflected or emitted by it.

Each of these four features of EM radiation may be interdependent i.e. shape may be different at different times, or in different spectral bands. A measure of these variations and correlating them with the known features of an object provides signature of the object concerned. The knowledge of the state of polarization of the reflected radiation in addition to spectral signatures of various objects in remote sensing adds another dimension for analysis and interpretation of remote sensing data. These parameters are extremely useful in providing valuable data for discriminating the objects.

Spectral Response of various Land Cover Features

Spectral Reflectance and Spectral Signature of Vegetation

The spectral reflectance of vegetation over EMR spectrum depends upon

1. Pigmentation
2. Physiological structure
3. Leaf moisture content

The hemispherical reflectance of any individual leaf is insufficient to describe the remotely sensed bi-directional reflectance of a vegetation canopy. This is because a vegetation canopy is not a large leaf but is composed of a mosaic of leaves, other plant structures, background and shadow. Hence spectral reflectance of vegetation canopy could vary appreciably due to the effect of the soil background, the presence of senescent vegetation, the angular elevation of Sun and sensor, the canopy geometry and certain episodic and phenological canopy changes. Among these some are considered for discussion here.

Effect of Pigmentation absorption

The primary pigments are chlorophyll a, chlorophyll b, B carotene and xantophyll, all of which absorb visible light for photosynthesis. Chlorophyll a and chlorophyll b, which are more important pigments, absorb portions of blue and red light; chlorophyll a absorbs at wavelengths of 0.43 µm and chlorophyll b at wavelengths of 0.45 µm and 0.65 µm. The carotenoid pigments, carotene and xantophyll, both absorb blue to green light.

Physiological structure and reflectance in NIR

The discontinuities in the refractive indices within a leaf determine its near reflectance. These discontinuities occur between membranes and cytoplasm within the upper half of the leaf and more importantly between individual cells and air spaces of the spongy mesophyll within the lower half of the leaf.

The combined effects of leaf pigments and physiological structure give all healthy green leaves their characteristic reflectance properties: low reflectance of red and blue light, medium reflectance of green light and high reflectance of near infrared radiation (Fig 1). The major difference in leaf reflectance between species, are dependent upon leaf thickness, which affects both pigment content and physiological structure. For example, a thick wheat flat leaf will tend to transmit little and absorb much radiation whereas a flimsy lettuce leaf will transmit much and absorb little radiation.

The hemispherical reflectance of a Rhododendron leaf.

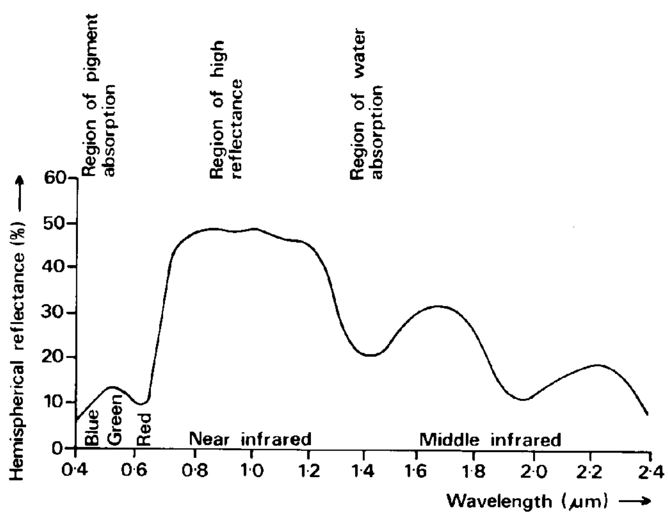

Fig. 1: Spectral reflectance of leaf

Effect of Leaf moisture

Leaf reflectance is reduced as a result of absorption by three major water absorption bands that occur near wavelengths of 1.4 µm, 1.9 µm and 2.7 µm and two minor water absorption bands that occur near wavelengths of 0.96 µm, and 1.1 µm (Fig. 2). The reflectance of the leaf within these water absorption bands is negatively related to both the amount of water in the leaf and the thickness of the leaf. However, water in the atmosphere also absorbs radiation in these water absorption bands and therefore the majority of sensors are limited to three 'atmospheric windows' that are free of water absorption at wavelengths of 0.3 to 1.3 µm; 1.5 to 1.8 µm; and 2.0 to 2.6 µm. Fortunately within these wavebands, electromagnetic radiation is still sensitive to leaf moisture.

