INTERACTIONS OF ELECTROMAGNETIC SPECTRUM WITH SURFACE FEATURES OF EARTH

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Electromagnetic energy interactions and interrelationships

- **RS technology uses the visible and microwave regions of the EMS (solar radiation) to collect information about the various objects on the earth's surface.**
- **Visible region is used to view objects with our eye.**
- **Electromagnetic energy incident on any given earth surface give rise to three energy interactions**
- **Reflection**
- **Absorption**
- **Transmission**
- **Interrelationship of these inter actions are expressed as**

$E1\ (\lambda) = E_R(\lambda) + E_A(\lambda) + E_T(\lambda)$

Where E_I denotes the incident energy,

- **E_R denotes the reflected energy,**
- **E_A denotes the absorbed energy,**
- **E_T denotes the transmitted energy,**

All energy components being a function of wavelength λ.

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Factors affecting reflectance

Material type

- **The proportions of energy reflected, absorbed, and transmitted will vary for different earth features, depending on their condition.**
- **Differences permit us to distinguish different features on an image**

Wavelength dependency

- **Within a given feature type, the proportion of reflected, absorbed, and transmitted energy will vary at different wavelengths.**
- **Two features may be indistinguishable in one spectral range but be very different in another wavelength band**

Contd……

- Within the visible portion of the spectrum, these spectral variations result in the visual effect called colour.
- Objects are "blue "when they reflect highly in the blue portion of the spectrum,
- "Green" when they reflect highly in the green spectral region, and so on.
- Thus, the eye utilizes spectral variations in the magnitude of reflected energy to discriminate between various objects.
- Geometric manner in which an object reflects energy is also an important consideration.
- This factor is primarily a function of the surface roughness of the object

Specular reflectors

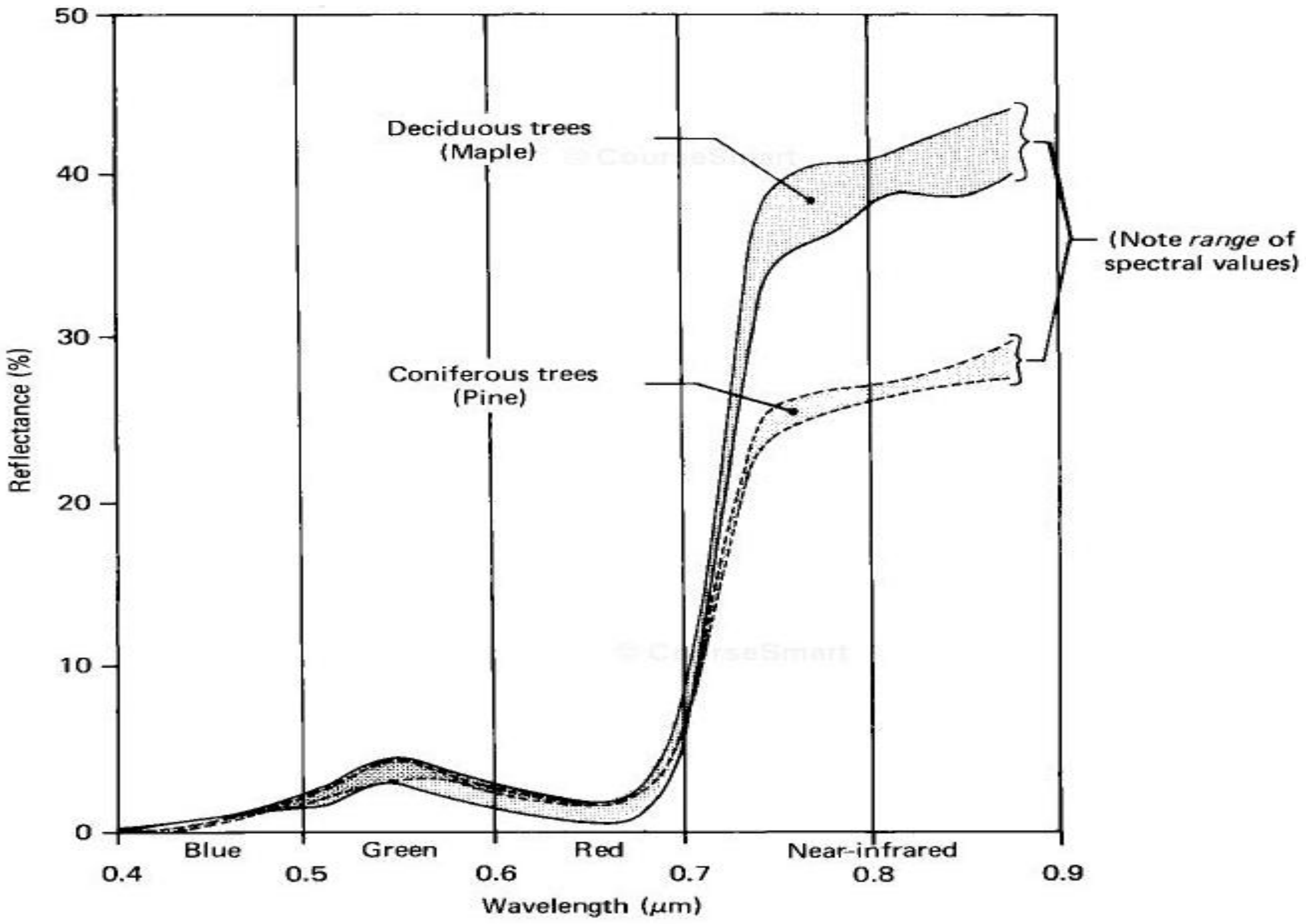
- **Flat surfaces that manifest mirror like reflections have equal angle of reflection and the angle of incidence.**

