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LAND MANAGEMENT ENVIRONMENT & SOLID-WASTE

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MICRO-CREDENTIAL

LAND MANAGEMENT IN CENTRAL ASIA

11.- Electromagnetic Radiation and Energy Interaction

Radiation-Matter Interaction

LM-W11-V73

Why This Topic Matters

Learning outcomes for bachelor-level understanding and practical interpretation

1. Explain the physics

Relate wavelength and photon energy.
Identify reflection, absorption, transmission, emission, and scattering.

4. Apply in land management

Connect interaction processes to crop health, salinity, water, and land-cover mapping.
Choose sensible products for interpretation.

2. Read material responses

Describe typical behavior of vegetation, water, soil, and built surfaces.
Use the term spectral signature correctly.

3. Link physics to sensors

Understand why optical, thermal, and radar systems observe different properties.
Recognize the role of atmospheric windows and correction.

Key question
Why does one sensor band see a target better than another?

From physics to decision support

Energy
Signal
Image
Meaning

Understanding the interaction stage reduces confusion during interpretation and product selection.

Remote Sensing Signal Chain

Radiation–matter interaction sits at the centre of the measurement process

1. **Energy source**
   Sun or an active instrument provides energy.
2. **Atmosphere**
   Scattering and absorption modify the path.
3. **Surface target**
   Vegetation, water, soil, and built materials interact with energy.
4. **Sensor**
   The instrument records reflected, emitted, or returned energy.
5. **Data product**
   Radiance, reflectance, temperature, or backscatter are stored.
6. **Interpretation**
   Analysts convert measurements into maps, indices, and decisions.

If the signal changes anywhere along this chain, the final image changes too. That is why calibration, atmospheric correction, and timing matter.

Electromagnetic Spectrum Used in Remote Sensing

Only selected wavelength regions are practical because of atmospheric transmission and sensor design

UV	Visible	NIR	SWIR	Thermal IR	Microwave
0.3–0.4 µm	0.4–0.7	0.7–1.3	1.3–2.5	8–14	mm–cm

Visible + NIR

Plant pigments and leaf structure

SWIR

Water content, minerals, dry matter

Thermal

Surface temperature and energy balance

Microwave

Structure, roughness, moisture, clouds-penetrating radar

Atmospheric windows

Optical window

SWIR window

Thermal window

Radar window

Not all wavelengths reach the sensor equally well.

Why Wavelength Matters

Photon energy, penetration depth, and atmospheric transmission all influence what a band can detect

$$E = hc / \lambda$$

Shorter wavelength → higher photon energy

Moving right across the spectrum usually means lower photon energy

Implication 1: interaction depth

Some wavelengths interact with surface pigments.
Others respond more to water, structure, or temperature.

Implication 2: atmospheric effects

Scattering is stronger at shorter wavelengths.
Absorption by gases creates blocked spectral regions.

