ERASMUS-EDU-2023-CBHE
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LESLIE
LAND MANAGEMENT
ENVIRONMENT &
SOLID-WASTE

MICRO-CREDENTIAL

LAND MANAGEMENT IN CENTRAL ASIA

12.- Sensors and Remote Sensing Platforms

Optical Sensors

LM-W12-V79

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Learning outcomes

Concept map

By the end of this lesson, students should be able to explain, compare, and choose optical sensors.

Define
What optical sensors measure

Explain
The sunlight–surface–sensor chain

Compare
Panchromatic, multispectral, hyperspectral

Select
Sensor data for land management tasks

Evaluate
Strengths, limits, and uncertainty

Guiding question

When is an optical image better than a radar image, and when is it not enough?

Skills focus

Reading bands, understanding reflectance, and choosing sensor data for a real problem.

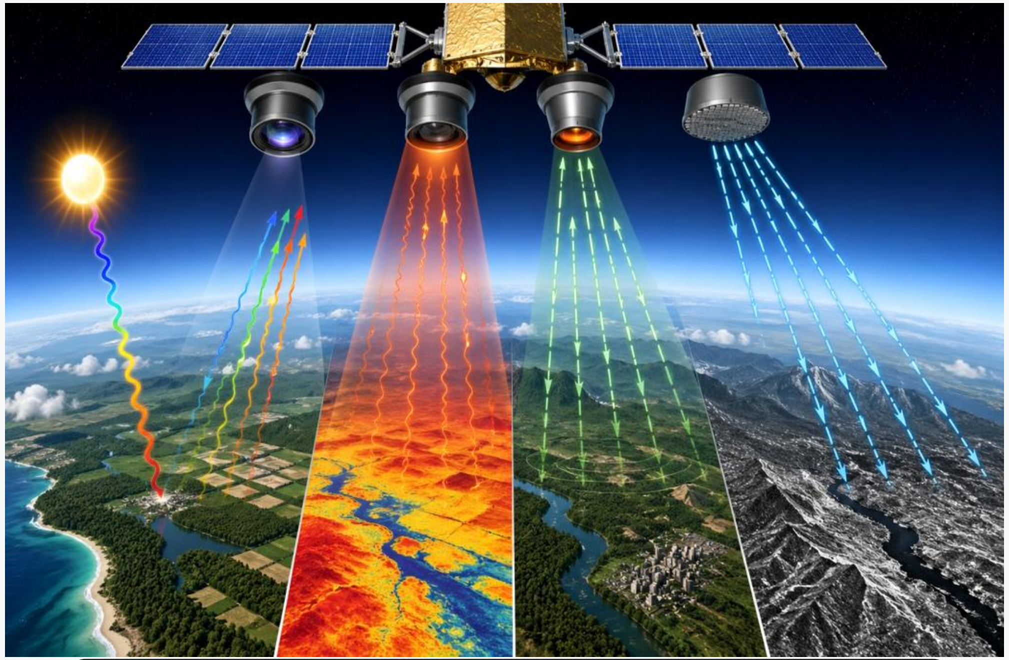
Practical link

Crop monitoring, irrigation mapping, land cover change, and environmental assessment.

What is an optical sensor?

Core concept

An optical sensor records electromagnetic energy mainly in visible, near-infrared, and shortwave-infrared wavelengths.



Optical sensing uses light-like wavelengths

Passive by design
Most optical Earth-observation sensors depend on sunlight reflected by the surface.

Surface response matters
Vegetation, soil, water, and buildings reflect different wavelengths differently.

Digital measurement
The sensor converts incoming energy into pixel values that can be corrected, analyzed, and mapped.

Sunlight — Surface — Sensor — Image

Source note: NASA Earthdata explains that passive instruments detect energy emitted or reflected from observed objects.

From sunlight to pixel: the optical signal chain

Process

A useful image is created through a sequence of physical interactions and processing steps.

1

Solar illumination

Sunlight reaches the Earth–atmosphere system

2

Atmosphere

Scattering and absorption modify the signal

3

Target surface

Materials reflect, absorb, or transmit energy

4

Optics & detector

Lens/mirrors focus energy onto detectors

5

Digital image

Pixel values are stored, corrected, and interpreted

Important interpretation rule

Optical pixel values are not "pure object labels." They are measurements affected by surface condition, atmosphere, illumination angle, sensor design, and processing level.

Main optical spectral regions

Spectrum

Optical remote sensing uses wavelength bands that reveal different surface properties.

Visible

Human-like color information; useful for water turbidity, soil color, vegetation greenness, and urban features.

Near-infrared

Very sensitive to vegetation structure and biomass; strong contrast between healthy vegetation and water.

