LAND MANAGEMENT, ENVIRONMENT & SOLID-WASTE: INSIDE EDUCATION AND BUSINESS IN CENTRAL ASIA
ERASMUS-EDU-2023-CBHE Project Number: 101129032

MICRO-CREDENTIAL

LAND MANAGEMENT IN CENTRAL ASIA

14.- Radar and Laser Remote Sensing

Activity

Analyze radar or LiDAR-derived data

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1. Purpose of this workbook

This activity package helps students analyse radar or LiDAR-derived data for practical land management questions. It is designed for undergraduate students who already know the basic logic of remote sensing and are ready to compare different types of Earth observation evidence. Students do not need advanced programming skills. The activity can be completed with prepared screenshots, downloaded sample layers, or a GIS project prepared by the instructor.

2. Learning objectives

By the end of the activity, students should be able to explain why radar and LiDAR are active remote sensing systems; identify what radar backscatter and LiDAR elevation products represent; compare radar and optical data for flood, moisture, roughness, and land-cover interpretation; distinguish DSM, DTM/DEM, canopy height, slope, and hillshade products; and prepare a short evidence-based interpretation for land management in Central Asia.

3. Required materials and software

The instructor may choose one of three formats: a paper-based interpretation activity using printed maps, a GIS laboratory using QGIS or ArcGIS Pro, or a Google Earth Engine demonstration using Sentinel-1. The minimum materials are: one Sentinel-1 SAR image or derived map, one optical reference image, one DEM or LiDAR-derived elevation layer, a boundary layer for the study area, and the worksheets in this document.

Suggested study area

Use a local or regional area familiar to students, for example an irrigated district, river floodplain, peri-urban zone, mountain foothill, or erosion-prone landscape in Uzbekistan or Central Asia. Local context helps students connect sensor physics with land management decisions.

4. Short technical background

Radar and LiDAR both use their own energy source, so they are classified as active remote sensing systems. Radar systems send microwave energy and measure the returned signal. SAR is useful because it can acquire imagery day or night and through most weather conditions. NASA Earthdata describes SAR as a technology that can create high-resolution imagery regardless of daylight and weather, while ESA describes Sentinel-1 as an all-weather, day-and-night radar mission.

LiDAR systems send laser pulses and measure the time taken for pulses to return to the sensor. The result is commonly represented as a point cloud and converted into products such as digital surface models, digital terrain models, canopy height models, slope layers, and hillshade visualizations. USGS 3DEP provides lidar point clouds and digital elevation models through The National Map, and NASA GEDI provides spaceborne lidar observations of forest canopy height, vertical structure, and surface elevation.

Technology	Main signal	Typical products	Strong uses in land management	Main caution
SAR / radar	Microwave backscatter	VV/VH images, backscatter maps, coherence, flood masks, deformation maps	Flood mapping, soil moisture indicators, surface roughness, crop structure, all-weather monitoring	Speckle, layover, shadow, incidence angle and difficult visual interpretation
LiDAR	Laser pulse return time	Point cloud, DEM/DTM, DSM, CHM, slope, hillshade, profiles	Terrain modelling, drainage analysis, erosion risk, building height, forest/canopy structure	Data size, cost, coverage limits, need for classification and quality checks

5. Instructor preparation notes

Before the lesson, prepare one small study area and reduce the data volume. Students should focus on interpretation, not on downloading large datasets. A good practical package includes a SAR image before and after a flood or irrigation event, a hillshade or DEM layer, an optical reference image, and a simple vector boundary. If LiDAR point clouds are too large, provide derived raster products such as DTM, DSM, slope, or canopy height.

6. Activity workflow

The activity is organised as a sequence. Students first choose which data source fits a land management problem. Then they read radar backscatter patterns, interpret LiDAR-derived elevation products, combine evidence, and prepare a short technical conclusion. The instructor may complete all sections in a 90–120 minute laboratory or divide the activity into classroom and homework components.

Stage	Student task	Main skill	Expected output	Time
A	Review the study area and problem statement	Problem framing	Short statement of objective	10 min
B	Compare optical, radar, and LiDAR data options	Sensor selection	Data-source justification table	15 min
C	Interpret radar backscatter and change	SAR interpretation	Annotated radar observations	25 min
D	Interpret LiDAR/DEM products	Terrain interpretation	Elevation and slope notes	25 min
E	Combine evidence and write conclusion	Evidence synthesis	One-page interpretation note	20–30 min

7. Activity 1 – Select the right data source

Students work in pairs. For each land management problem, decide whether optical data, SAR data, LiDAR-derived data, or a combination is most suitable. Write a short reason. The purpose is not to say that one technology is always better, but to match the sensor to the information need.