Diffuse (or Lambertian) reflectors

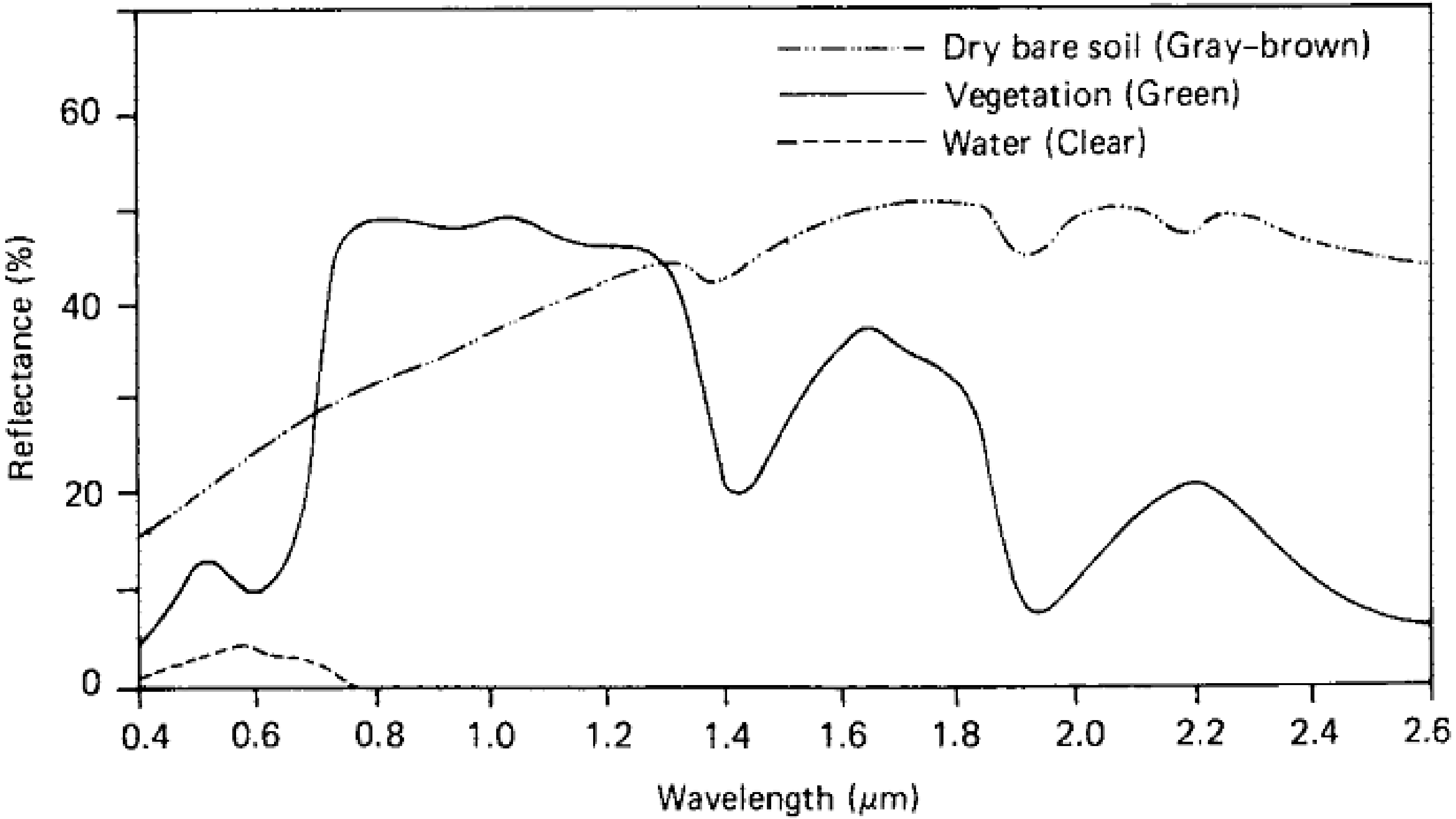
- **Are rough surfaces that reflect uniformly in all directions.**
- **Most earth surfaces are neither perfectly specular nor diffuse reflector.**
- **Their characteristics are somewhat between the two extremes**

Nature of reflectance patterns

- **Different objects reflect in different parts of the EMS and exhibit characterisitc spectral signatures**
- **In the relatively long wavelength radio range, rocky terrain can appear smooth to incident energy**
- **In the visible portion of the spectrum, even a material such as fine sand appears rough.**
- **Diffuse reflections contain spectral information on the "colour" of the reflecting surface, whereas specular reflectances do not.**
- **Hence, in remote sensing, we are most often interested in measuring the diffuse reflectance properties of terrain features.**
- **The reflectance characteristics of earth surface features may be quantified by measuring the portion of incident energy that is reflected**
- **This is measured as a function of wavelength and is called spectral reflectance.**
- **A graph of the spectral reflectance of an object as a function of wavelength is termed a spectral reflectance curve**



. **Generalized spectral reflectance envelopes for deciduous (broad-leaved) and coniferous (needle- bearing trees)**



Typical spectral reflectance curves of earth features

Factors governing spectral response pattern of soil

In near infrared (NIR) and middle infrared (MIR) domain, absorption feature of soil components in solid phase originate primarily from the vibrations of bounded nuclei

- colour
- texture
- structure
- mineralogy
- organic matter
- free carbonates
- salinity
- moisture
- oxides/hydroxides of iron and manganese

Interaction of visible and near infrared EMR with SOIL

- In general, soil surfaces are brown to the human eye.
- ‘Brown’ colouring is a product of green and red EM radiation such that ‘brown’ surfaces absorb more blue EMR than either green or red
- Further more, very little energy is transmitted through soils, the majority of the incident flux is absorbed or reflected
- The technical term for these types of surface is single scatterer.
- Soil surfaces the level of reflectance gradually increases with wavelength in the visible and near infrared spectral regions.