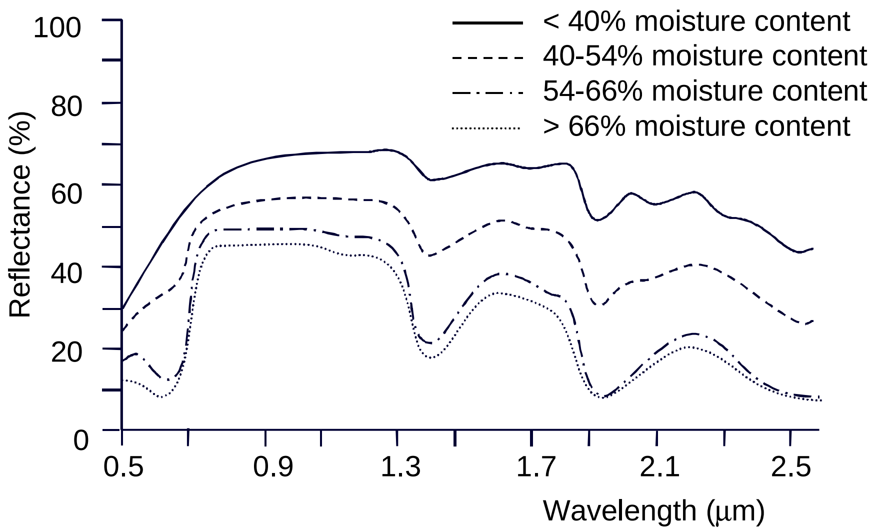

Fig. 2: Influence of the moisture content of maize leaves on the spectral reflectance

The effect of the soil background

The bi-directional reflectance of the soil has a considerable effect on bi-directional reflectance of the vegetation canopy. The soil/waveband combinations that are unsuitable for the remote sensing of vegetation can be identified. For example, on dark toned soils with low red bi-directional reflectance there is little change in the red bi-directional reflectance of the canopy with an increase in the canopy LAI as the leaves have similar reflectance properties to the soil. On a light toned soil with a high bi-directional reflectance, the relationship between near infrared bi-directional reflectance and LAI is weaker than on a dark soil, as on a dark soil the contrast between leaves and soil is high in near infrared wavelengths.

The effect of vegetation senescence

As the vegetation senesces due to aging and the crop begins to ripen, the near infrared reflectance of the leaf does not significantly decrease. However, the breakdown of the plant pigments, result in a rise in the reflectance of blue and red wavelengths. As a result there is a positive relationship between bi-directional reflectance, at each wavelength, and the LAI of senescent vegetation.

The effect of canopy geometry

The geometry of a vegetation canopy will determine the amount of shadow seen by the sensor and will therefore influence the sensitivity of bi-directional reflectance measurements to angular variation in sun and sensor. For example, the reflectance of a rough tree canopy unlike a smoother grassland canopy is greatly dependent upon the solar angle.

The effect of phenology

The seasonal change has influence in canopy bi-directional reflectance. From quantitative studies it is known that for a non-deciduous canopy (e.g. grassland) red bi-directional reflectance is maximised in autumn and minimised in spring, and near infrared bi-directional reflectance is maximised in the summer and minimised in the winter. These relationships can be presented as hysteresis loops of bi-directional reflectance. Each hysteresis plot contains the expected pattern, with minor variations for the vegetation of the nature reserve and corn crop and major variations for the wheat and rice crop. The wheat crop has a lower than expected red bi-directional reflectance in the summer; probably due to high productivity and a higher than expected near infrared bi-directional reflectance in autumn, probably as a result of senescent stubble left in the fields. Irrigation status as well as Leaf Area Index (LAI) of the crop determines the bi-directional reflectance of rice crop; for example, in the summer the wet soil background reduces the otherwise high near infrared bi-directional reflectance of the crop.

