- Skye eGuides -

theory into practice

N° 2

Spectral Reflectance

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CONTENTS

1 INTRODUCTION

The series of Skye eGuides on Remote Sensing have been written to help researchers choose which of the Skye Instruments range of sensors and systems could add valuable data and information to their monitoring projects, and also how to get the best results from the instruments.

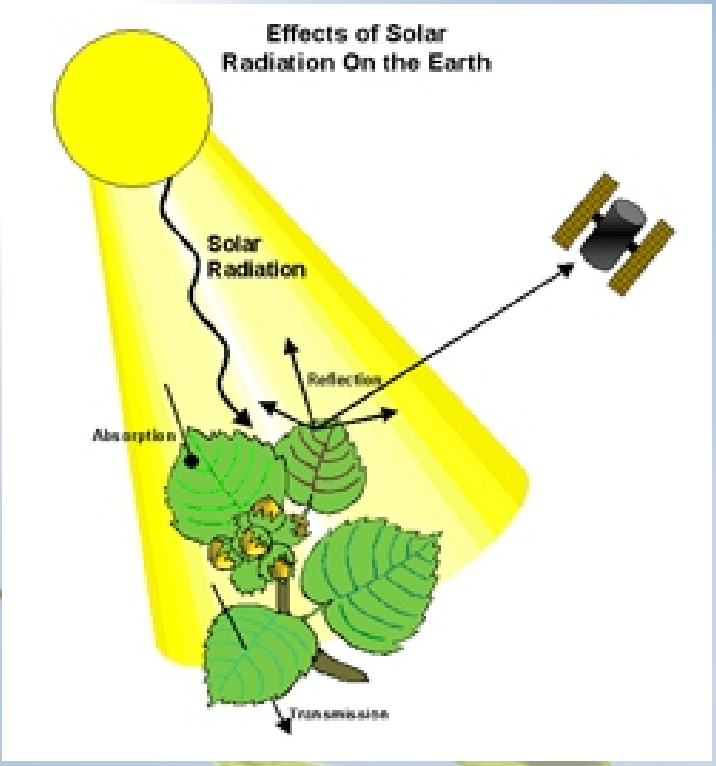
This eGuide Notes introduces Spectral Reflectance and how the technique can be used to observe, map and monitor the Earth's surface, both from space and at ground level.

The Skye Instruments Spectral Reflectance sensors and systems are also described, with their many applications.

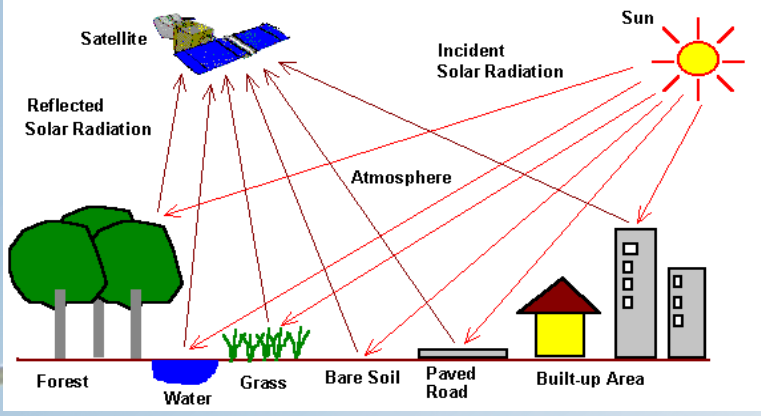
2 SPECTRAL REFLECTANCE

Solar radiation that is not absorbed or scattered in the atmosphere can reach and interact with the Earth's surface. There are three forms of interaction that can take place when energy strikes, or is incident upon the surface. These are absorption, transmission, and reflection. The total incident energy will interact with the surface in one or more of these three ways. The proportions of each will depend on the wavelength of the energy and the material and condition of the feature at the surface.