Most important characteristics of a soil that determine its reflectance properties

- Moisture content, Organic matter content, Texture, Structure

Least important- Iron oxide

Soil moisture content

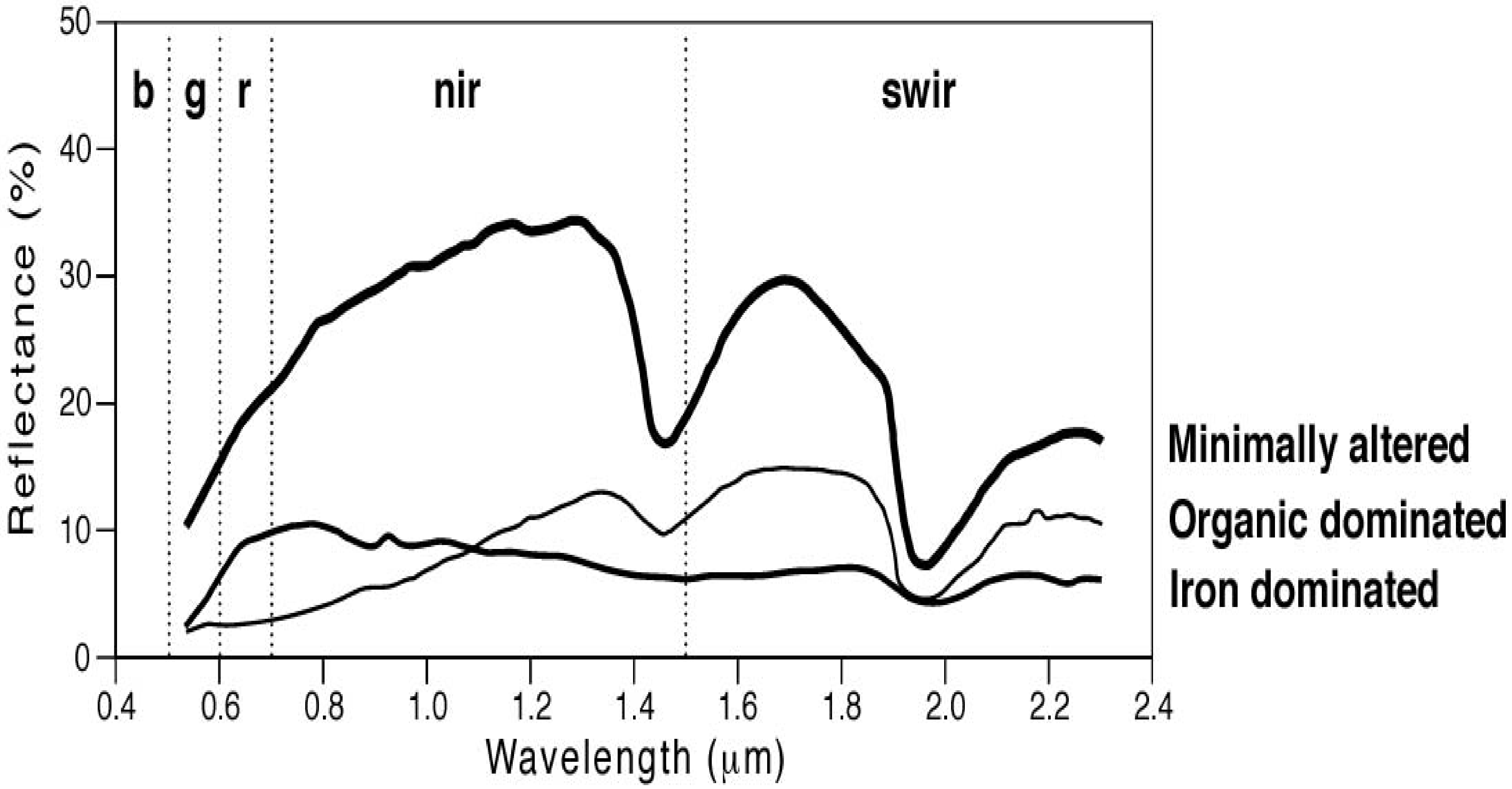
- Soil moisture reduces the surface reflectance of soil at all visible wavelengths. This occurs until the soil is saturated, at which point further additions of moisture have no effect on reflectance.
- Reflectance at near infrared wavelengths is also negatively related to soil moisture; an increase in soil moisture will result in a particularly rapid decrease in reflectance due to water and hydroxyl (HO) absorption features at 0.9 µm, 1.4 µm, 1.9 µm, 2.2 µm and 2.7 µm.
- The effect of water and hydroxyl absorption is more noticeable in clay soils because they have much bound water and very strong hydroxyl absorption properties.