Spectral Reflectance and Spectral Signature of Soil

The majority of the flux incident on a soil surface is reflected or absorbed and little is transmitted. The reflectance properties of the majority of soils are similar, with a positive relationship between reflectance and wavelengths. The five characteristics of a soil that determine its reflectance properties are, in order of importance: its moisture content, organic content, texture, structure and iron oxide content. These factors are all interrelated, for example the texture (the proportion of sand, silt and clay particles) is related to both the structure (the arrangement of sand, silt and clay particles into aggregates) and the ability of the soil to hold moisture.

Effect of soil texture, structure and soil moisture

The relationship between texture, structure and soil moisture can best be described with reference to two contrasting soil types. A clay soil tends to have a strong structure, which leads to a rough surface on ploughing; clay soils also tend to have high moisture content and as a result have a fairly low diffuse reflectance. In contrast, a sandy soil tends to have a weak structure, which leads to a fairly smooth surface on ploughing; sandy soils also tend to have a low moisture content and a result have fairly high and often specular reflectance properties. In visible wavelengths the presence of soil moisture considerably reduces the surface reflectance of soil. This occurs until the soil is saturated; at which point further additions of moisture has no effect of reflectance.

Spectral reflectance curves for wet and dry silt loam and wet and dry clay. (Modified from Bowers and Hanks 1965; Hoffer and Johannsen 1969)

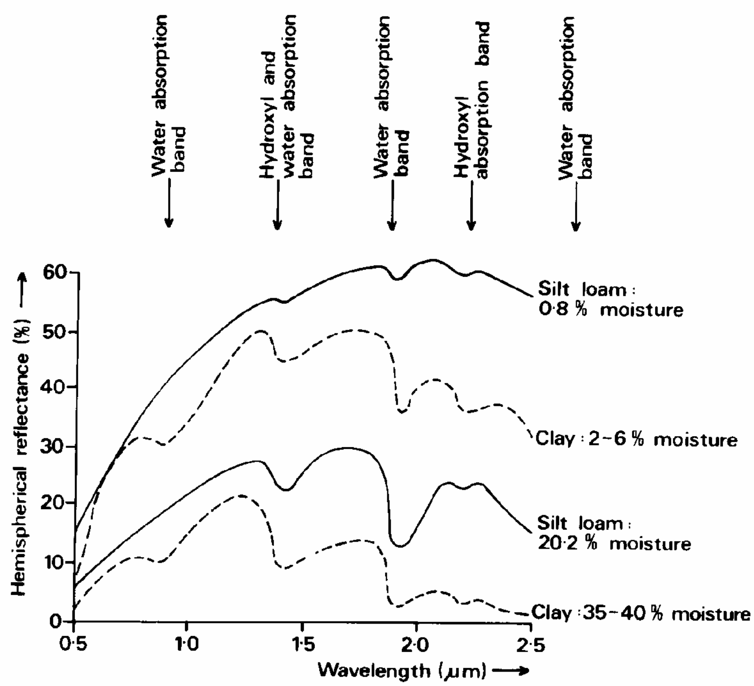

Fig. 3: Effect of Soil Moisture on Soil Spectral Reflectance.

Reflectance in near and middle infrared wavelengths is also negatively related to soil moisture. An increase in soil moisture will result in a rapid decrease in reflectance in water (H_2O) and hydroxyl (H_2O) absorbing wavebands that absorb at wavelengths centered at approximately 0.9 μm, 1.9 μm, 2.2 μm and 2.7 μm. The effect of water and hydroxyl absorption is more noticeable in clay soils for these soils have much bound water and very strong hydroxyl absorption properties, as can be seen in Fig. 3.