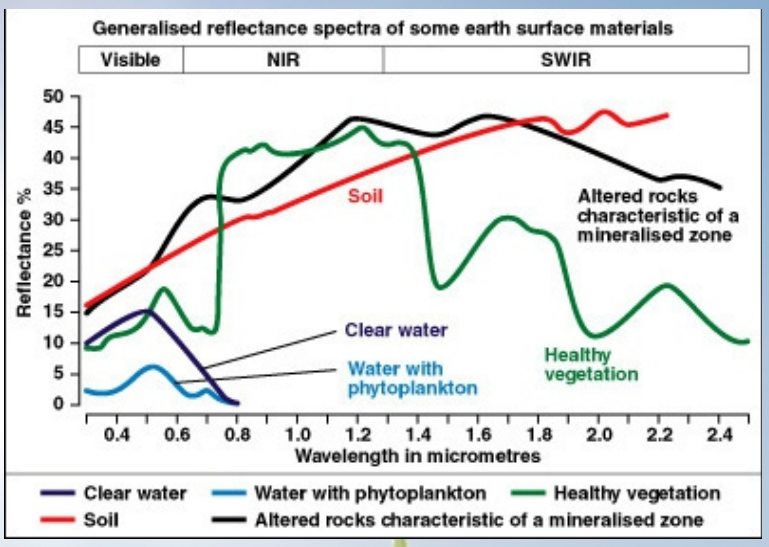
Absorption occurs when radiation is absorbed into the target, while transmission occurs when radiation passes through a target. Reflection occurs when radiation "bounces" off the target and is redirected. In remote sensing, measuring the radiation reflected from targets is the main interest.



Solar Reflection or Reflectance with respect to wavelength is called Spectral Reflectance. A basic assumption in remote sensing is that spectral reflectance is unique and different from one surface to another. This allows easy identification and mapping of land cover, oceans, forests, deserts etc by satellite sensors.



This graph shows a spectral reflectance "fingerprint" of different surfaces, in the Visible (VIS), Near Infra-Red (NIR) and Short Wave Infra-Red (SWIR) wavelengths. It shows high values for Reflectance and low values for Absorption.



Water

In the visible region of the spectrum, the transmission of water is significant and so both the absorption and the reflection are low. Reflectance is maximum at the blue end of the spectrum and decreases as wavelength increases, making clear water appears bluish to the human eye. Water containing phytoplankton reflects more green wavelengths and so appears greener than clear water. The absorption of water rises rapidly in the NIR where both transmission and reflection are low.

Soil

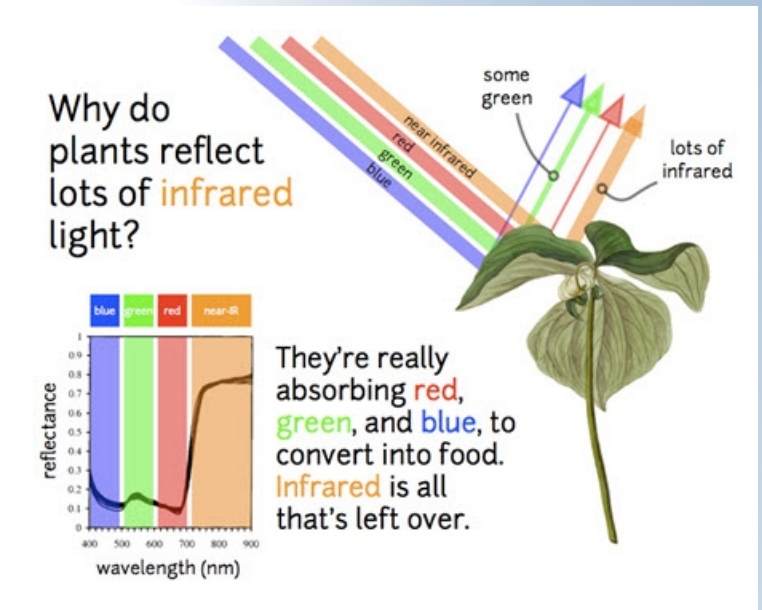
Soil has very different characteristics in the VIS and NIR. The increase of reflection with wavelength in the visible is consistent with the human eye's observation that soils can have a red or brown colour to them. The reflectance curve is affected by moisture content, soil texture, surface roughness, presence of iron oxide and organic matter, although each factor is not as dominant as features observed in vegetation reflectance spectra. Soil water content can be estimated from the absorption bands in the SWIR region.