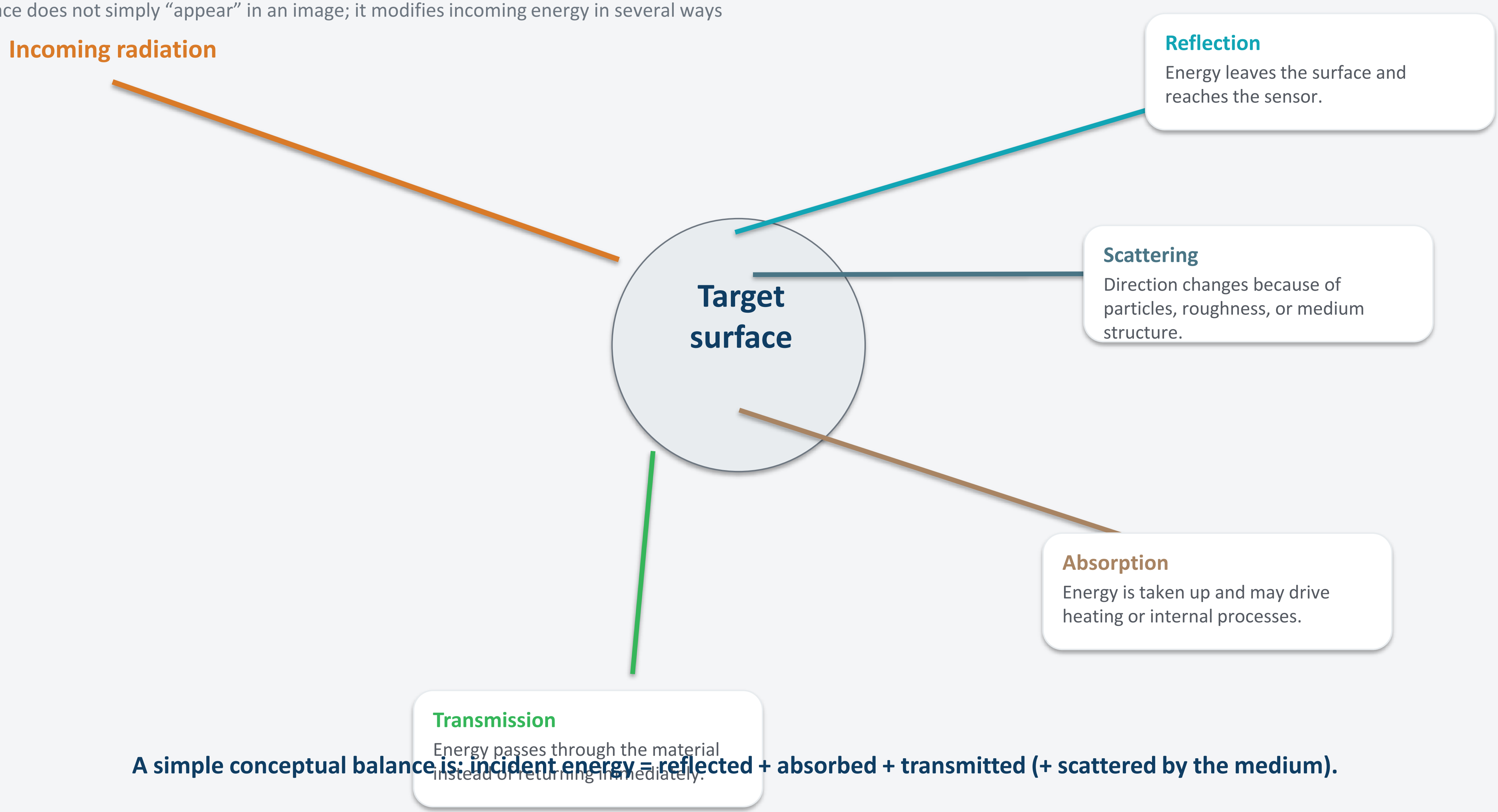
Implication 3: sensor design

Band placement is never arbitrary.
It targets specific physical responses and applications.

Blue haze — Red edge — Water absorption — Thermal emission — Radar

Four Core Interaction Processes

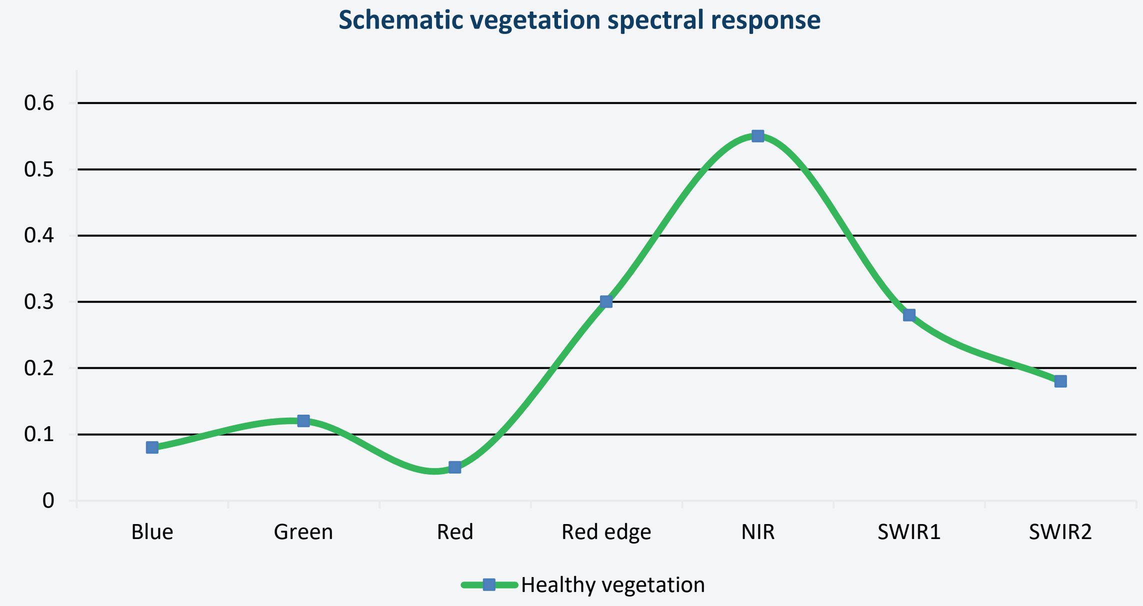
A surface does not simply "appear" in an image; it modifies incoming energy in several ways



A simple conceptual balance is: incident energy = reflected + absorbed + transmitted (+ scattered by the medium).

