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

11.- Electromagnetic Radiation and Energy Interaction

Activity

Analyze spectral curves of land surface objects

Co-funded by the European Union

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Activity Overview and Source Base

This activity trains students to interpret spectral curves of common land surface objects: healthy vegetation, stressed or sparse vegetation, dry soil, moist soil, open water, snow, and built surfaces. The activity is designed as a bridge between physical theory and applied remote sensing practice. Students do not only label curves; they explain why the curves have their shape and how that shape supports band selection, index calculation, and land-management interpretation.

The activity uses the Week 11 lecture materials on electromagnetic radiation, the electromagnetic spectrum, radiation-matter interaction, spectral characteristics of natural objects, reflection, absorption, transmission, and spectral behavior of vegetation, soil, and water. It is supplemented with trustworthy external learning resources from NASA, USGS, ESA/Copernicus, Penn State GEOG 480, University of Twente/ITC, Natural Resources Canada, and standard remote sensing textbooks.

The practical logic is simple: a remotely sensed image is a set of physical measurements. A pixel is bright or dark in a band because the target reflected, absorbed, transmitted, emitted, or backscattered energy in a particular way. When students can explain the curve, they can explain the image more responsibly.

Recommended student level: second- or third-year bachelor students who have already studied the basic remote sensing chain, electromagnetic spectrum regions, and introductory multispectral imagery.

What Students Should Be Able to Do After the Activity

- Define a spectral curve or spectral signature as a wavelength-by-wavelength response pattern, not a single brightness value.
- Recognize typical reflectance behavior of vegetation, water, soil, snow, and built surfaces in visible, near-infrared, and shortwave infrared regions.
- Explain curve shapes using physical processes such as chlorophyll absorption, internal leaf scattering, water absorption, soil moisture effects, turbidity, and surface roughness.
- Choose useful bands or band combinations for a specified land-management question.
- Calculate and interpret simple spectral indices from sample band values.
- Identify common sources of error, including atmosphere, cloud, shadow, sun glint, mixed pixels, season, crop growth stage, and sensor differences.
- Write a short evidence-based interpretation of a spectral-curve comparison without overclaiming.

Contents

Suggested Timing

Stage	Student task	Time	Output
Warm-up	Read the reference curve and predict target classes	10 min	Initial labels
Part A	Plot or inspect spectral curves	20 min	Completed curve table
Part B	Explain physical processes behind curve shapes	20 min	Short explanations
Part C	Select bands for land-management questions	15 min	Band-choice table
Part D	Calculate NDVI, NDWI, NDMI, and NDSI from sample values	20 min	Index table
Part E	Write an interpretation paragraph and discuss uncertainty	15-25 min	Final answer paragraph

1. Activity Purpose and Learning Sequence

The purpose of this activity is to move students from memorizing spectral patterns to using those patterns as evidence. In many beginner lessons, students learn that vegetation is bright in near infrared, water is dark in near infrared and shortwave infrared, and dry soil often increases gradually from visible to infrared wavelengths. Those statements are useful, but they become more meaningful when students connect them to physical causes.

The activity therefore follows a five-step reasoning model. Students first observe the curve. Then they label the likely object. Next, they identify the spectral regions that make the object distinctive. After that, they explain the likely physical processes. Finally, they link the interpretation to an applied question such as crop condition, water extent, salinity, snow mapping, or land degradation.

Reasoning Model

1. Observation: What does the curve do in visible, NIR, and SWIR regions?
2. Identification: Which land surface object is most consistent with that curve?
3. Physical explanation: Which material property explains the high or low reflectance?
4. Band choice: Which wavelength region best separates the target from others?
5. Application: What land-management decision could use this spectral contrast?

