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POPULAR SCIENCE ARTICLE

Spectral Signature Curves

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Abstract

Spectral signature curves indicate the variation in reflectance or emittance of materials as a function of wavelength in the electromagnetic spectrum, enabling their identification based on unique spectral responses. Different surfaces interact with radiation through absorption, reflection and transmission, producing distinct signatures. Among major Earth surface features, vegetation, water and soil exhibit distinct patterns. Vegetation shows low reflectance in the visible and high in the near-infrared region, water exhibits consistently low reflectance in the near-infrared and soils display gradual increases in reflectance as influenced by moisture and composition. These spectral characteristics form the basis of remote sensing applications such as land cover mapping, crop assessment and water and soil analysis.

Keywords: Spectral, Reflectance, Remote Sensing, Vegetation, Soil, Hyperspectral

Introduction

A graphical representation of the variation in reflectance or emittance of a material as a function of wavelength across the electromagnetic spectrum, used to uniquely identify and characterize that material is called as spectral signature curve.

All natural and man-made objects interact with incoming electromagnetic radiation in a distinctive way by absorbing, reflecting or transmitting energy at different wavelengths. This interaction depends on the physical and chemical properties of the material. When the reflected or emitted energy from a surface is measured and plotted against wavelength, it produces a spectral signature curve, which is unique for each material such as vegetation, soil or water.

These curves form the scientific basis of remote sensing, enabling the identification, classification and analysis of Earth surface features using data acquired from sensors mounted on satellites, aircraft or drones. Spectral signature curves are especially important in fields like agriculture, environmental monitoring, geology and land-use mapping.

Principle

The working of spectral signature curves is based on the interaction between electromagnetic radiation and Earth surface materials. Solar radiation reaching the Earth is partly absorbed, reflected and transmitted by different natural and man-made objects such as vegetation, soil and water. The proportion of reflected energy varies with wavelength and depends on the physical and chemical properties of the material. Hyperspectral or multispectral sensors mounted on satellites or airborne platforms record this reflected energy across multiple narrow wavelength bands. Each pixel in the acquired image contains detailed spectral information representing the reflectance of that specific surface feature. When these reflectance values are plotted against wavelength, a spectral signature curve is obtained, which is characteristic and unique for each material. This uniqueness allows for accurate identification and discrimination of surface features, forming the basis for applications such as crop health monitoring, land use classification and environmental assessment in remote sensing (Lillesand *et al.*, 2015; Jensen, 2009).

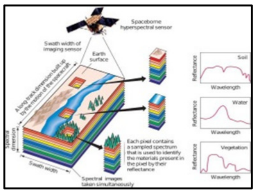

Fig 1. Formation of Spectral Signature Curves from reflected radiations using Hyperspectral Remote Sensing

Spectral Signature Curves

It describes the variation in reflectance of plants across different wavelengths of the electromagnetic spectrum. Generally, vegetation shows low reflectance in the blue and red regions due to chlorophyll absorption, moderate reflectance in the green region and high reflectance in the near-infrared (NIR) region due to internal leaf structure (Congalton, 2015).

Healthy vegetation exhibits a sharp increase in reflectance (red edge) and high NIR reflectance, whereas stressed vegetation shows reduced NIR reflectance and relatively higher red reflectance, enabling assessment of plant health and condition (Melesse *et al*., 2007).

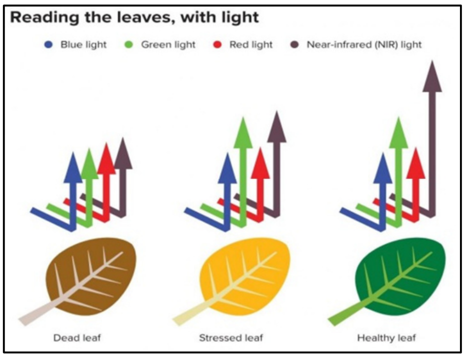

Fig 2. Plant health as influenced by spectral signature curves

The spectral response of water varies depending on the condition. Clear water shows very low reflectance across all wavelengths, whereas turbid or sediment-laden water exhibits higher reflectance, especially in the visible region due to suspended particles. Very turbid water shows the highest reflectance in visible region, while brown water maintains relatively low reflectance due to higher organic matter absorption. In all cases, reflectance decreases sharply beyond 700 nm, indicating strong absorption in the near-infrared region. Similarly, the presence of algae or organic matter can increase reflectance in the green region. These variations help in identifying water quality, depth and content using remote sensing techniques.

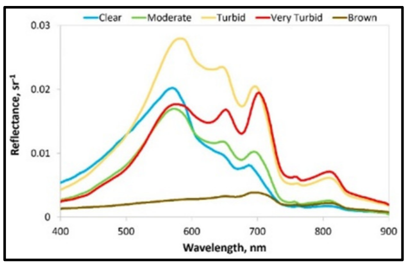

Fig 3. Spectral reflectance of water

In general, soils show a gradual increase in reflectance from the visible to the near-infrared (NIR) region. The reflectance is typically lower in moist soils and higher in dry soils, as water strongly absorbs radiation. Dry soils exhibit higher reflectance in the NIR and shortwave infrared regions, whereas moist soils show reduced reflectance. Increasing soil moisture lowers overall reflectance and smoothens the spectral curve, making it useful for estimating soil moisture Soil colour, texture organic matter and mineral composition significantly influence the shape of the curve. For instance, dark soils rich in organic matter exhibit lower reflectance, whereas light-coloured sandy soils show higher reflectance.

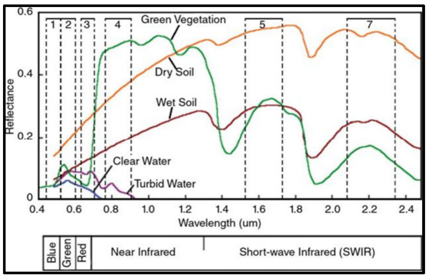

Fig 4. Spectral reflectance of soil

Applications of Spectral Signature Curves

- **Crop health monitoring**: Identifies healthy and stressed vegetation using reflectance differences.
- **Precision agriculture**: Helps in irrigation management, nutrient assessment and yield prediction.
- **Land use and land cover mapping**: Differentiates vegetation, soil, water and urban areas.
- **Water quality assessment**: Detects turbidity, sediments and pollutants in water bodies.
- **Forest monitoring**: Assesses Forest health, biomass and detects deforestation.
- **Soil analysis**: Determines soil moisture, texture and organic matter content.
- **Mineral and geological mapping**: Identifies minerals based on their unique spectral properties.
- **Disaster management**: Used in flood mapping, drought assessment and damage evaluation.

Reference

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