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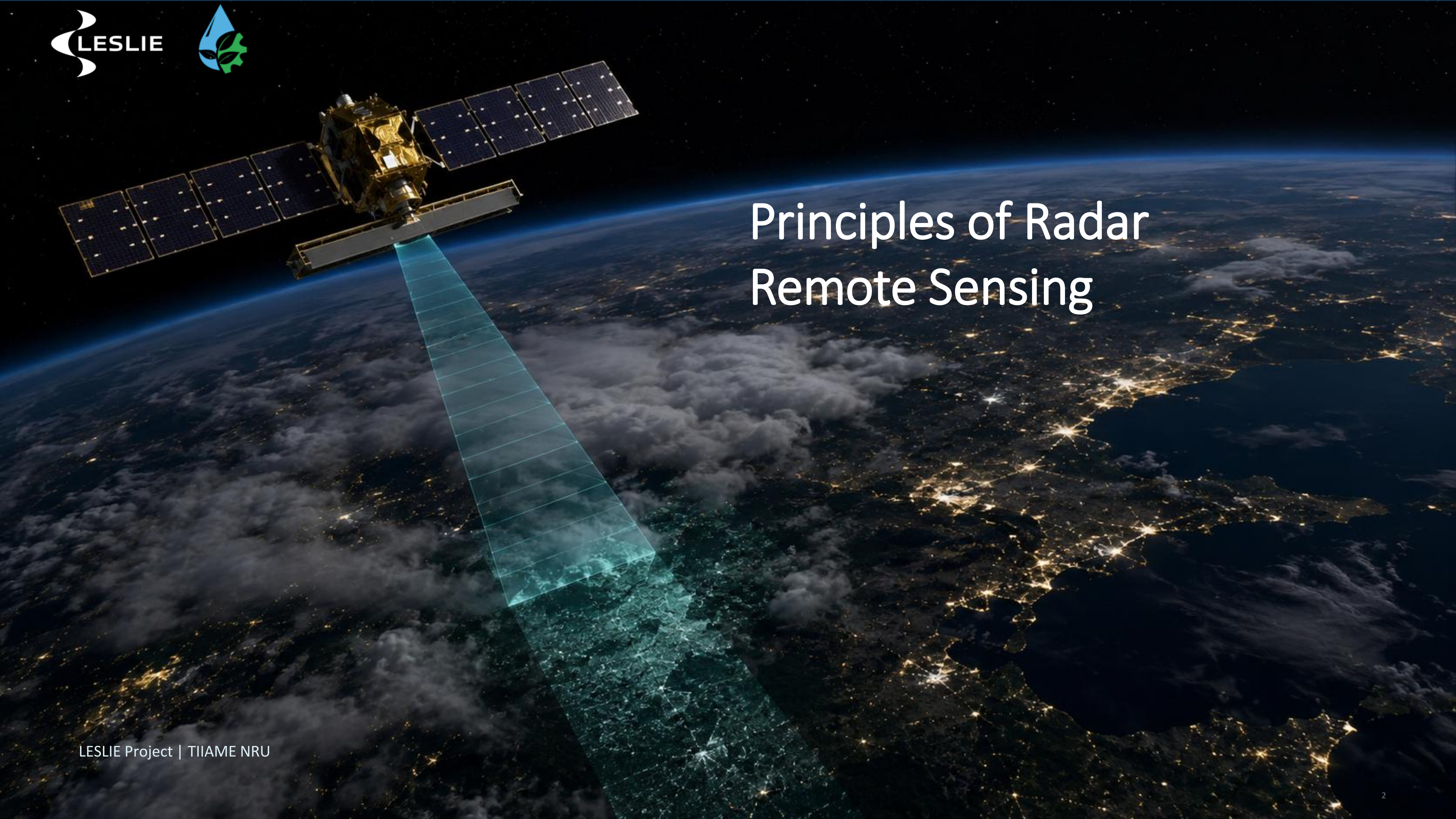
LAND MANAGEMENT IN CENTRAL ASIA