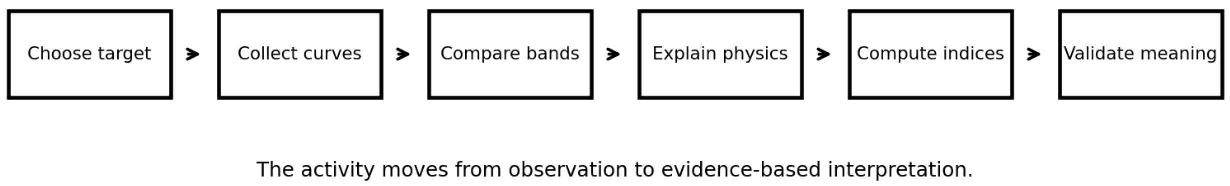

Figure 1. Activity workflow from target selection to validation.

This model is important because spectral curves are not fixed magical fingerprints. They are characteristic patterns under specific conditions. Moisture, canopy density, growth stage, suspended sediment, surface roughness, snow grain size, atmosphere, and mixed pixels can all change the measured signal. The best student answer should therefore combine recognition with caution.

2. Required Materials and Preparation

Minimum Classroom Materials

- Printed copy of this activity manual or a digital version accessible during class.
- Pencil, calculator, and blank plotting grid or spreadsheet software.
- The sample spectral-reflectance values provided in the worksheet.
- A projector or board for class discussion of curve shapes and band choices.

Recommended Computer-Lab Materials

- ArcGIS Pro, QGIS, Google Earth Engine, SNAP, or another GIS/remote-sensing environment.
- A cloud-free Sentinel-2 or Landsat surface reflectance image over an agricultural or mixed land-cover area.
- Optional field boundary polygons, land-cover sample points, or known locations of water, crops, bare soil, and built surfaces.
- A spreadsheet or GIS table for storing band values, indices, and interpretation notes.

Instructor Preparation Checklist

Preparation item	Why it matters	Completed?
Select 5-7 land surface objects	Students need enough contrast for comparison	
Prepare sample values or image points	The activity should not depend only on visual guessing	
Confirm band names and units	Students must not confuse Red, NIR, SWIR1, and SWIR2	
Prepare one example interpretation	A model answer improves consistency	
Decide assessment mode	Individual worksheet, group presentation, or short written report	

3. Conceptual Reminder: From Energy to Spectral Curve

A spectral curve describes how a surface responds across wavelength. In optical remote sensing, the curve is commonly expressed as reflectance: the fraction of incoming solar radiation reflected by a target and recorded after correction to surface reflectance. In practice, students often see this information as band values from sensors such as Landsat or Sentinel-2.

The curve is shaped by the target and the observation conditions. Vegetation curves are controlled by pigments, leaf structure, canopy architecture, and leaf water content. Water curves are controlled by absorption, depth, suspended sediment, algae, bottom visibility, and surface waves. Soil curves are controlled by moisture, texture, organic matter, iron oxides, salts, crusting, and roughness. Snow and cloud are often bright in visible bands, but they differ in SWIR behavior. Built surfaces can be highly variable because urban pixels mix asphalt, concrete, rooftops, shadows, vegetation, and bare soil.

Core Physical Processes

Process	Simple meaning	Example	Interpretation warning
Reflection	Energy leaves the target and may reach the sensor	High NIR reflectance from healthy leaves	Brightness depends on geometry and atmosphere
Absorption	Energy is taken into the material	Chlorophyll absorption in red; water absorption in SWIR	Absorption features can be masked by mixtures
Transmission	Energy passes through a medium or material	Some visible light passes through shallow clear water	Bottom effects can confuse shallow water
Emission	Objects emit radiation because they have temperature	Thermal infrared surface temperature	Emissivity affects thermal interpretation
Scattering	Energy changes direction due to particles or structure	Leaf internal scattering; suspended sediment in water	Scattering can increase or reduce apparent brightness

The most important habit in this activity is to separate what is observed from what is inferred. A curve may show high NIR reflectance; this observation supports the interpretation of healthy vegetation, but the final claim should still consider season, species, canopy density, soil background, atmosphere, and validation data.

