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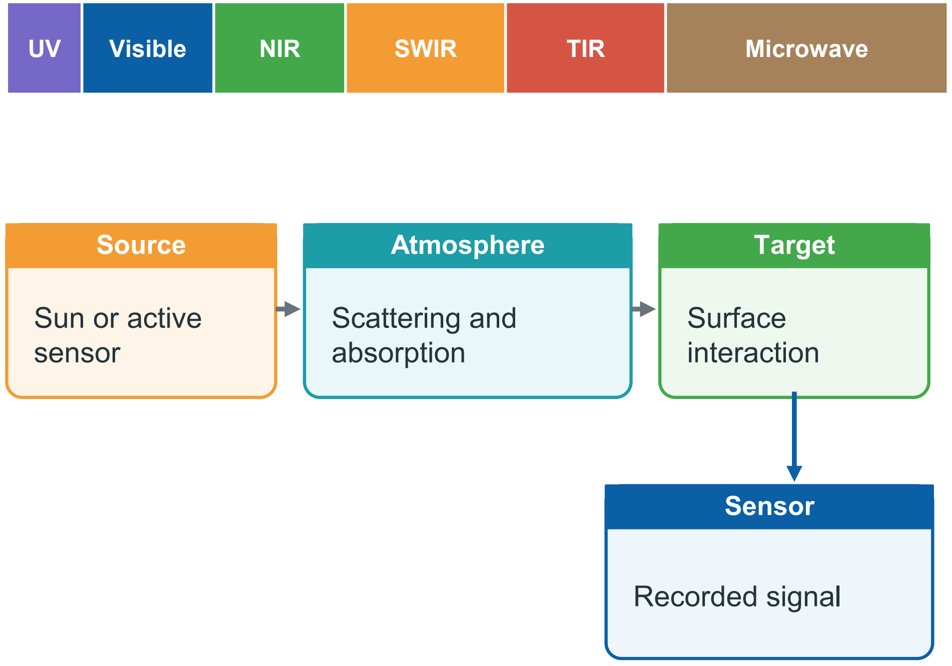
LAND MANAGEMENT IN CENTRAL ASIA

11.- Electromagnetic Radiation and Energy Interaction

Electromagnetic Energy Review

LM-W11-V77

Electromagnetic Energy Review



energy → interaction → measurement

Week 11 Review Map

1. Radiation	2. Spectrum	3. Atmosphere	4. Interaction	5. Signatures
Energy is the information carrier.	Wavelength and energy relationships.	Signal modification before and after interaction.	Reflection, absorption, and transmission.	Materials show distinct responses.

Remote sensing is a process, not just an image product.
Each step in the chain helps explain what the sensor records.
Understanding the chain improves interpretation and band selection.

Outcome

Physics-based understanding of image interpretation

Key idea: Week 11 links basic energy physics with practical remote sensing use.

Electromagnetic Radiation

UV	Visible	NIR	SWIR	TIR	Microwave

Visible
Color and basic surface appearance

NIR
Vegetation vigor and land–water contrast

SWIR
Moisture, minerals, and burn effects

TIR
Surface temperature and emitted energy

Microwave
Radar, clouds, and roughness sensitivity

The Sun is the main source for optical remote sensing.
The Earth emits thermal radiation.
Active sensors such as radar create and measure their own energy.

Main message

Different parts of the spectrum provide different kinds of information.

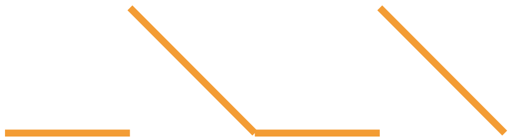
Key idea: Remote sensing works because electromagnetic radiation carries measurable information from the Earth to the sensor.

Wavelength, Frequency, and Energy

Wavelength (λ)	Frequency (v)	Photon energy (E)
Distance between two wave peaks	Number of oscillations per second	Energy carried by a photon

Short wavelength → High frequency → High energy

shorter wavelength



longer wavelength

These relationships help explain why different bands interact differently with matter.
Sensor design and image interpretation both depend on wavelength behavior.

Key idea: Remember the pattern: shorter wavelength means higher frequency and higher photon energy.

Main Spectrum Regions for Remote Sensing

UV	Visible	NIR	SWIR	TIR	Microwave

Visible
0.4–0.7 µm

Human vision, color, land cover appearance

Near Infrared
0.7–1.3 µm

Vegetation health and biomass sensitivity

Shortwave IR
1.3–3 µm

Moisture, minerals, burn and stress signals

Thermal IR
3–14 µm

Emitted energy and surface temperature

Microwave
>1 mm

Radar imaging and roughness information

Each spectral region has a specific practical role.
The correct band depends on the process or material being studied.
Remote sensing success depends on matching the spectral region to the objective.