Organic matter content

- **Soil organic matter is dark and its presence will decrease the reflectance from the soil up to an organic matter content of around 4 - 5%. When the organic matter content of the soil is greater than 5%, the soil is 'black' and any further increases in organic matter will have little effect on reflectance (Curran, 1985).**

Texture and structure

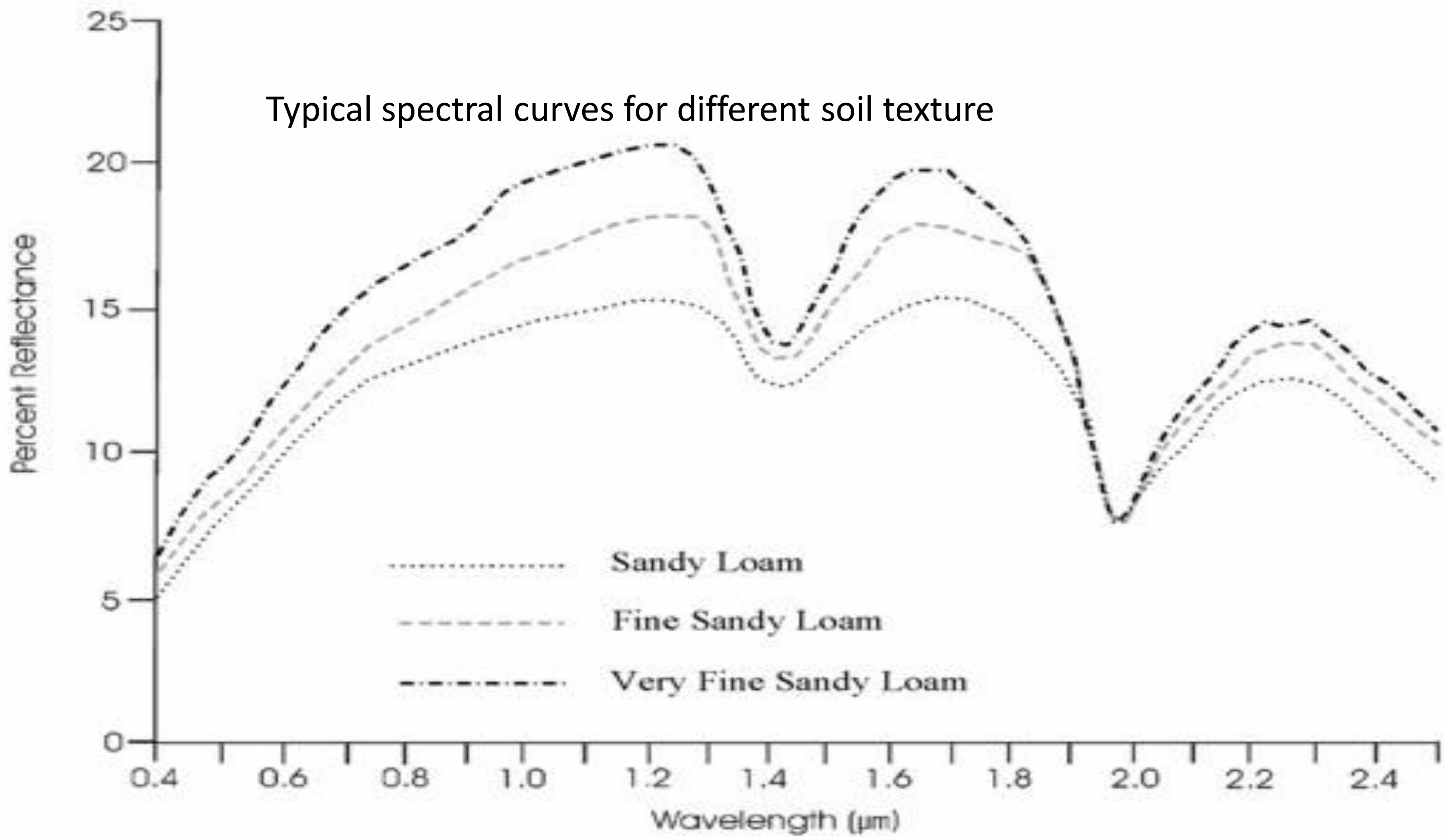
- **A clay soil tends to have a strong structure which leads to a rough surface on ploughing, causing small shadows and lowering reflectance values.**
- **In contrast a sandy soil exhibits weak structure which leads to a fairly smooth surface on ploughing with few shadows**
- **It should be noted that the effects of soil structure complement other properties such as low moisture and organic matter content to increase the level of sandy soil reflectance**


b
g
r
nir
swir
Reflectance (%)
Wavelength (μm)
0
10
20
30
40
50
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
Minimally altered
Organic dominated
Iron dominated