Land management problem	Best data choice	Why this choice fits	Possible limitation
Mapping flood extent after several cloudy days			
Estimating terrain slope for erosion-risk planning			
Checking surface wetness in irrigated fields			
Estimating tree height or shelterbelt structure			
Mapping buildings and vertical urban structure			
Classifying crop type during clear weather			
Monitoring deformation or land subsidence			
Planning drainage channels in flat irrigated land			
Student hint			
Optical images are usually intuitive for land cover and vegetation colour, but clouds and darkness limit them.			

SAR is useful when clouds or timing are a problem and when moisture, roughness, or structure are important. LiDAR is strongest when accurate elevation, height, terrain form, or 3D structure is needed.

8. Activity 2 – Read and compare radar backscatter

Use a Sentinel-1 image or prepared SAR map. If actual data are not available, the instructor may provide two grayscale images: before and after a rainfall, flood, or irrigation event. Students should compare tone, texture, and change. They should remember that radar brightness does not mean optical brightness. It represents the strength of microwave backscatter returned to the sensor.

Observation point / area	Radar tone: dark, medium, bright	Likely surface condition	Evidence from texture or pattern	Confidence: low/medium/high
Area 1				
Area 2				
Area 3				
Area 4				
Area 5				
Area 6				

Radar interpretation guide

Radar pattern	Possible meaning	Land-management interpretation question
Very dark, smooth area	Specular reflection away from the sensor; often open water or very smooth wet surface	Could this area be flooded, ponded, or a reservoir?
Bright rough area	Strong backscatter from rough surface, urban structures, or double-bounce reflections	Is this settlement, infrastructure, rough bare soil, or mixed vegetation?
Moderate textured agricultural fields	Variation caused by crop structure, row direction, soil moisture, and management	Can field differences indicate crop stage or irrigation status?
Sharp linear bright features	Roads, embankments, canals, levees, or building edges	Could these features control water movement or land access?
Patchy change between dates	Moisture, crop growth, tillage, flood recession, or acquisition geometry	Which change is likely physical and which may be sensor-related?

9. Activity 3 – Interpret LiDAR elevation products

Use a LiDAR-derived DTM/DEM, DSM, hillshade, slope map, or terrain profile. If no local LiDAR exists, use any high-quality elevation product prepared by the instructor. Students should identify landforms and explain why the information matters for land management.

Elevation product	What it shows	Student interpretation task	Management use
DTM / DEM	Ground elevation after removing objects where possible	Find low areas, ridges, depressions, drainage pathways	Flood planning, drainage design, erosion assessment
DSM	Surface height including buildings, trees, and objects	Compare DSM with DTM to identify vertical structures	Urban planning, forest structure, infrastructure risk
Hillshade	Shaded relief visualisation of terrain	Identify gullies, terraces, channels, embankments	Visual interpretation of landforms
Slope	Rate of elevation change	Locate steep areas and potential erosion zones	Soil conservation, construction suitability
Canopy Height Model	Vegetation height above ground	Estimate tree or shelterbelt structure	Agroforestry, biomass, wind protection
Feature to	**Where is it located?**	**Evidence from**	**Why it matters**

identify		DEM/hillshade/slope	
Main drainage line			
Lowest flood-prone zone			
Steepest slope			
Possible erosion gully			
Road or embankment influence			
Potential safe construction zone			

10. Activity 4 – Combine SAR and LiDAR evidence

Remote sensing interpretation becomes stronger when students combine several types of evidence. In this activity, students compare what radar shows and what elevation products show. The aim is to avoid one-layer conclusions. For example, a dark SAR area may suggest water, but a DEM helps confirm whether the area is topographically low and likely to collect water.

Question	SAR evidence	LiDAR/DEM evidence	Optical/reference evidence	Final interpretation
Is the area flooded or only dark because of smooth surface?				
Is a bright radar zone caused by buildings or rough bare soil?				
Do low-elevation zones match observed water accumulation?				
Which field or parcel has high moisture or drainage risk?				
Where should land managers prioritize field verification?				

Evidence rule

A strong interpretation should explain what each dataset contributes and what it cannot confirm alone. Students should clearly separate observed evidence from assumptions.