Rocks

Rocks and mineral detection by remote sensing is not practical. Rocks are usually made up of a number of mineral types in varying mixtures, and are often covered by further layers of minerals deposited in weathering processes (not to mention by soil and vegetation). In addition, the scanners employed on most remote sensing platforms have a limited number of spectral channels, which often have a fairly broad wavelength range. These instruments lack the spectral sensitivity necessary to distinguish between similar reflectance profiles.

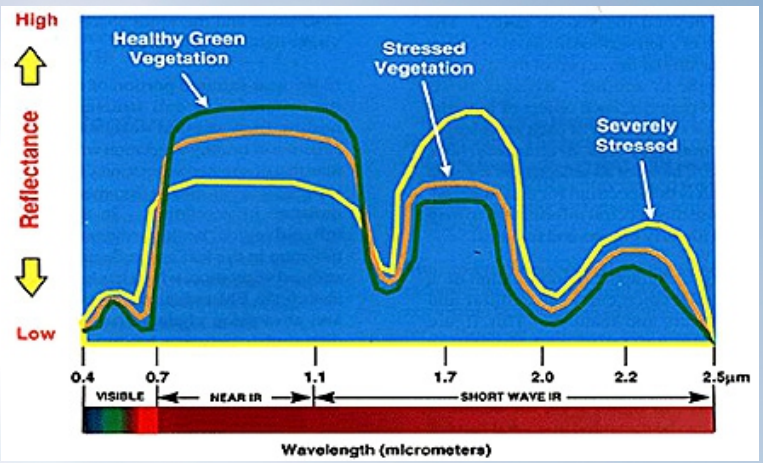
Vegetation

Chlorophyll strongly absorbs radiation in the red and blue wavelengths but reflects green wavelengths. Leaves appear "greenest" to the human eye in the summer, when chlorophyll content is at its maximum. In autumn, there is less chlorophyll in the leaves, so there is less absorption and proportionately more reflection of the red wavelengths, making the leaves appear red or yellow (yellow is a combination of red and green wavelengths). The internal structure of healthy leaves act as excellent diffuse reflectors of near-infrared wavelengths. If human eyes were sensitive to near-infrared, vegetation would appear extremely bright at these wavelengths.The water absorption bands can also be clearly seen in the SWIR region.



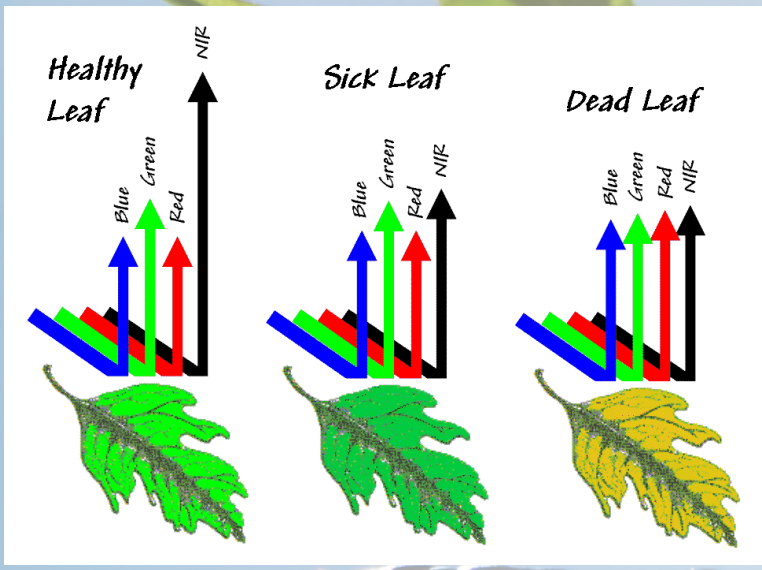
3 NIR REFLECTANCE

Measuring and monitoring the NIR reflectance can determine how healthy or stressed vegetation may be. If the vegetation is reflecting a high ratio of NIR to VIS wavelengths, then it is photosynthesising and it is healthy. If the ratio of NIR to VIS reduces, less VIS wavelengths are being absorbed, meaning the photosynthesis rate is reduced, indicating an unhealthy or stressed plant system.