Vegetation: One of the Most Distinct Spectral Targets

Plant pigments, internal leaf structure, and water content together shape the curve



Illustrative pattern, not a sensor-specific calibration curve.

Visible region

Strong absorption in blue and red by chlorophyll.
Small green peak explains why leaves look green.

Near infrared

Very high reflectance from internal leaf structure.
Useful for vigor and canopy condition.

Shortwave infrared

Reflectance drops as leaf water content increases.
Supports moisture and stress interpretation.

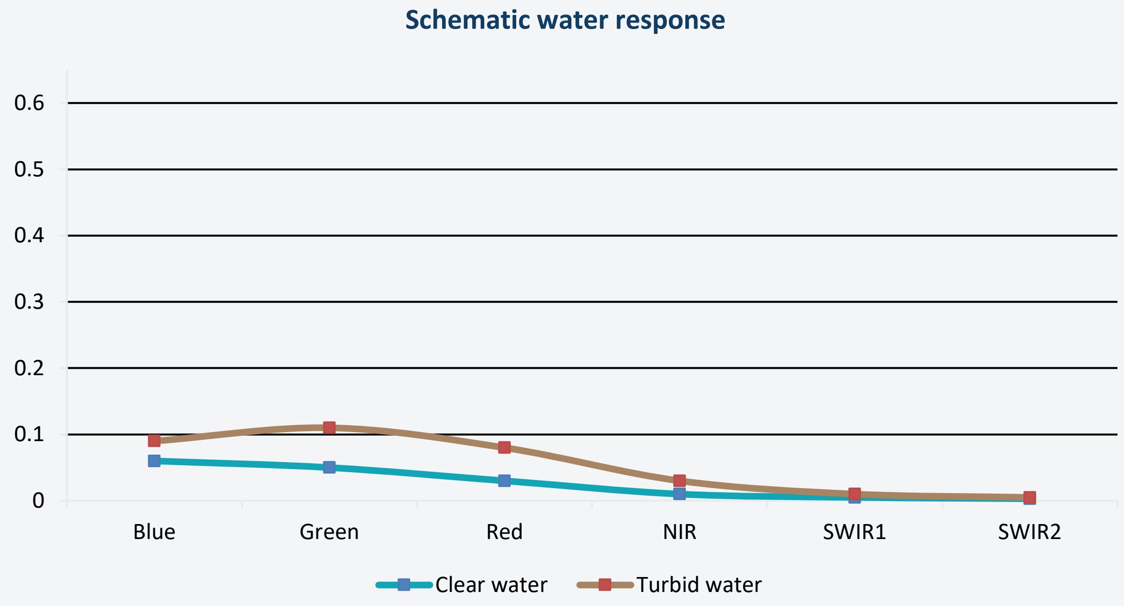
Management meaning

Red + NIR bands support NDVI and related indices.
Stress often alters the curve before damage is visible.

The “red edge” is especially valuable because it marks the rapid transition from strong red absorption to high NIR reflectance.

Water: Usually Dark in NIR and SWIR

Absorption dominates, but turbidity, depth, bottom effects, and surface condition also matter



Turbid water can be brighter in visible bands because suspended material increases backscatter.

Clear water

Low reflectance overall, especially in NIR and SWIR. Often appears dark in false-colour composites.

Turbid or shallow water

Sediment, algae, or bottom visibility can raise visible reflectance.
Interpret with context and timing.

Surface condition

Waves and specular reflection can change brightness.
Sun glint may create false highlights.

Applications

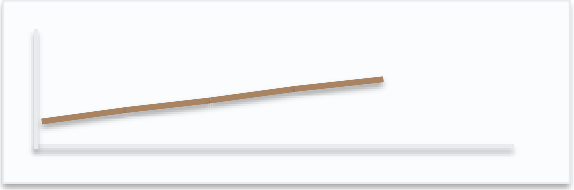
Reservoir extent, irrigation, wetlands, floods, and waterlogging.
NIR/SWIR are especially useful for water separation.

Dark NIR/SWIR response helps isolate water bodies

Soil, Minerals, and Built Surfaces

These targets are more variable than vegetation and water, so context and wavelength choice are essential

Soil



schematic pattern

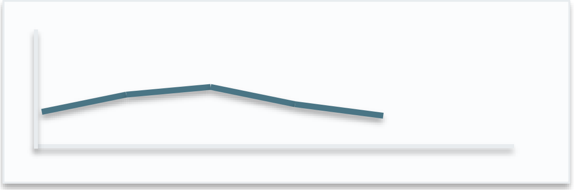
Brightness often rises from visible to NIR.
Moisture lowers reflectance and can mask mineral clues.
Organic matter and texture also change the curve.