11. Mini-case A – Flood mapping with Sentinel-1 SAR

A river floodplain experienced heavy rain for three days. Optical imagery is mostly cloudy. A district authority needs a rapid map of possible flooded land to protect villages, roads, and irrigated fields.

Tasks: compare pre-event and post-event SAR images; mark areas that became darker after the event; check whether these areas match low elevation in the DEM; identify settlements, roads, or irrigation infrastructure at risk; write a short recommendation for field verification.

Required output	Student response
Main problem	

Key evidence	
Recommended action	

12. Mini-case B – Terrain and erosion risk from LiDAR DEM

A foothill agricultural area shows signs of rill erosion after intense seasonal rainfall. The local land management office wants to identify where conservation measures should be prioritized.
Tasks: use the DEM, slope, and hillshade to identify steep slopes, gullies, and drainage lines; rank three priority zones; propose two soil conservation measures; explain what additional field data would be needed before final planning.

Required output	Student response
Main problem	
Key evidence	
Recommended action	

13. Mini-case C – Urban expansion and vertical structure

A peri-urban area near an irrigated zone is expanding. Planners need to distinguish low agricultural land, built-up areas, trees, canals, and possible flood-risk zones.
Tasks: compare radar brightness, optical reference, and DSM/DTM differences; identify urban structures and trees; locate low-lying land where expansion may create drainage problems; prepare a short planning note explaining where development should be avoided or carefully assessed.

Required output	Student response
Main problem	
Key evidence	
Recommended action	

14. Student output template

Students submit a short interpretation note. It should be concise, evidence-based, and written in clear academic English. The final answer should not simply describe colours on a map. It should connect radar or LiDAR-derived evidence to a land management decision.

Section	Required content	Space for notes
Study area and objective	Where is the area and what land management question is being studied?	
Data used	List radar image/date, LiDAR or DEM layer, optical/reference layer, and boundary data.	
Main observations	Describe at least three observed patterns using correct terminology.	
Interpretation	Explain what the patterns probably mean and how confident you are.	
Limitations	State at least two uncertainties or possible errors.	
Recommendation	Give one practical land management action or field verification step.	

15. Assessment rubric

Criterion	Excellent	Adequate	Needs improvement
Correct data	Clearly explains why SAR,	Chooses a reasonable	Chooses data without clear

selection	LiDAR, optical data, or a combination fits the problem.	dataset but explanation is limited.	relation to the problem.
Technical interpretation	Uses terms such as backscatter, DEM, DSM, slope, hillshade, speckle, and elevation correctly.	Uses some terms correctly but with minor confusion.	Uses terms incorrectly or only describes colours.
Evidence integration	Combines radar and LiDAR/DEM evidence logically and identifies uncertainty.	Uses more than one source but integration is partial.	Relies on one layer or makes unsupported claims.
Land management relevance	Connects results to flood, drainage, erosion, crop, urban, or infrastructure decisions.	Mentions management relevance but not deeply.	No clear practical recommendation.
Communication	Clear, concise, well-structured, and suitable for a technical note.	Understandable but uneven in structure.	Difficult to follow or incomplete.

16. Reflection questions

When is radar more useful than optical imagery for land management?
What types of land management questions require accurate elevation or 3D structure?
Why should SAR interpretation be checked against terrain, field knowledge, or optical reference data?
How could radar or LiDAR support monitoring of irrigated land, drainage, erosion, or flood risk in Uzbekistan?

17. References

European Space Agency (ESA). Sentinel-1 mission information. The mission provides all-weather, day-and-night radar imagery of Earth's surface.

NASA Earthdata. Synthetic Aperture Radar (SAR) data basics and SAR applications. NASA explains that SAR can observe Earth day and night and through most weather conditions.

NASA Earthdata. Global Ecosystem Dynamics Investigation (GEDI) LiDAR. GEDI provides measurements of forest canopy height, canopy vertical structure, and surface elevation.

U.S. Geological Survey (USGS). 3D Elevation Program (3DEP). 3DEP provides lidar point clouds and digital elevation models through The National Map.

Shokirov, Sh. S., Musaev, I. M., & Akbarov, M. S. (2015). Masofadan zondlash. Tashkent: Tashkent Institute of Irrigation and Melioration.

LESLIE Micro-Credential Lesson Template. Land Management, Environment & Solid-Waste: Inside Education and Business in Central Asia, Erasmus+ CBHE Project No. 101129032.