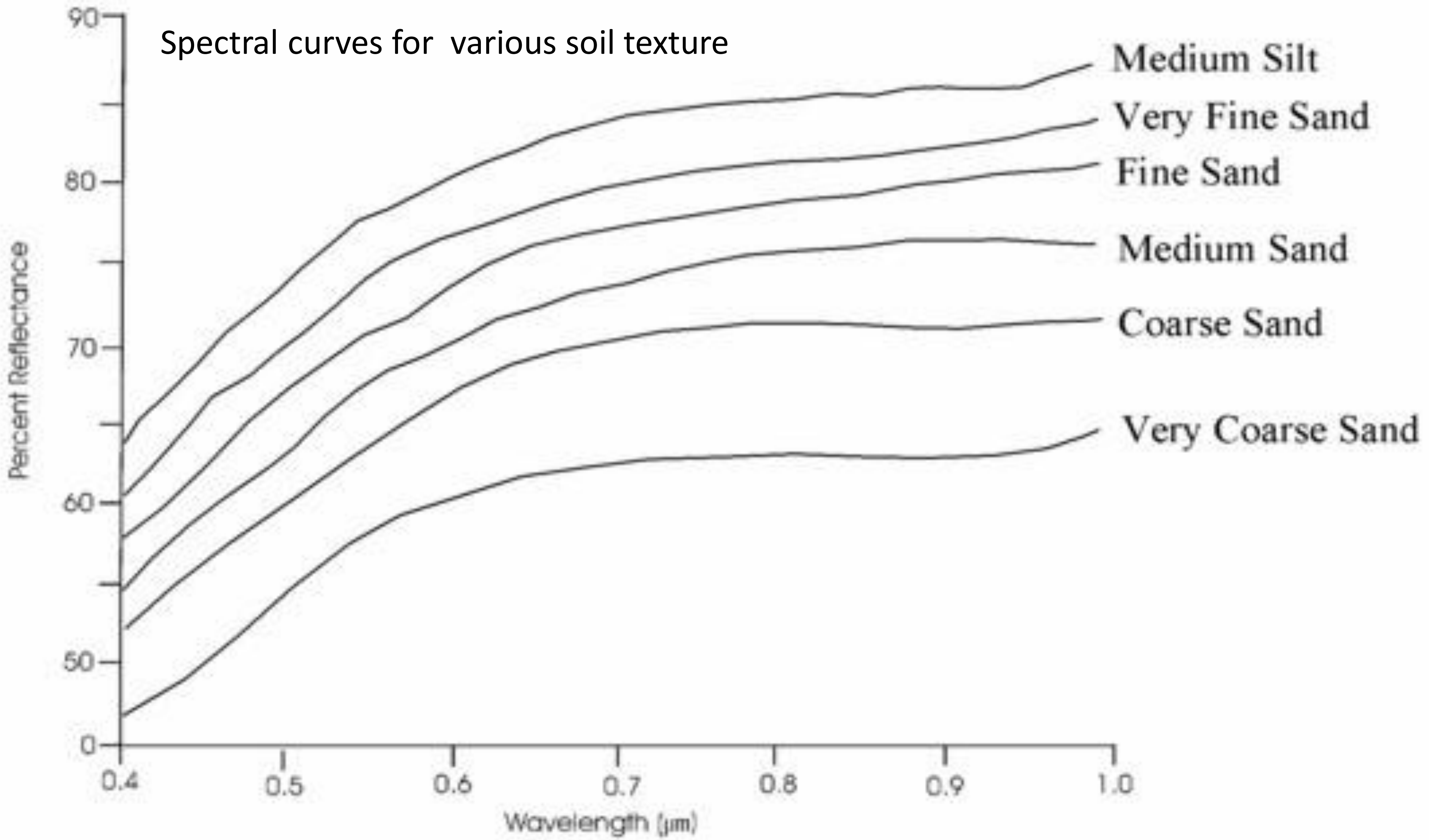
- **Iron oxide content**
- **Iron oxide gives many soils their ‘rusty’ red colouration by coating or staining individual soil particles. Iron oxide selectively reflects red light (0.6 - 0.7 µm) and absorbs green light (0.5 - 0.6 µm). This effect is so pronounced that Vincent (1973) used a ratio of red to green reflectance to locate iron ore deposits.**
- **Interaction of visible and near infrared wavelengths of EMR with WATER**
- **Unlike soil, the majority of the radiant flux incident upon water is not reflected but is either absorbed or transmitted**
- **At visible wavelengths of EM radiation little energy is absorbed, a small amount, usually under 5%, is reflected and the majority is transmitted.**
- **Water absorbs strongly at near infrared wavelengths, leaving little radiation to be either reflected or transmitted**

- **Water surfaces may be more homogeneous than soil surfaces we can still expect some variability in the reflectance of a body of water.**
- **The two most important factors are the depth of the water and the materials within the water**
- **In shallow water some of the radiation is reflected not by the water itself but from the bottom of the water body.**
- **Shallow pools and streams it is often the underlying material that determines the water body's reflectance properties.**

Typical spectral curves for different soil texture



Spectral curves for various soil texture



Variability of reflectance in water bodies

- **The three most common materials suspended in water are non-organic sediments, tannin and chlorophyll**
- **: *Non-organic silts and clays* increase the reflectance at visible wavelengths due to interaction with and scattering by soil-like particles**
- **In agricultural scenes the main colouring agent is *tannin* produced by decomposing humus. This is yellowish to brown in colour and results in decreased blue and increased red reflectance**
- **Water bodies that contain excessive levels of *chlorophyll* have reflectance properties that resemble, at least in part, those of vegetation with increased green and decreased blue and red reflectance.**