14.- Radar and Laser Remote Sensing

Principles of Radar Remote Sensing

LM-W14-V92



Principles of Radar Remote Sensing

Learning objectives

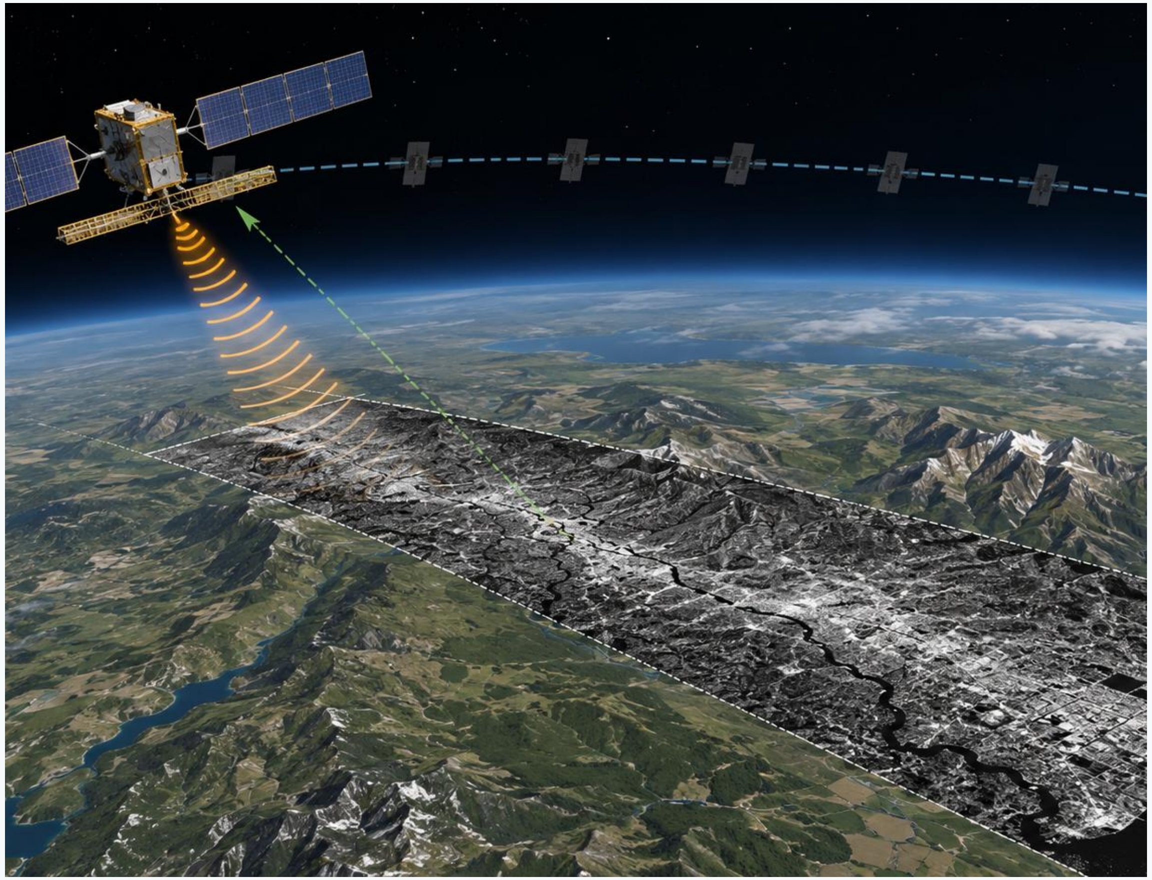
By the end of this lesson, students should understand how radar systems collect and interpret Earth observation data.

1. Define radar remote sensing and SAR
2. Explain active microwave imaging
3. Describe radar geometry and backscatter
4. Interpret common radar image patterns
5. Connect radar data to land management tasks

What is radar remote sensing?

Radar uses its own microwave signal to observe the Earth surface from aircraft or satellites.

RADAR means Radio Detection and Ranging.
It is an active system: the sensor transmits pulses and records the returned echo.
Microwave wavelengths allow observation during day or night and through many cloud conditions.
The recorded signal is influenced by surface roughness, moisture, structure, and viewing geometry.



Key idea: radar images do not show “colour” like optical images. They show the strength and pattern of returned microwave energy.

Active microwave principle

Radar observation follows a transmit–interact–return–record logic.

1 Transmit	2 Interact	3 Backscatter	4 Receive	5 Process

Radar sends a pulse and measures two main properties: how long the echo takes to return, and how strong the echo is.

The echo carries information about distance, surface roughness, orientation, dielectric properties, and moisture.

Classroom analogy

Like shouting in a canyon and listening to the echo, radar “illuminates” the surface and interprets the returning signal.

Microwave wavelengths and radar bands

Radar systems use longer wavelengths than visible light, so they interact with surfaces differently.