Key idea: Different wavelength regions reveal different aspects of the Earth surface.

Atmospheric Effects and Atmospheric Windows

Sun / source
Incoming radiation

→ **Atmosphere**
Scattering + absorption

→ **Surface**
Interaction with matter

→ **Sensor**
Recorded signal

Scattering
Redirection of energy; haze and reduced contrast

Absorption
Selected gases remove energy at specific wavelengths

Atmospheric windows
Preferred wavelength regions for sensor design

The signal is influenced by the atmosphere before and after surface interaction.
Atmospheric windows allow more efficient transmission in specific wavelength ranges.

Key idea: The recorded signal contains both surface information and atmospheric influence.

Energy Interaction with Matter

Incident energy = Reflected energy + Absorbed energy + Transmitted energy

Incident energy

Incoming radiation

Reflection

Leaves the surface and can be recorded by optical sensors

Absorption

Enters the material and may cause heating or biochemical response

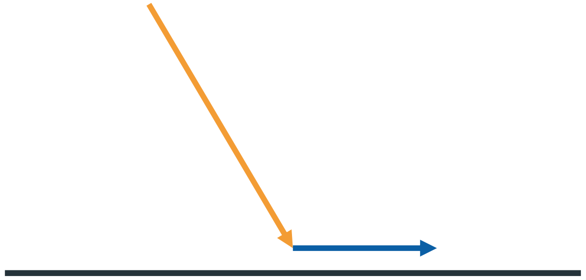
Transmission

Passes through the material depending on wavelength and material type

Key idea: Different materials divide the same incoming energy in different ways.

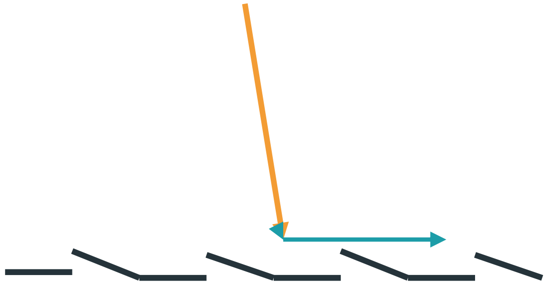
Reflection Review: Diffuse and Specular

Specular reflection



smooth surface

Diffuse reflection



rough natural surface

Interpretation effect

Specular reflection may create glare, while diffuse reflection usually gives a more stable signal for analysis.

Key idea: Many optical images are interpreted mainly through reflected energy, so surface roughness and geometry matter.

Absorption and Transmission Review

absorbed

Absorption

Energy enters the target. Examples include chlorophyll absorption in blue and red, and water absorption in NIR and SWIR.

incident

Target

Material

transmitted

Transmission

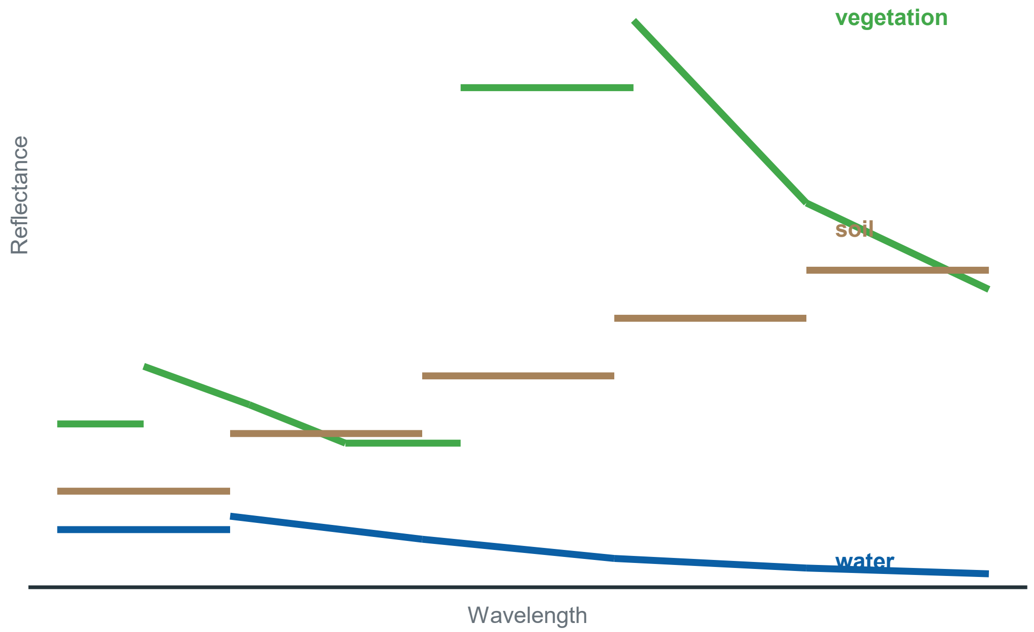
Energy passes through a material. This can happen in leaves, clear water, glass, and parts of the atmosphere.