Appendix A. SAR preprocessing and quality checklist

Use this checklist when students work with real Sentinel-1 or other SAR data. The goal is to help them understand that radar interpretation depends not only on the image, but also on preprocessing and geometry. In a beginner laboratory, the instructor may already complete these steps and ask students only to review the checklist.

Step	Why it matters	Student check	Done?
Orbit file or	Improves geolocation and confirms	Record date, pass direction, and	

metadata check	acquisition date, mode, polarization, and orbit direction.	polarization.	
Thermal noise removal / calibration	Converts raw image values into comparable backscatter values.	Confirm that calibrated sigma nought or similar product is used.	
Speckle filtering	Reduces granular noise while preserving important boundaries.	Note whether a filter was applied and whether details were lost.	
Terrain correction	Places SAR pixels in correct map geometry using a DEM.	Check projection and whether the layer aligns with roads or rivers.	
Conversion to dB	Makes backscatter easier to display and compare visually.	Record display range and explain it in the report.	
Masking and interpretation	Separates reliable observations from layover, shadow, or no-data zones.	Mark uncertain areas before writing conclusions.	

Appendix B. SAR change-detection worksheet

This worksheet is useful for flood, irrigation, wet soil, and crop-stage examples. Students compare two dates and decide whether the change is physically meaningful. They should avoid automatic conclusions and should check terrain, field pattern, and reference information.

Area	Date 1 backscatter / tone	Date 2 backscatter / tone	Observed change	Likely explanation	Need field check?
1					
2					
3					
4					
5					
6					
7					
8					

Interpretation rule: darkening may indicate open water or a smoother wet surface, but it may also be affected by geometry. Brightening may indicate rougher surface, vegetation structure, double-bounce reflections near buildings or flooded vegetation, or changes in moisture.

Appendix C. LiDAR profile and terrain-form worksheet

Students draw or inspect one terrain profile across a river channel, irrigation canal, road embankment, gully, or urban edge. The profile helps them understand that elevation data are not only maps; they are measurements of vertical structure that can support land management decisions.

Profile element	Start point	End point	Observed height/elevation change	Interpretation	Management relevance
Profile line name					
Lowest point					
Highest point					
Slope break / terrace edge					
Drainage obstruction or embankment					
Recommended action					

Optional drawing space: students may sketch the profile shape in their notebook or insert a screenshot from the GIS software. They should label the vertical axis, horizontal distance, and any important landform.

Appendix D. Group presentation template

Each group prepares a 3–5 minute presentation. The purpose is to communicate the interpretation clearly, not to show many maps. One map with clear annotations is better than several unclear screenshots.

Slide / speaking point	Content to include	Quality check
1. Study area and problem	Location, land management issue, and why SAR or LiDAR is relevant.	Is the objective clear in one sentence?
2. Data and method	List datasets, dates, products, and basic processing or prepared layers.	Are dates and products named correctly?
3. Main observations	Show 2–4 observations from radar and LiDAR/DEM layers.	Are observations separated from interpretation?
4. Interpretation and uncertainty	Explain what the patterns probably mean and what remains uncertain.	Are limitations honest and specific?
5. Recommendation	State one practical action: field check, drainage improvement, monitoring priority, or planning restriction.	Does the recommendation follow from evidence?

Appendix E. Instructor support notes

The activity can be adjusted according to available data and class time. For a short seminar, use printed screenshots and focus on interpretation. For a full GIS laboratory, allow students to load layers, change symbology, create profiles, and digitize interpretation zones. For advanced students, add basic SAR preprocessing or Google Earth Engine scripts.

Common student error	How to correct it	Suggested instructor prompt
Treating radar brightness like optical brightness	Explain that radar tone represents microwave backscatter, not visible colour.	What surface property could make this area return more radar energy?
Calling every dark SAR zone water	Ask students to check terrain position, date, and reference imagery.	Is this area topographically low and connected to water flow?
Ignoring speckle	Show how speckle creates granular texture and why filtering may help.	Which pattern is noise and which pattern is a real boundary?
Using DEM and DSM as the same product	Explain that DSM includes surface objects, while DTM/DEM aims to represent ground elevation.	Could this high value be a building, tree, or ground surface?
Writing conclusions without uncertainty	Require one limitation and one field verification need in each report.	What cannot be confirmed from this dataset alone?

Appendix F. Optional practical tasks for GIS laboratory

The following optional tasks can be used when students have access to QGIS, ArcGIS Pro, SNAP, or Google Earth Engine. The instructor may select only two or three tasks depending on the level of the group. Students should save screenshots and write short explanations rather than submitting unlabelled maps.