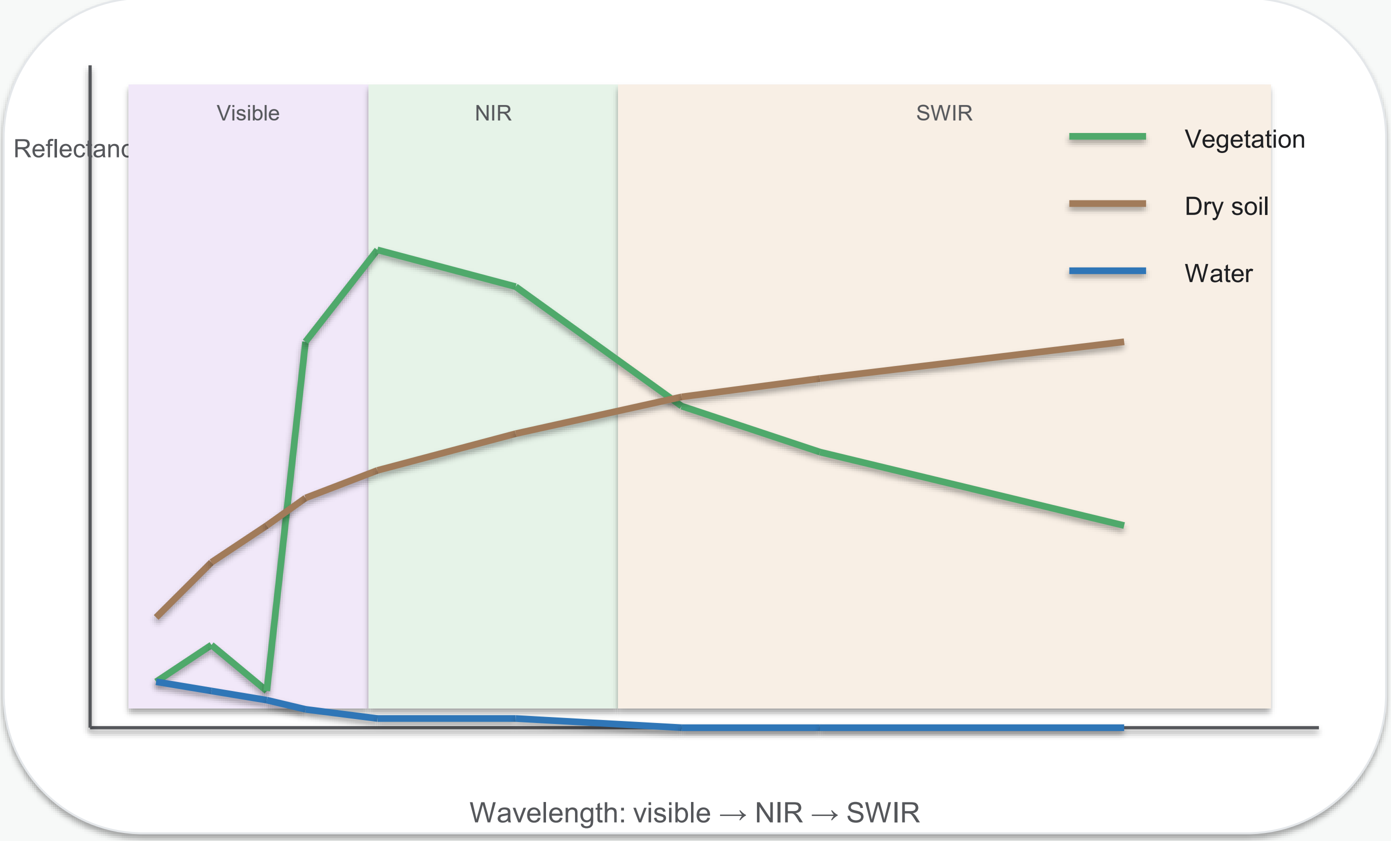
Shortwave infrared

Sensitive to moisture, minerals, burned areas, and dry vegetation or bare soil conditions.

What optical sensors measure: reflectance patterns

Spectral response

Different land-cover types create different spectral signatures.



Vegetation

Low red reflectance + high NIR reflectance is the classic basis for NDVI.

Soil

Soil often shows a smoother increase across visible and infrared wavelengths; moisture reduces reflectance.

Water

Clear water has low reflectance, especially in NIR and SWIR, making shorelines easier to separate.

Families of optical sensors

Sensor types

The number and width of bands strongly influence what we can detect.

Panchromatic

One broad band
Very sharp spatial detail; limited material separation.
Examples: High-resolution base maps; pan-sharpening

Multispectral

Several broad bands
Balanced detail and spectral information; common for land monitoring.
Examples: Landsat OLI, Sentinel-2 MSI, MODIS

Hyperspectral

Many narrow bands
Fine spectral detail for minerals, vegetation stress, water quality, and material mapping.
Examples: NASA AVIRIS: 224 contiguous bands from 400–2500 nm

Inside an optical sensor

Instrument anatomy

Optical sensors are measurement systems, not just cameras.