4. Spectral Curve Reference Sheet

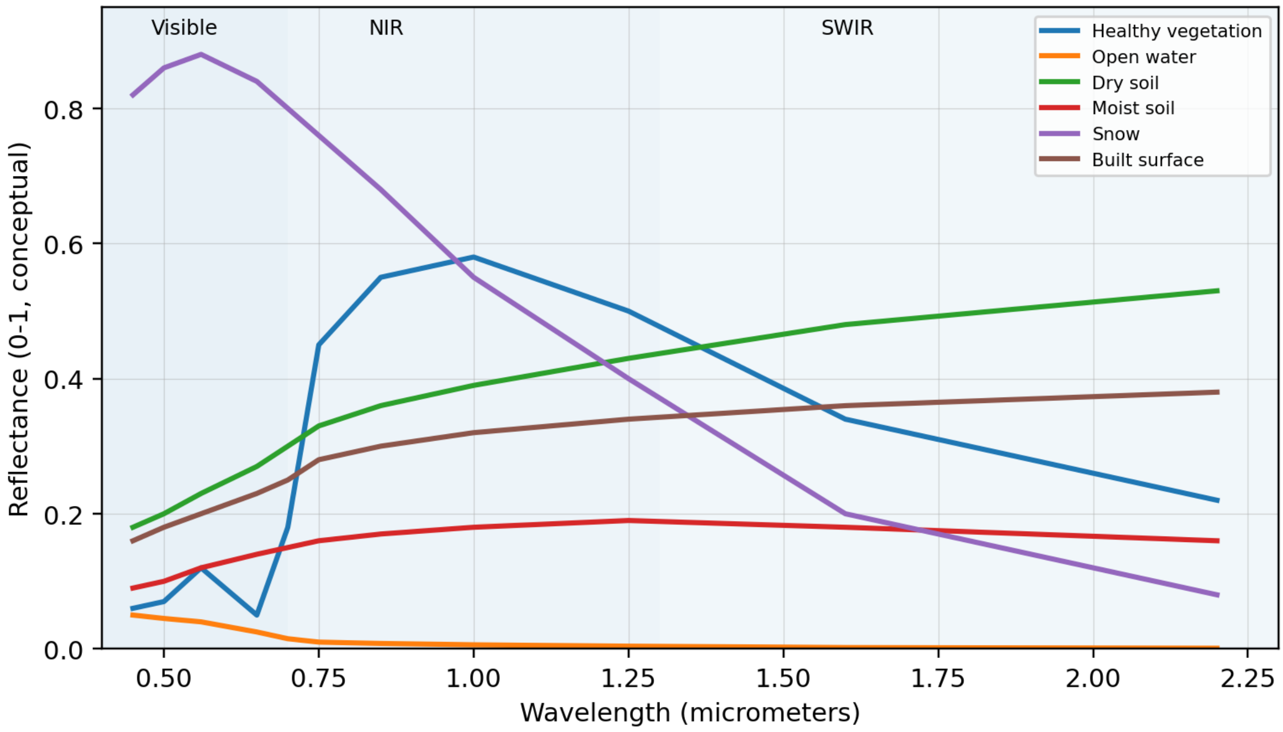

Figure 2. Conceptual spectral curves for common land surface objects. Curves are for teaching, not sensor-specific calibration.

Figure 2 is a conceptual comparison. It should be used to understand typical curve shapes, not as a fixed universal library. Real spectral values differ by sensor, location, season, atmospheric correction, target condition, and scale. The main learning goal is to recognize the pattern and explain why it occurs.