Task	Procedure	Expected evidence	Common mistake to avoid
Create a SAR water mask	Display pre- and post-event SAR images, choose a threshold for dark water-like pixels, and compare the result with known rivers or canals.	A simple water/flood candidate layer and explanation of threshold choice.	Using one threshold for every landscape without checking context.
Compare VV and VH	Display VV and VH polarizations separately and note which land covers are easier to interpret in each.	A table comparing built-up areas, fields, vegetation, and water.	Assuming VV and VH always show the same information.
Create hillshade from DEM	Use a DEM to generate hillshade with a clear illumination angle.	A hillshade map with labelled gullies, ridges, and channels.	Interpreting hillshade as actual elevation values.
Extract a terrain profile	Draw a profile line across a canal, river terrace, gully, or road embankment.	A profile graph and short interpretation of elevation change.	Forgetting to note horizontal and vertical units.
Overlay land parcels	Overlay field or parcel boundaries on SAR or DEM products.	Parcel-level notes on moisture, flood, or slope risk.	Ignoring mixed pixels or boundary misalignment.
Prioritize field verification	Select three locations where the remote sensing evidence is important but uncertain.	A field-check plan with coordinates or map labels.	Treating remote sensing interpretation as final proof.

Submission suggestion: each group submits one PDF or Word page with one annotated map, one table of observations, one limitation, and one land management recommendation. This keeps the activity focused on interpretation quality rather than map decoration.

Appendix G. Example answer structure for instructors

The examples below are not fixed answers because the correct interpretation depends on the dataset and study area. They show the level of reasoning expected from students. Instructors may adapt the examples to Uzbekistan, Central Asia, or another local case.

Situation	Strong student reasoning	Possible recommendation
Dark SAR area appears after rainfall	The area became darker after the event, lies in a low part of the DEM, and is connected to a drainage line. This combination supports a possible flood or ponding interpretation. However, smooth wet soil can also appear dark, so field verification is needed.	Prioritize field checking and temporary drainage observation in the low-lying parcels.
Bright SAR zone near a road	The brightness may be caused by double-bounce reflection from buildings or vertical structures, not necessarily by bare soil. Optical reference and DSM should be checked before classification.	Use DSM or field data to separate built-up structures from rough agricultural surfaces.
High slope and visible gullies in hillshade	The DEM and hillshade show converging drainage lines and steep slope zones. These areas are more exposed to rill and gully erosion after intense rainfall.	Recommend contour-based soil conservation, vegetative buffer strips, or controlled runoff pathways.
Tall vegetation in CHM near fields	The canopy height model indicates trees or shelterbelts along field boundaries. These structures may reduce wind erosion and protect crops, but may also affect shadow and water competition.	Assess shelterbelt condition and include it in land management planning.
Low terrain near peri-urban expansion	The DTM shows low elevation and weak drainage, while radar shows possible moisture accumulation. Urban development in this zone may increase flood or salinity risk.	Require drainage assessment before construction approval and protect critical irrigation infrastructure.

A strong answer should include three components: observed evidence, cautious interpretation, and practical land management relevance. It should not present remote sensing output as absolute truth without considering processing quality, field verification, and local knowledge.

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Appendix H. Key terms for quick review

Students may use this glossary while completing the activity. The definitions are intentionally short and practical. For formal definitions, students should review the reading material and the listed references.

Term	Practical meaning in this activity	Example question
Active sensor	A sensor that sends its own energy and measures the returned signal.	What does the sensor transmit and what does it receive?
Backscatter	Radar energy returned from the ground or objects to the sensor.	Why is this field brighter than the neighboring field?
Speckle	Granular noise-like pattern common in radar images.	Is this small bright/dark pattern real or speckle?
Polarization	Orientation of transmitted and received radar waves, such as VV or VH.	Which polarization better separates fields and buildings?
Incidence angle	Angle between the radar beam and the surface normal.	Could geometry affect the brightness of this slope?
DEM / DTM	Raster representing ground elevation.	Where are the low areas and drainage paths?
DSM	Raster representing surface height, including buildings and trees.	Is this height from ground, trees, or buildings?
Hillshade	A shaded visualisation of terrain form.	Can gullies or terraces be seen more clearly?
Canopy Height Model	Vegetation height estimated by subtracting terrain from surface height.	How tall are trees or shelterbelts?
Field verification	Checking uncertain remote sensing results on the ground.	Which locations should be checked before decisions?