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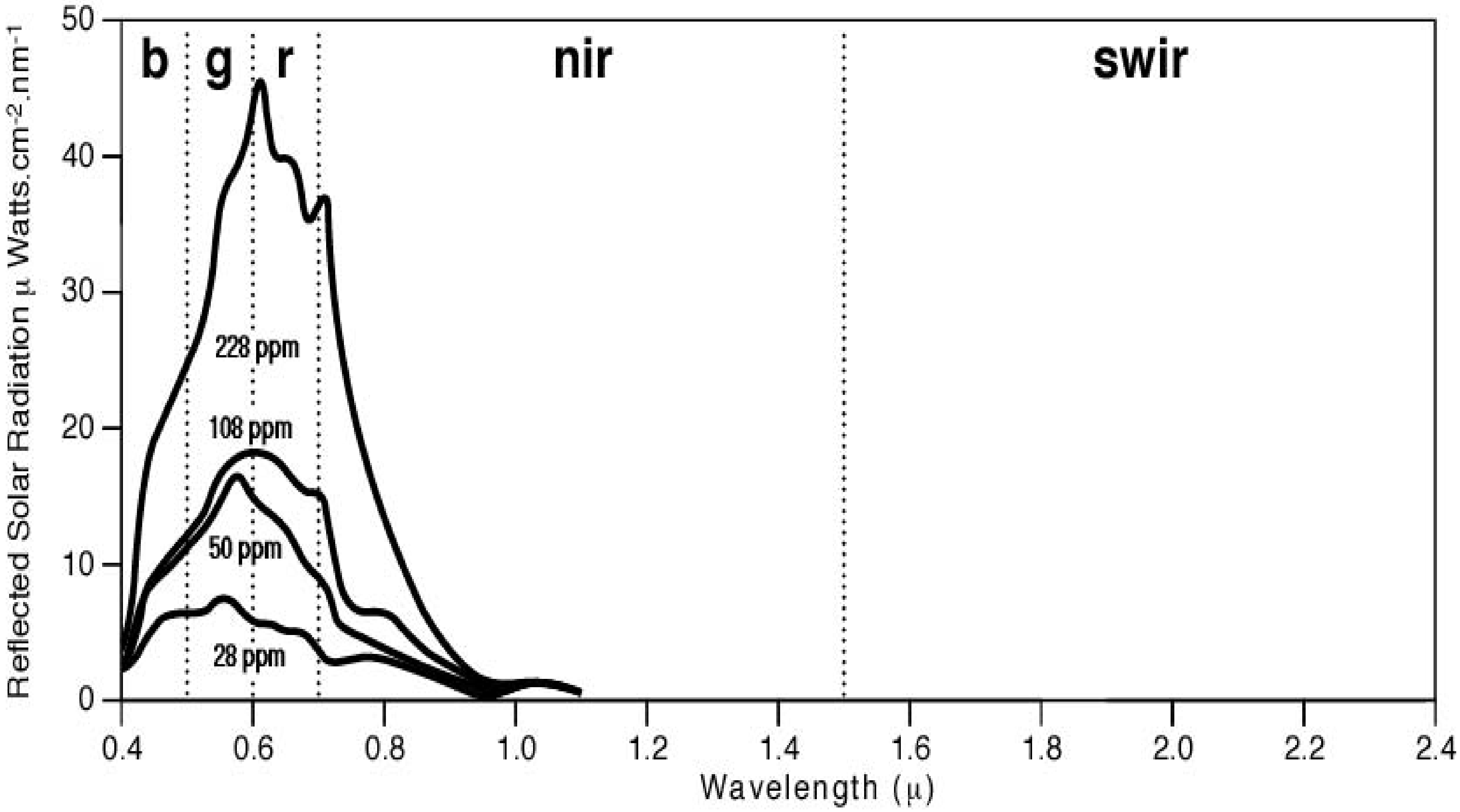
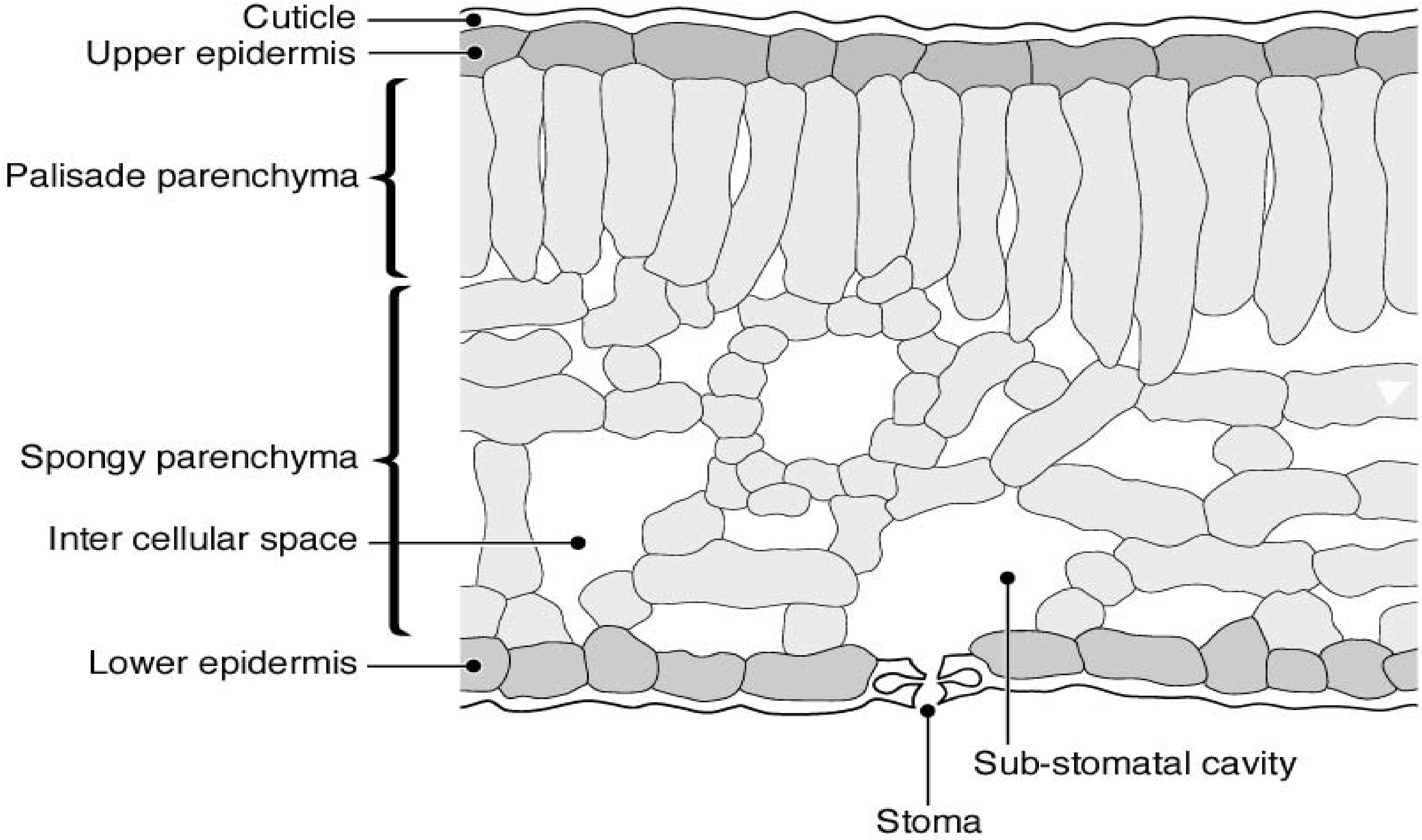