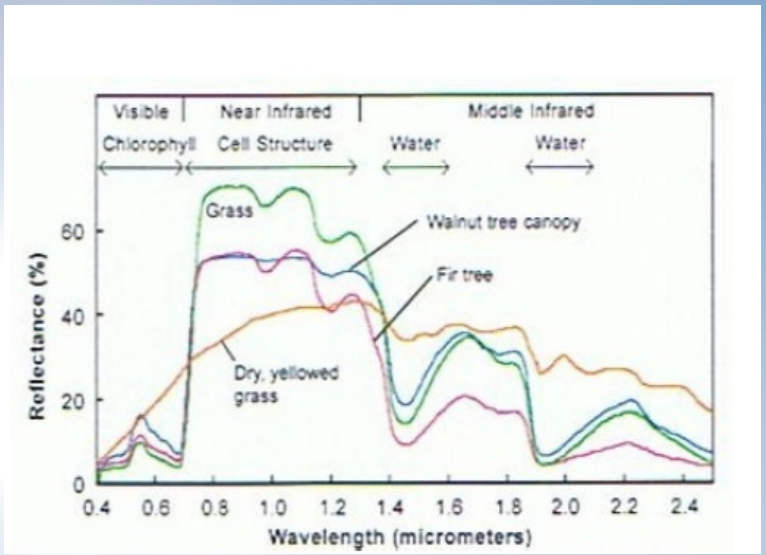


Measuring the spectral reflectance of vegetation can help to identify unhealthy plants before it becomes visible to the human eye. This is extremely useful in crop management in Precision Agriculture, and also important in remote sensing of vulnerable ecosystems.

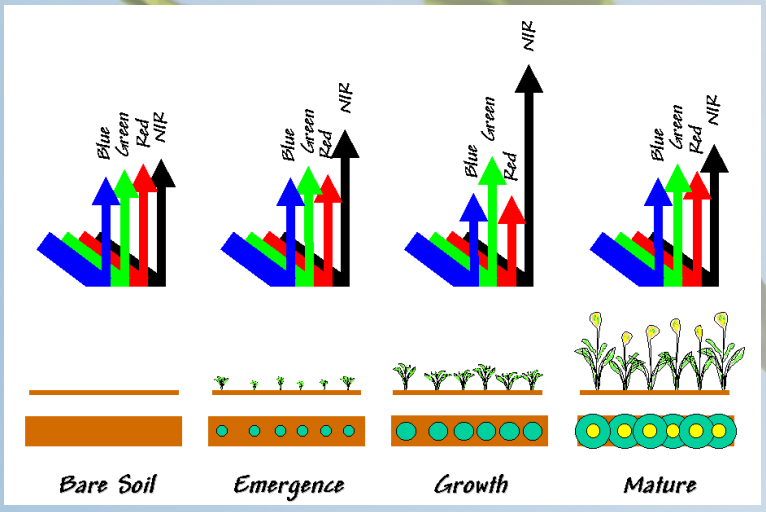
Note the relative ratio of the Red to NIR wavelengths in particular. The "sick" leaf still looks green to the eye, yet the spectral reflectance indicates low VIS absorption, and a low rate of photosynthesis.



Vegetation species can also be differentiated using spectral reflectance, e.g. deciduous trees have a higher reflectance than the coniferous in the NIR.