Band	Approx. wavelength	Typical land information
X	≈ 2.4–3.8 cm	Fine surface texture; urban detail; crop structure
C	≈ 3.8–7.5 cm	Agriculture; wetlands; flood mapping; deformation
L	≈ 15–30 cm	Vegetation structure; forest; soil moisture sensitivity
P	≈ 30–100 cm	Deeper vegetation penetration; special missions

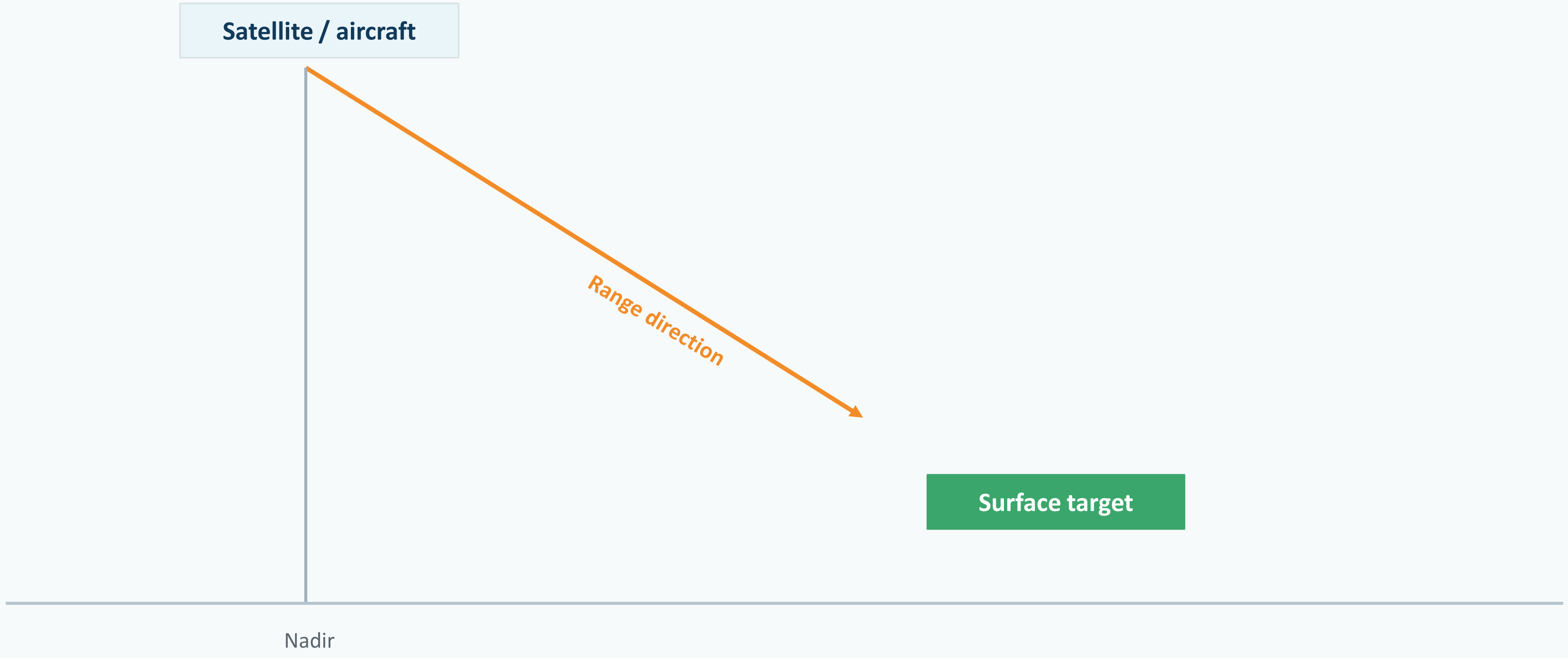
Important: longer wavelength usually interacts with larger structures and can penetrate further into vegetation or dry surface materials than shorter wavelength radar.

RADAR BANDS

shorter → longer

Radar viewing geometry

Most imaging radar systems look to the side, not straight down.



Incidence angle: angle between the radar beam and the vertical direction at the target. It strongly affects brightness and interpretation.

Range is across the radar look direction. Azimuth follows the flight path. Both are used to locate image pixels.

What controls radar backscatter?

Backscatter is the portion of transmitted energy that returns to the sensor.

Surface roughness

Rough surfaces usually return stronger signals than smooth surfaces at the same wavelength.

Moisture / dielectric properties

Wet soil, water-filled vegetation, and moist surfaces often increase radar response.