Reflectance of water with different sediment loadings

Interaction of Visible and Near Infrared Wavelengths of EMR with Vegetation

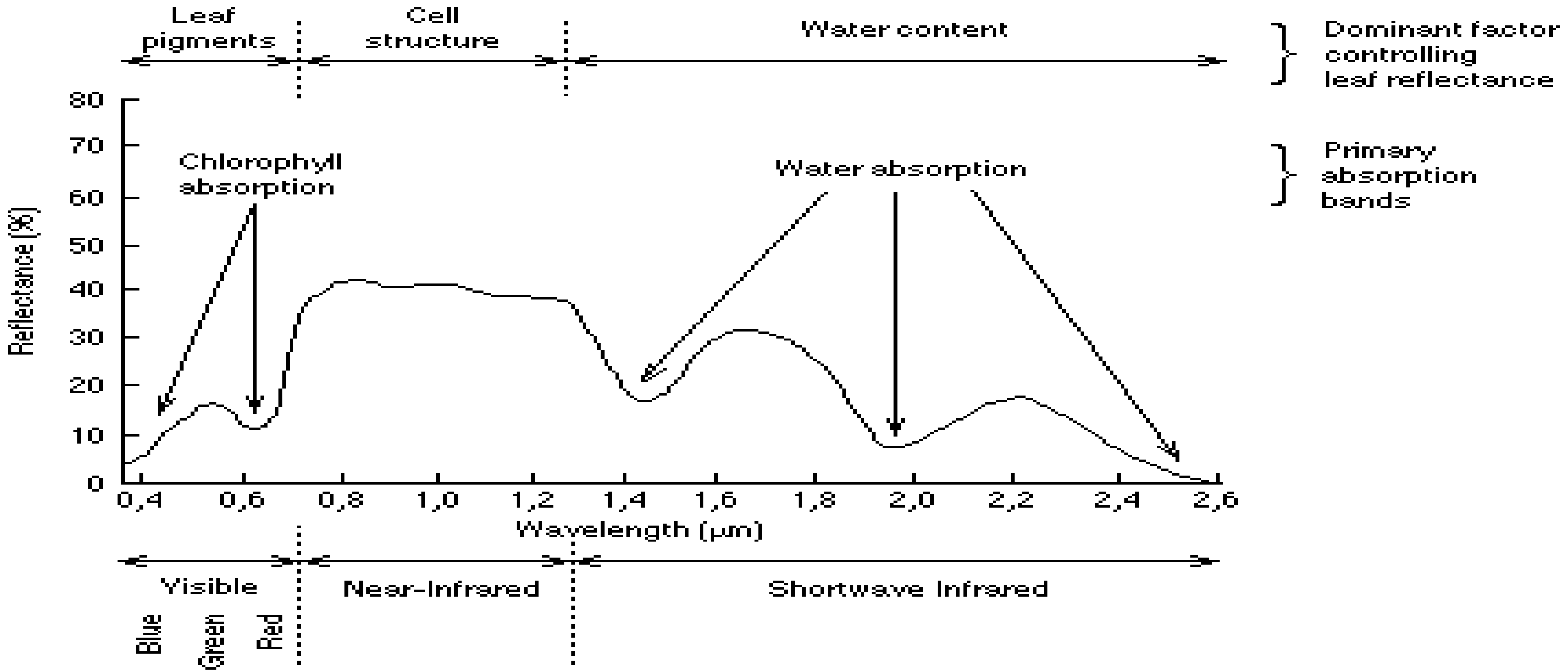
- ***Reflectance of a leaf***
- **A leaf is built of layers of structural fibrous organic matter, within which are pigmented, water-filled cells and air spaces**
- **Pigmentation, physiological structure and water content have an effect on the reflectance, absorption and transmittance properties of a green leaf.**
- **Each feature dominates the reflectance in particular spectral regions - pigment absorption at visible wavelengths,**
- **physiological structure at near infrared wavelengths**
- **Absorption by water molecules at specific wavelengths in the near infrared region.**



Physiological structure of a leaf (cross-sectional view)

Pigment absorption at visible wavelengths

- **Vegetation is green i.e. it reflects more green EMR than either blue or red EMR.**
- **This is because higher plants contain four primary pigments, chlorophyll a, chlorophyll b, ß carotene and xanthophyll, all of which absorb visible light for photosynthesis.**
- **Chlorophyll a and b, which are the more important pigments, absorb portions of blue and red light; chlorophyll a absorbs at wavelengths of *0.43 µm and 0.66 µm* and chlorophyll b at wavelengths of *0.45 µm and 0.65 µm.***
- **Subsequently, healthy vegetation has relatively less absorption (and higher reflectance) at green wavelengths**
- **The less important carotenoid pigments, carotene and xanthophyll, both absorb blue to green light at a number of wavelengths**
- **Pigment absorption only occurs at visible wavelengths and does not affect reflectance at near infrared wavelengths.**