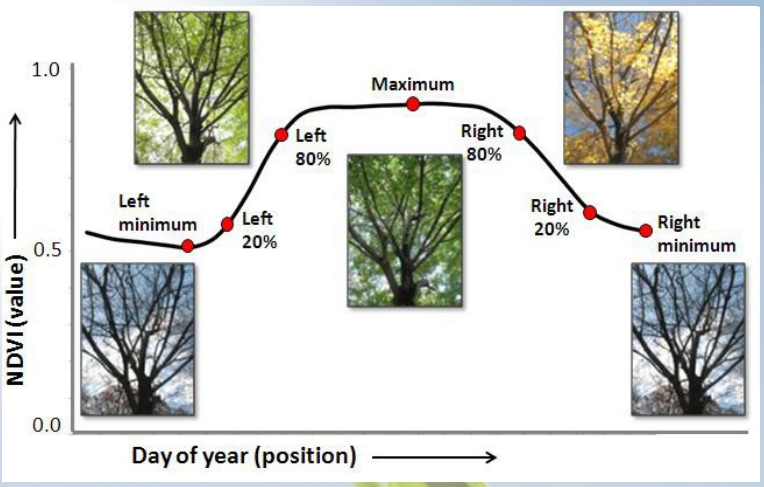


The growth rate and ground cover of crops and vegetation can also be easily measured and monitored over time. Note again the relative ratio of the Red to NIR wavelengths, and how this increases as the plants grow and cover a bigger area of the ground. This technique gets less valid once the plant matures and flowers.



The spectral reflectance ratio of NIR to Red wavelengths has special significance in plant and vegetation studies, as can be seen above. The Normalised Differential Vegetation Index (NDVI) uses NIR and Red ratios to detect photosynthesising vegetation. NDVI is explained in more detail in the Skye eGuide on Vegetation Indices.

NIR to Red ratios and NDVI are very useful tools in Phenology, which studies plant seasons and cycles. The spectral reflectance clearly shows the "greening up" of deciduous trees in springtime, and the "greening down" in autumn.



5 SKYE PRODUCTS FOR SPECTRAL REFLECTANCE

Skye Instruments have been specialising in Light and Radiation sensors since 1983. All are designed, manufactured and calibrated to the highest standards. Each is supplied with an individual Calibration Certificate traceable to the UK's National Physical Laboratory (NPL).

Sensors are available with Calibrated wavelength responses from 280nm (UV), through VIS, NIR to 2400nm (SWIR). There are thirteen popular models of fixed wavelengths, plus custom models where the wavebands are built and calibrated to the user's individual requirements.

The range includes single channel sensors and 2 and 4 multichannel radiometers. There is a choice of sensor design for Irradiance / Incident light measurements, and Radiance / Reflected light measurements, a pair of which is known as a Spectral Albedometer.

The Spectral Albedometers are used for measuring Spectral Reflectance. Solar Irradiance and Radiance from the observed area are measured simultaneously, minimising errors due to changing light levels throughout the day, making these sensors ideal for long term datalogging.

All Skye Light and Radiation sensors can be supplied as complete systems, with hand held SpectroSense2+ logging meters and GPS mapping, or with DataHog dataloggers for automatic recording. The sensors are also compatible with dataloggers from other manufacturers.

Skye sensors for use in Spectral Reflectance applications are as follows:

fPAR Measurements

fPAR can be recorded in two ways:

a)using the PAR Quantum sensor response in a multichannel spectral albedometer Incident and Reflected PAR is measured simultaneously, the ratio of which calculates the fraction of PAR absorbed by the area under measurement

b)using NDVI sensors and the calculation fPAR = 1.24 * NDVI - 0.168
This calculation is available as standard in the Skye SpectroSense2+ meter
Information on these sensors can be found here:
PAR Quantum Sensor
Sensors for NDVI

NDVI Measurements
NDVI sensors include 2 wavebands, in the Red and NIR wavelength regions.
A 2 channel spectral albedometer (which consists of a pair of Irradiance and Radiance radiometers) is used to measure incident and reflected light simultaneously.
Individual measurements from all 4 channels are recorded separately, and the NDVI calculation is available as standard in the Skye SpectroSense2+ meter

Information on these sensors can be found here:
Sensors for NDVI
SKR 1860 Sensors

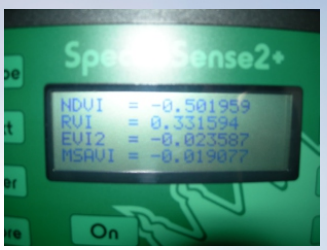
PRI Measurements
PRI sensors include 2 wavebands, in the 531nm and 570nm wavelength regions.
A 2 channel spectral albedometer (which consists of a pair of Irradiance and Radiance radiometers) is used to measure incident and reflected light simultaneously.
Individual measurements from all 4 channels are recorded separately, and the PRI calculation is available as standard in the Skye SpectroSense2+ meter