Meaning

Reflection, absorption, and transmission together create the spectral response measured by sensors.

Key idea: A pixel value reflects the physical partitioning of energy by the target.

Spectral Signatures



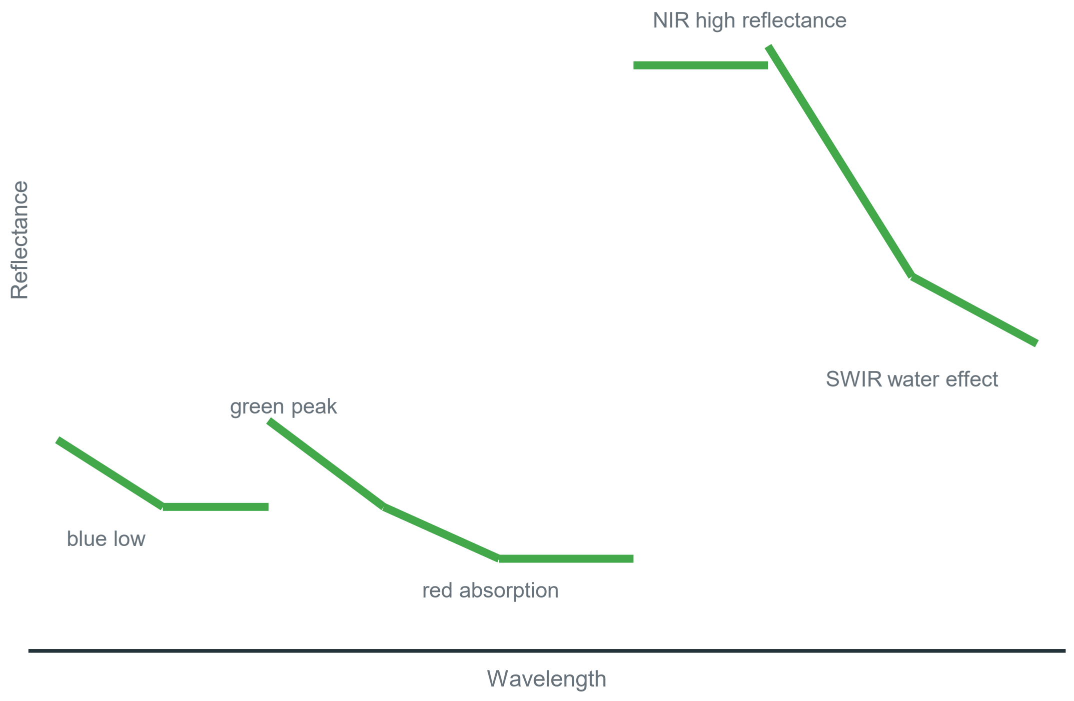
A spectral signature is the characteristic response of a material across wavelengths.
It helps distinguish vegetation, soil, water, and many other materials.
The shape can change with moisture, roughness, health, or season.

Interpretation rule

A signature is powerful evidence, but it should still be used with context and supporting information.

Key idea: Spectral signatures are the practical result of energy–matter interaction.

Spectral Behavior of Vegetation



Chlorophyll absorbs blue and red wavelengths.
Green light is reflected more strongly, so plants appear green.
Healthy leaves reflect strongly in the near infrared.
Water in leaves reduces reflectance in the shortwave infrared.

Application

This distinctive pattern supports vegetation mapping and indices such as NDVI.

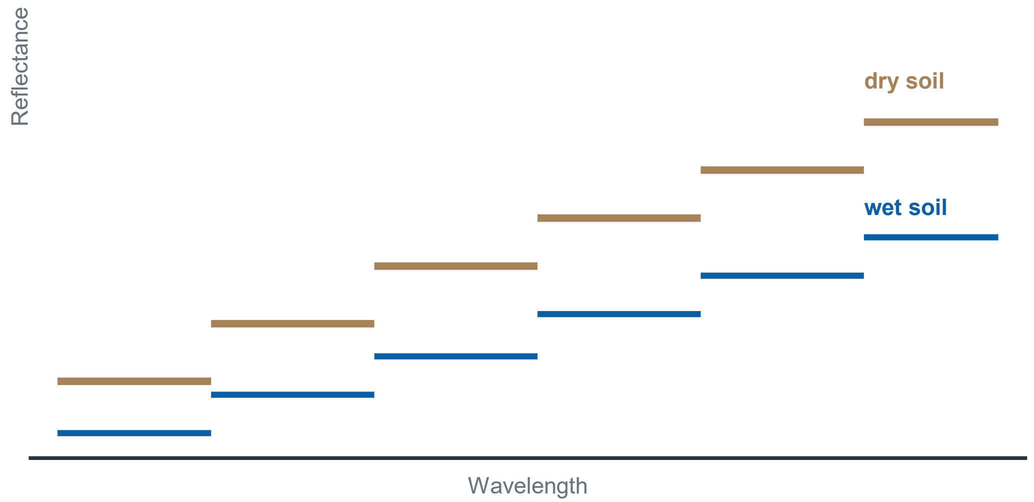
Key idea: Vegetation is often easy to identify because its red absorption and strong NIR reflectance create a distinctive pattern.