The surface roughness (determined by the texture and structure) and the moisture content of soil also affect the way in which the reflected visible and near infrared radiation is polarized. This is because when polarized sunlight is specularly reflected from a smooth wet surface it becomes weakly polarized to a degree that is positively related to the smoothness and the wetness of that surface. This effect has been used to estimate soil surface moisture from aircraft-borne sensors at altitudes of up to 300 metres.

Organic matter

Soil organic matter is dark and its presence decreases the reflectance from the soil up to an organic matter content of around 4-5 percent. When the organic matter content of the soil is greater than 5 percent, the soil is black and any further increases in organic matter will have little effect on reflectance.

Iron Oxide

Iron oxide gives many soils their 'rusty' red coloration by coating or stating individual soil particles. Iron oxide selectively reflects red light (0.6-0.7 μm). This effect is so marked that workers have been able to use a ratio of red to green bi-directional reflectance to locate iron ore deposits from satellite altitudes.

Spectral Reflectance and Spectral Signature of Water

The majority of radiant flux incident upon water is either not reflected but is either absorbed or transmitted. In visible wavelengths of EMR, little light is absorbed, a small amount, usually below 5% is reflected and the rest is transmitted. Water absorbs NIR and MIR strongly, (Fig. 4) leaving little radiation to be either reflected or transmitted. This results in sharp contrast between any water and land boundaries.

The factors, which govern the variability in reflectance of a water body, are the depth of the water, suspended material within the water and surface roughness of the water.

In shallow water some of the radiation is reflected not by the water itself but from the bottom of the water body. Therefore, in shallow pools and streams it is often the underlying material that determines the water body's reflectance properties and colour in the FCC.

Among the suspended materials the most common materials are non-organic sediments, tannin and chlorophyll. The effect of non-organic silts and clays increase the scatter and the reflectance, in visible wavelengths.

Water bodies that contain chlorophyll have reflectance properties that resemble, at least in part, those of vegetation with increased green and decreased blue and decreased red reflectance. However, chlorophyll content must be very high enough to detect these changes.

The roughness of water surface can also affect its reflectance properties. If the surface is smooth then light is reflected specularly from surface, giving very high or very low reflectance, dependent upon the location of the sensor. If the surface is very rough then there will be increased scattering at the surface, which in turn will increase the reflectance.

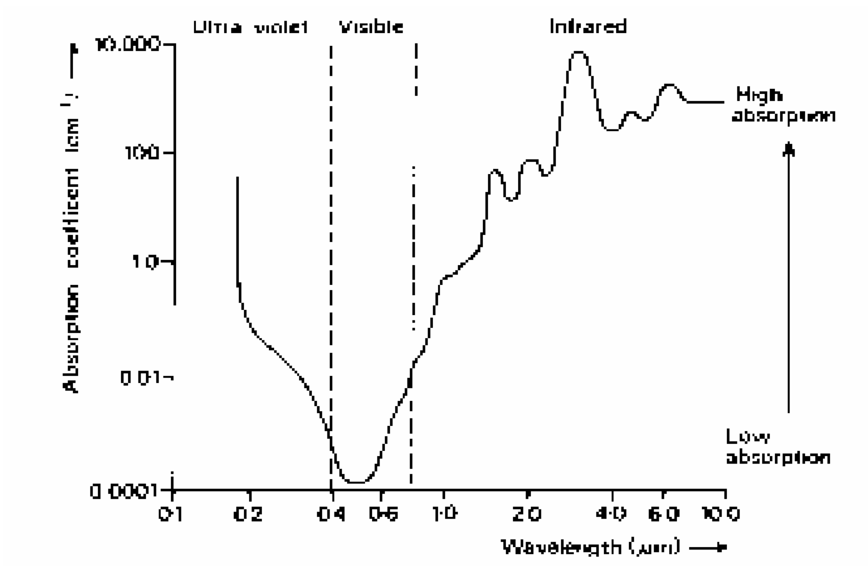

Fig. 4: Absorption of electromagnetic radiation by sea water