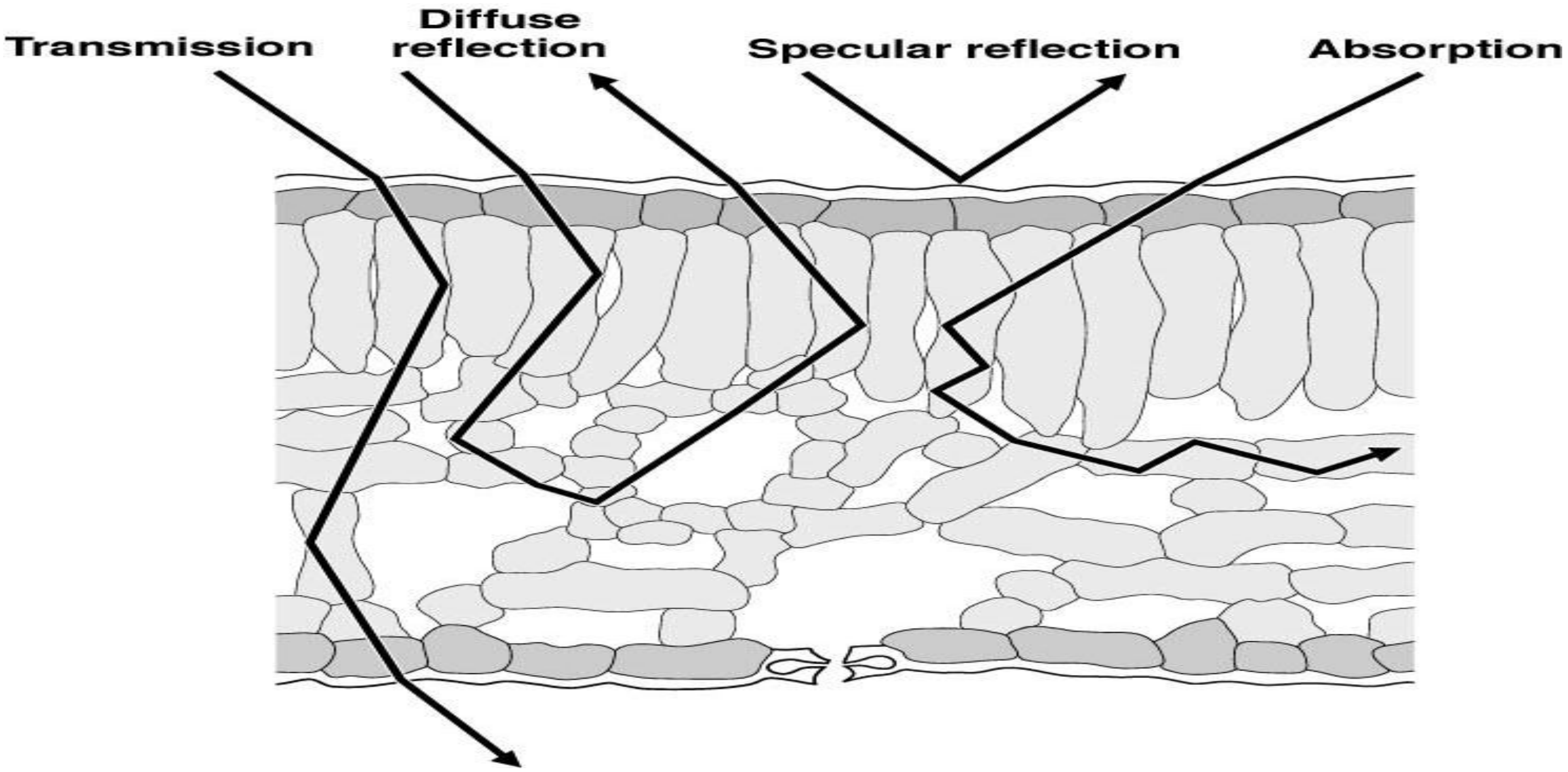


Spectral reflectance curve of typical vegetation showing chlorophyll and water absorption bands

- 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
- High reflectance of near infrared radiation
- The sharp contrast between red and near infrared reflectance is commonly known as the red edge.

Physiological structure and reflectance at Near Infrared wavelengths

- Leaves are ‘juicy’ because they consist of water-filled cells and air spaces.
- Light bends when it passes across the boundary of two media with different refractive indices - the process of refraction.
- Air and water have different refractive indices and therefore as rays of light are transmitted through a leaf they are refracted at every cell boundary in the mesophyll and at other discontinuities such as those between membranes and cytoplasm, in the upper part of the leaf.
- Unlike visible EMR, near-infrared EMR is not absorbed by the various pigments present in ‘green’ leaves.
- The amount of near-infrared radiation ‘reflected’ by a leaf at these wavelengths is the sum of specular reflection from the cuticle and upper epidermis and diffuse reflection produced by the ‘scattering effect’ of multiple internal refractions



EMR pathways through a leaf

Water absorption at near infrared wavelengths

- **Near infrared reflectance of a leaf may be less than 50% due to absorption by water**
- **Leaf reflectance at all visible and near infrared wavelengths is reduced as a result of absorption by water.**
- **Three major diagnostic absorption features occur in the near infrared region near wavelengths of *1.4 µm, 1.9 um and 2.7 µm***
- **Two minor features occur near wavelengths of *0.96 µm and 1.1 µm***
- **Reflectance of the leaf at these wavelengths is negatively related to both the amount of water in the leaf and the thickness of the leaf.**

Thank You