Spectral Behavior of Soil

Soil response varies with moisture, texture, organic matter, roughness, and mineral composition.
Dry bare soil often reflects more energy than wet soil.
Wet soil appears darker because water increases absorption.
Soil interpretation is more variable and context-dependent than vegetation interpretation.

Practical note

Soil studies often combine multispectral images with field sampling or laboratory support.



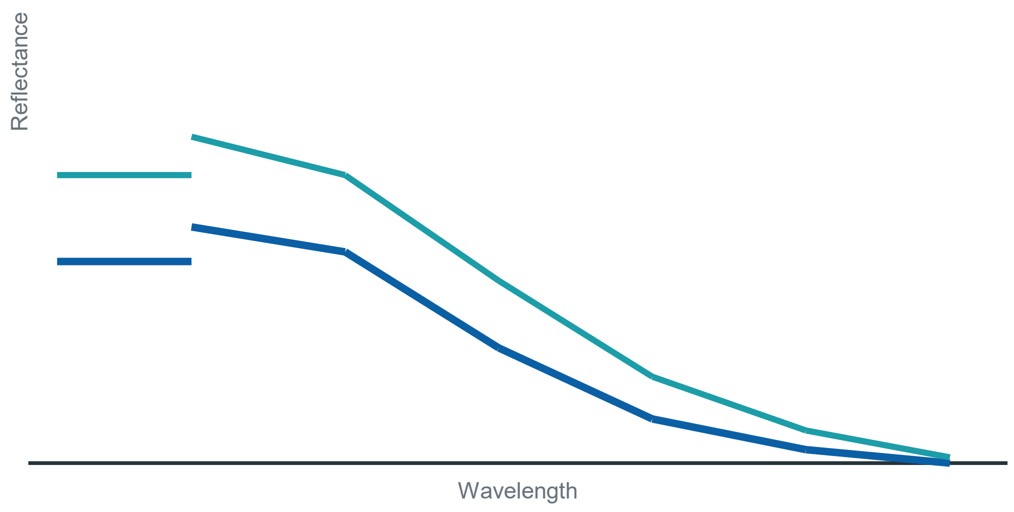
Key idea: Soil is spectrally useful, but it is more variable than vegetation and often needs stronger contextual interpretation.

Spectral Behavior of Water

Water strongly absorbs near infrared and shortwave infrared energy.
As a result, water bodies usually appear dark in those bands.
Visible response depends on depth, suspended sediment, algae, and shallow bottom effects.
Turbid water may look brighter than clear water in some visible wavelengths.

Mapping benefit

Water–land separation is often easiest in NIR and SWIR because water absorbs strongly there.



Key idea: Water behavior changes with wavelength, so both mapping and interpretation should be band-aware.

Choosing Bands and Sensors

Vegetation vigor	Moisture / stress	Temperature	Cloudy or night conditions	General appearance
Red + NIR	SWIR	Thermal IR	Microwave radar	Visible bands

Sensor choice should always be guided by target behavior and wavelength response.
The correct data are chosen because the physics supports the question being asked.
Understanding spectral behavior improves classification, monitoring, and mapping decisions.

Bridge from theory to practice

Physics tells us which measurement is most meaningful for a specific application.

Key idea: Band selection is not random; it should be based on the spectral behavior of the target.

Summary and Recommended Literature

Summary of Week 11

Electromagnetic radiation carries information. The atmosphere modifies the signal. Matter interacts through reflection, absorption, and transmission. Vegetation, soil, and water each show characteristic spectral behavior.

Core textbooks

Lillesand, Kiefer, and Chipman – Remote Sensing and Image Interpretation.
Jensen – Introductory Digital Image Processing: A Remote Sensing Perspective.
Campbell and Wynne – Introduction to Remote Sensing.
Schowengerdt – Remote Sensing: Models and Methods for Image Processing.

Trusted university-based resources

University of Twente – ITC remote sensing learning materials.
ETH Zurich – Earth Observation and Remote Sensing resources.
University of Cambridge – Earth observation and related teaching materials.
University College London – Earth observation study resources.

Independent study tip

Compare theory from these references with real examples from Landsat or Sentinel images. This makes the ideas easier to remember and apply.

Thank you for your attention.

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