Minerals

schematic pattern

Diagnostic absorption features are common in SWIR and thermal regions.
Iron oxides influence visible colours.
Spectroscopy is powerful for lithology and alteration mapping.

Built surfaces



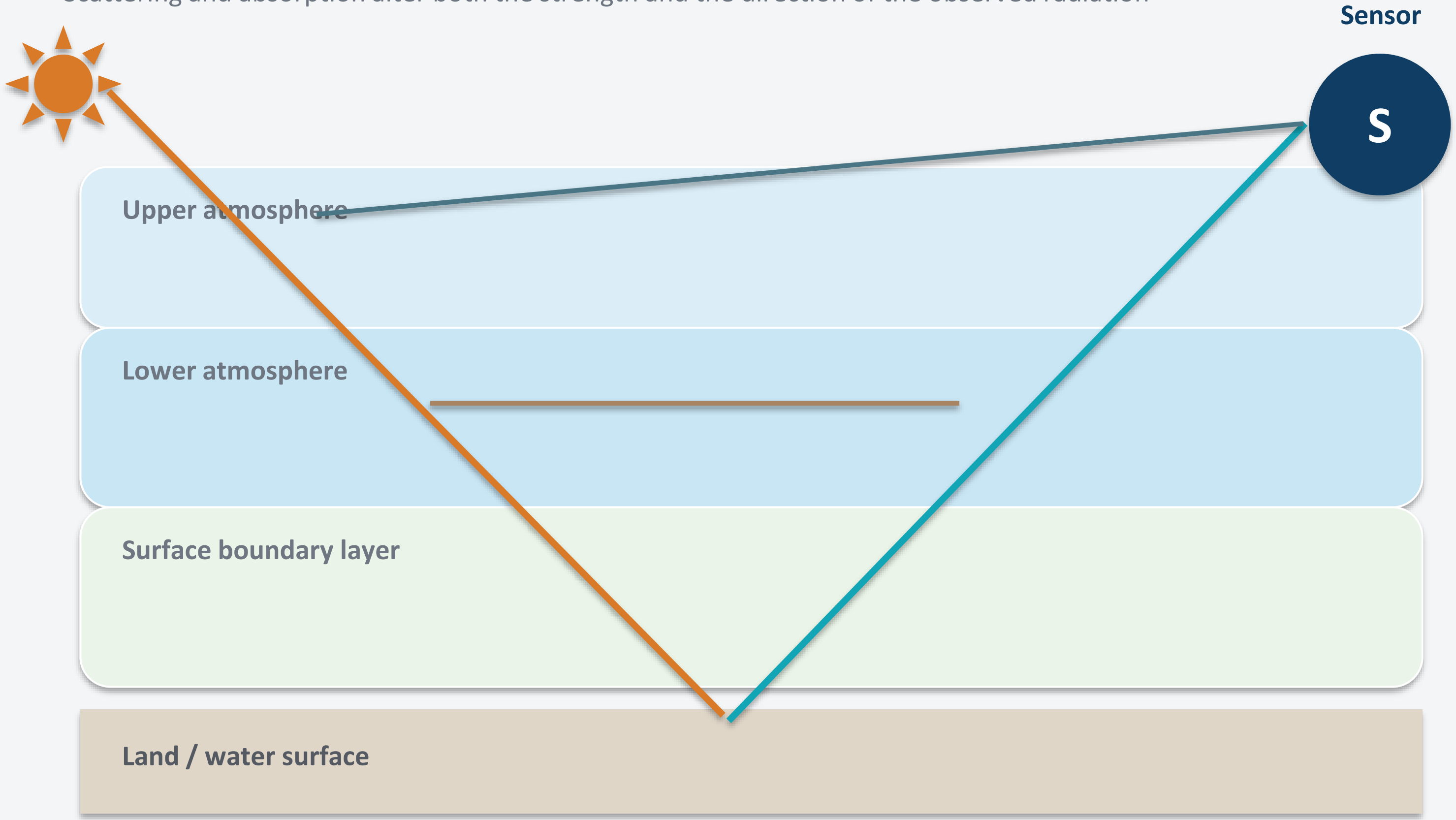
schematic pattern

Concrete, asphalt, metal, roofing, and dry urban soil do not behave the same.
Urban pixels are often mixed.
Thermal response can differ strongly from optical colour.