How to Read the Reference Curves

- Healthy vegetation: low reflectance in blue and red, a small green peak, strong NIR reflectance, and lower SWIR when leaf water absorption is strong.
- Open water: generally low reflectance, especially in NIR and SWIR; visible brightness can rise with sediment, algae, shallow bottom effects, or sun glint.
- Dry soil: often increases gradually from visible to NIR/SWIR; brightness depends on mineral composition, texture, organic matter, moisture, and roughness.
- Moist soil: usually darker than dry soil because water increases absorption and changes scattering.
- Snow: bright in visible wavelengths but lower in SWIR, which helps separate snow from many clouds and bright land surfaces.
- Built surfaces: variable and often mixed; concrete, asphalt, metal roofing, tile, shadow, and vegetation do not share one universal curve.

Band Regions Used in the Activity

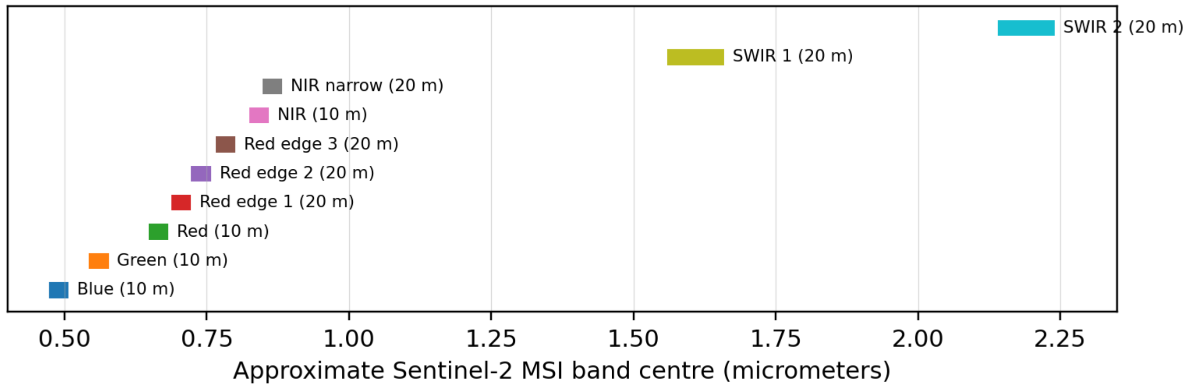

Figure 3. Approximate Sentinel-2 MSI land bands commonly used for curve interpretation.

Band-reading tips: visible bands help students read colour and pigment differences; NIR usually separates healthy vegetation from water; SWIR is especially useful for moisture, snow discrimination, dry surfaces, and some mineral or salinity clues. Students should write the physical reason for each selected band, not only the band name.

Region	Student should ask	Typical answer
Visible	Is colour or pigment contrast enough?	Useful for natural interpretation, turbidity clues, and snow brightness.
NIR	Does leaf structure or water absorption create contrast?	Vegetation is usually bright; water is usually dark.
SWIR	Is moisture, snow, burn, salt, or dry material important?	Water absorption and material differences often become clearer.

5. Activity Part A: Observe and Label Spectral Curves

In Part A, students inspect six curve profiles and assign a likely land surface object to each one. The instructor may use the sample table below, a real spectral library, or values extracted from a satellite image. If real imagery is used, students should record whether values are top-of-atmosphere reflectance, surface reflectance, or scaled integer values converted to reflectance.

Sample Reflectance Values for Classroom Use

Object code	Blue 0.49	Green 0.56	Red 0.66	NIR 0.84	SWIR1 1.61	SWIR2 2.19	Likely object
A	0.06	0.12	0.05	0.55	0.34	0.22	
B	0.05	0.04	0.03	0.01	0.00	0.00	
C	0.18	0.23	0.27	0.36	0.48	0.53	
D	0.09	0.12	0.14	0.17	0.18	0.16	
E	0.82	0.88	0.84	0.68	0.20	0.08	
F	0.16	0.20	0.23	0.30	0.36	0.38	

Task A1. Plot the six objects on the blank graph or in spreadsheet software. Use wavelength on the x-axis and reflectance on the y-axis. If time is limited, students may inspect the values directly and draw simplified curves by hand.