Optical sensor measurement chain

Aperture
Collects light

Detector array
Converts photons to signal

Optics
Focuses energy

A/D conversion
Stores digital numbers

Filters / grating
Separates wavelengths

Calibration is essential: raw digital numbers must be converted into reliable radiance or reflectance before scientific comparison.

Resolution trade-offs in optical sensing

Decision framework

Choosing a sensor means balancing detail, spectral power, timing, and data volume.

Spatial resolution

Smaller pixels can show fields, roads, canals, and boundaries more clearly.

Spectral resolution

More and narrower bands help separate materials that look similar in true color.

Temporal resolution

Frequent revisit matters for clouds, crop stages, irrigation events, and sudden change.

Good sensor choice begins with the question, not with a popular satellite name.

Case study: Landsat Operational Land Imager (OLI)

Example sensor

Landsat OLI is a widely used optical sensor for long-term land monitoring.

Band	Name	Wavelength
B1	Coastal	0.43–0.45 µm
B2	Blue	0.45–0.51 µm
B3	Green	0.53–0.59 µm
B4	Red	0.64–0.67 µm
B6	SWIR1	1.57–1.65 µm
B7	SWIR2	2.11–2.29 µm
B8	PAN	0.50–0.68 µm
B9	Cirrus	1.36–1.38 µm

Sensor profile

Nine OLI spectral bands, including a 15 m panchromatic band and 30 m multispectral bands.

Why it matters

Landsat provides decades of comparable imagery, enabling long-term land change analysis.

Typical use

Land cover, vegetation, surface water, burned areas, urban expansion, and dryland monitoring.

Download Level-2 → Cloud mask → Composite → Index → Map

Case study: Sentinel 2 Multispectral Instrument (MSI)

Example sensor

Sentinel-2 MSI is important for frequent land and vegetation monitoring.

13
spectral bands

10 / 20 / 60 m
band-dependent resolution

290 km
swath width

5 days
revisit time at equator with two satellites

How to read Sentinel-2 bands

10 m bands support detailed mapping of visible/NIR patterns; 20 m red-edge and SWIR bands support vegetation, moisture, and stress analysis; 60 m bands support atmospheric correction.

From bands to useful optical products

Products

A single optical sensor can support many products depending on band combination and processing.

True color

Red + Green + Blue
Human-like view for visual interpretation

False color

NIR + Red + Green
Vegetation appears brighter and easier to separate

NDVI

(NIR − Red) / (NIR + Red)
Vegetation vigor and greenness

NDWI / MNDWI

Green–NIR or Green–SWIR
Surface water mapping and wetlands

NBR

NIR and SWIR
Burn severity and dry vegetation stress

Cloud mask

QA + spectral tests
Removes cloudy and shadowed pixels

Best practice: use surface reflectance products, mask clouds and shadows, compare dates carefully, and validate with field observations.

Applications for land management in Central Asia

Regional relevance

Optical sensors are especially useful where land, water, and vegetation change across seasons.

Irrigation monitoring
Field condition, canals, uneven water delivery

Crop development
NDVI timing, growth stages, stress detection

Surface water change
Reservoirs, lakes, wetlands, floodwater

Salinity & degradation
Bare soils, vegetation stress, long-term trends

Urban and infrastructure
Settlement expansion, roads, corridor analysis

Strengths and limitations of optical sensors

Critical thinking

Optical data is powerful, but interpretation must be cautious.

Strengths

- Intuitive visual interpretation for beginners
- Rich spectral information for vegetation, soil, water, and built surfaces
- Frequent free imagery from public missions such as Landsat and Sentinel-2
- Strong integration with GIS, field data, and machine learning workflows

Limitations

- Clouds, haze, and shadows can block or distort reflected sunlight
- Illumination changes make dates harder to compare
- Different surfaces can look similar in some bands
- Field validation is still needed for reliable land-cover labels

Practical rule: optical sensors answer many land questions well, but cloud masking, multi-date analysis, and field validation improve reliability.

Key takeaways and selected references

Summary

Review the concepts, then compare them with real Landsat and Sentinel-2 images.

Key takeaways

- Optical sensors mainly measure reflected sunlight in visible, NIR, and SWIR bands.
- Band choice determines what can be separated: vegetation, water, soil, urban surfaces, and moisture-related patterns.
- Multispectral systems such as Landsat OLI and Sentinel-2 MSI are practical for land management because they balance coverage, frequency, and spectral information.
- Results should be interpreted together with processing level, cloud mask, date, season, and field validation.

Selected references

- NASA Earthdata. Passive Instruments; Sentinel-2 MSI; MODIS; HLS.
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