Geometry and orientation

Slopes, buildings, and row direction can strongly change brightness.

Vegetation structure

Leaves, stems, trunks, and canopy density influence volume scattering.

Interpretation rule: the same land cover may look different under different wavelength, polarization, and incidence angle.

Polarization: direction of the radar wave

Polarization describes the orientation of transmitted and received microwave energy.

HH	VV	HV	VH
horizontal transmit horizontal receive	vertical transmit vertical receive	horizontal transmit vertical receive	vertical transmit horizontal receive

Co-polarization (HH, VV) often emphasizes surface and double-bounce responses.

Cross-polarization (HV, VH) often helps identify volume scattering in vegetation and complex structures.

Using more than one polarization improves interpretation because different scattering mechanisms become visible.

Synthetic Aperture Radar (SAR)

SAR improves spatial detail by using the motion of the platform to simulate a much larger antenna.

A real antenna receives echoes repeatedly as the satellite moves forward.
These echoes are combined coherently during processing.
The result is a high-resolution radar image across a wider area.
SAR data can be used for mapping water, soil moisture indicators, deformation, crops, forest, ice, and urban features.

The word “synthetic” means that the large antenna is created mathematically from many measurements collected along the flight path.

Reading a radar image

Radar image tones represent the strength and behaviour of microwave backscatter.

Dark tone	Smooth water or very smooth dry surfaces often return little energy.
Bright tone	Rough surfaces, wet soil, urban corners, or slopes facing the sensor may return strong energy.
Speckle	Radar images have granular noise because coherent waves interfere with each other.
Shadow / layover	Mountains and tall buildings can distort the image due to side-looking geometry.

Practical tip for students: always interpret radar brightness together with geometry, wavelength, polarization, and local knowledge.

Basic SAR processing workflow

SAR imagery usually needs several preparation steps before analysis.

1. Download SAR data → **2. Apply orbit file** → **3. Radiometric calibration** → **4. Speckle filtering** → **5. Terrain correction** → **6. Analysis / map output**

Calibration converts raw image values into physically meaningful backscatter measures.
Terrain correction improves the geometric location of pixels using a digital elevation model.
For land management, processed SAR layers can be combined with optical imagery, cadastre data, field observations, and GIS layers.

Applications for land management

Radar data are especially useful where clouds, timing, moisture, or surface structure matter.

Flood and wetland mapping

Separate open water and inundated zones even during cloudy weather.

Agriculture monitoring

Support crop structure, soil moisture indicators, and seasonal field observation.

Land degradation

Help detect changes related to salinity risk, surface wetness, erosion features, and drainage problems.

Urban and infrastructure

Identify built-up structures and support deformation monitoring with InSAR.

Mountain hazards

Map landslides, snow, glaciers, and terrain-related risks.

Central Asia example: irrigated landscapes

Radar can complement optical data in dryland and irrigated land management.

Typical questions radar can support

Where are wet fields, open water, or recently irrigated areas?
How do crop structures change during the season?
Where are drainage, salinity, or waterlogging risks likely to increase?
Which areas changed after flooding, extreme rain, or infrastructure failure?

For Uzbekistan and Central Asia, radar is strongest when it is combined with field data, optical satellite imagery, land parcel boundaries, and GIS-based spatial analysis.

Strengths and limitations

Radar is powerful, but interpretation must be careful and technically informed.

Strengths

Works day and night
Can observe through many cloud conditions
Sensitive to roughness, structure, and moisture
Useful for deformation and flood monitoring
Complements optical data in cloudy or urgent situations

Limitations

Requires special processing
Speckle complicates interpretation
Geometry can create layover and shadow
Brightness is not always simple to explain
Field knowledge is needed for reliable conclusions

Best practice: use radar as one layer in an evidence-based GIS workflow, not as a stand-alone truth.

Key points and references

Radar remote sensing expands the land management toolbox beyond optical imagery.

Radar is an active microwave system that transmits pulses and records echoes.
SAR uses platform motion and signal processing to create detailed radar images.
Backscatter depends on roughness, moisture, structure, wavelength, polarization, and geometry.
Radar is valuable for agriculture, floods, land degradation, infrastructure, and deformation monitoring.

Selected references

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Copernicus Data Space Ecosystem. Sentinel-1 data collection.
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Shokirov, Musaev, Akbarov. Masofadan zondlash, Tashkent, 2015.

Reflection question: In which land management task would radar provide more useful evidence than optical imagery alone?

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