Interpretation rule: these surfaces are often controlled by mixtures, moisture, roughness, and scale. That makes field knowledge and atmospheric correction especially important.

Atmospheric Effects Before the Signal Reaches the Sensor

Scattering and absorption alter both the strength and the direction of the observed radiation



Scattering

Rayleigh scattering is stronger at shorter wavelengths.
Haze raises path radiance and reduces contrast.

Absorption

Water vapour, ozone, and gases absorb selected bands.
This is why blocked and window regions exist.

Correction goal

Estimate surface reflectance rather than top-of-atmosphere signal when comparing dates or mapping materials.

Observed signal = surface response + atmospheric effects + sensor characteristics

What This Means for Sensor Choice

The target property should determine the band region, platform, and measurement mode

Passive optical

Measures reflected solar energy
Best for colour, vegetation, water, land cover

Thermal infrared

Measures emitted energy
Best for surface temperature and thermal anomalies

Active radar

Sends microwave pulses and records return
Best for roughness, structure, moisture, clouds/night

LiDAR / active laser

Measures pulse travel and return intensity
Best for elevation and canopy structure

Selection checklist

- Target property
- Atmosphere/clouds
- Spatial scale
- Revisit need
- Budget & processing

From Physics to Analysis Products

Indices and classification work well when they are grounded in real material behaviour

Surface reflectance

Atmospheric correction reduces non-surface effects.

Band combinations

Choose wavelengths that separate target responses.

Indices / features

Example: NDVI, NDWI, texture, temperature, backscatter.

Maps / decisions

Classification, monitoring, alerts, and management action.

Example 1: vegetation index

NDVI works because red absorption and NIR reflection differ strongly in plants.

Example 2: water mapping

NIR/SWIR-based contrasts help isolate water, flood extent, and wet surfaces.

Interpretation warning

A formula is useful only when it matches the physical context and sensor bands.

Why This Week Matters for Central Asia

Radiation–matter interaction is the physical basis behind many land and water applications in the region

Irrigation & crop stress

Red–NIR contrast supports crop vigor monitoring.
SWIR helps indicate canopy and soil moisture differences.

Salinity & waterlogging

Bright bare soils and wet surfaces respond differently across visible, NIR, and SWIR bands.
Thermal patterns may also reveal poor drainage.

Snow, glacier melt, and reservoirs

Visible/NIR/SWIR combinations help separate snow, water, and land.
Time series support seasonal water resource assessment.

Rangelands, dust, and degradation

Vegetation cover decline changes reflectance patterns.
Exposed soil and dust sources become easier to track over time.

In all four examples, the practical question is the same: which wavelength region captures the physical difference we care about?

Key Takeaways

A short checklist for review and exam preparation

1. Different materials modify radiation differently.
2. Key processes are reflection, absorption, transmission, emission, and scattering.
3. Vegetation, water, soil, and built surfaces have distinct—but not always simple—responses.
4. Atmospheric effects can distort the observed signal, so correction matters.
5. Good products come from matching bands and methods to physical meaning.

Ask these four questions whenever you read an image:

- What wavelength or band is being used?
- Which interaction process dominates the signal?
- How might the atmosphere or viewing geometry affect it?
- What land-management decision could this measurement support?

Remote sensing becomes much easier to understand when you treat the image as a physical measurement rather than a picture alone.

References and Suggested University Literature

Core sources used for this deck, plus reputable university sources for further study

Core references used

University of Twente / ITC. Principles of Remote Sensing (course and textbook resources).

Woldai, T. Electromagnetic Energy and Remote Sensing. In Principles of Remote Sensing.

NASA Applied Remote Sensing Training Program. Fundamentals of Remote Sensing.

NASA ARSET. Spectral Indices for Land and Aquatic Applications, Part 1.

U.S. Geological Survey. What is Remote Sensing and what is it used for?

U.S. Geological Survey. Landsat Collection 2 Surface Reflectance.

Suggested high-reputation university literature

ETH Zurich – Chair of Earth Observation and Remote Sensing (research and teaching materials).

University of Cambridge – Centre for Earth Observation (remote sensing of environmental change).

UCL – Environmental Modelling and Observation / Earth Observation-related research clusters.

Rees, W. G. Physical Principles of Remote Sensing. Cambridge University Press.

Schott, J. R. Remote Sensing: The Image Chain Approach. Rochester Institute of Technology tradition.

Campbell, J. B. & Wynne, R. H. Introduction to Remote Sensing.

For student use, prioritize official course pages, university textbooks, NASA/USGS documentation, and peer-reviewed Earth observation literature.

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