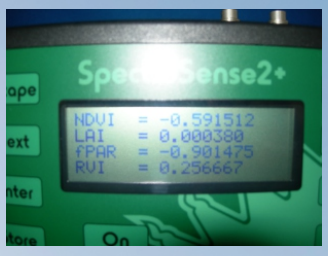
Information on these sensors can be found here:
Sensors for PRI
SKR 1860 Sensors

Other Wavelengths and Vegetation Indices
Skye custom sensors can be matched to the wavebands of a particular satellite for Ground Truth measurements. Multichannel spectral albedometers can be fitted with up to 4 different wavebands, allowing several VIs to be calculated using one pair of sensors. For example:
a) A 2 channel albedometer with Red and NIR wavebands can calculate:
NDVI, RVI, fPAR, EVI2, MSAVI2 and LAI
b)A 2 channel albedometer with 531nm and 570nm wavebands can calculate PRI
c)A 4 channel albedometer with Red, NIR, 531nm and 570nm wavebands can calculate:
NDVI, PRI, RVI, fPAR, EVI2, MSAVI2 and LAI
d)A 2 channel albedometer with 900nm and 970nm wavebands can calculate WBI
e)A 4 channel albedometer with MODIS Blue, Red, NIR, and PAR wavebands can calculate:
NDVI, RVI, fPAR, MODIS EVI, EVI2, MSAVI2 and LAI

Information on these sensors can be found here:
SKR 1860 Sensors
Land-based Systems

SpectroSense2+ Logging Meter
This Skye meter is an 8 channel display meter, with automatic datalogging and GPS mapping functions. It has a 4 line display for easy viewing of data from a pair of multichannel radiometers or albedometers. Sensors can be easily interchanged using the configurable sensor library.





The following Vegetation Indices can be displayed live on screen:
NDVI, PRI, fPAR, RVI, WBI, EVI, EVI2, MSAVI2, LAI from PAR sensors, LAI from NDVI sensors

Information on these meters can be found here:
SpectroSense2 range of meters

DataHog Datalogger

The Skye DataHog is a 16 channel datalogger designed specifically for light and radiation sensors. It is robust and waterproof, and can be linked to a GPRS remote communications module for automatic upload to a web site.

Up to 8 wavebands of Irradiance and Radiance measurements can be recorded simultaneously. Multichannel spectral albedometers with wavebands in the SWIR region can also be recorded using the DataHog, allowing calculations of other VIs as well, such as NDSI.
Information on these dataloggers can be found here:
DataHog2 Dataloggers
GPRS Module

Published Scientific References
Skye's sensors and systems have been used in Remote Sensing for many years, and the research they have contributed to has been published many times, in a variety of different scientific journals. Please click the link below to view a selection:
Scientific Papers

5 SKYE INSTRUMENTS LTD

Skye Instruments Ltd has been designing and manufacturing instrumentation for Environmental Monitoring, Plant Growth and Agricultural Research since 1983. The Company started on the Isle of Skye, Scotland and re-located to Wales in 1986.

We have a world-wide reputation for producing high quality instruments which stand up to life in the field, and for having excellent customer relationships. Although we are based in Wales, UK, we have representation in many countries as well as selling direct.

In 2009, Skye became an Employee-Owned Company. Skye has adopted the 'John Lewis' model whereby shares of the company are held in a trust, an Employee Benefit Trust. All employees are equal owners and benefit from profit-sharing.

Quality Policy

The Company recognises that its performance must be of a consistently high standard to secure the satisfaction, confidence and loyalty of its customer base.
It is the Policy of Skye Instruments Limited to satisfy all customers by offering a high standard of personal attention by trained and courteous employees.
It is the Policy of Skye Instruments to develop, produce and market high quality, precision instrumentation for environmental, botanical and laboratory use. The aim is to provide a first class product and service that fully satisfies the initial and continual needs and expectations of all customers.

Environmental Philosophy

Skye are an environmentally aware Company and strive to ensure our business activities have the minimum possible adverse impact on the environment. We are proud of the fact that many of our products will be used to improve the natural environment around the world by increasing the understanding of natural events and minimising damage caused by human activities.

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