Task A2. Assign each object code to one of the following classes: healthy vegetation, open water, dry soil, moist soil, snow, and built surface. For each label, write the most important evidence from the curve.

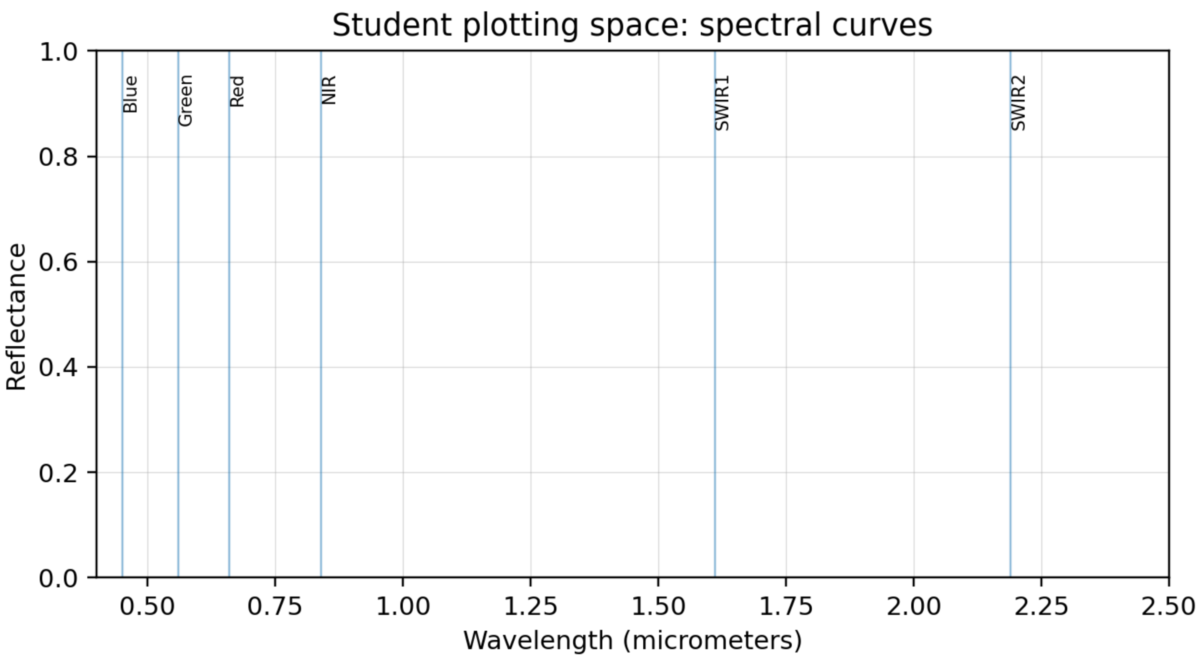

Figure 4. Blank plotting grid for student spectral curves.

6. Activity Part B: Link Curve Shape to Physical Causes

In Part B, students explain why each curve shape is physically plausible. The goal is not to memorize a label but to connect the band pattern to reflection, absorption, transmission, scattering, and surface condition.

Guiding Questions

6. Which curve has the strongest red-to-NIR jump? What physical feature explains it?
7. Which curve remains very dark in NIR and SWIR? Why is this typical of open water?
8. Which curve is bright in visible bands but drops strongly in SWIR? Which target does this suggest?
9. Which curve rises gradually from visible to SWIR? Why might this indicate dry soil or a built material?
10. Which curve is darker than dry soil but not as dark as water? What role could moisture play?
11. Which object would be easiest to separate using only NIR? Which would require SWIR or context?

Explanation Table

Object code	Observed curve feature	Likely process	Physical explanation	Confidence / uncertainty
A				
B				
C				
D				
E				
F				

Good answers should use precise language. Instead of writing only “A is vegetation,” students should write: “A is likely healthy vegetation because red reflectance is low, NIR reflectance is high, and the red-to-NIR transition is consistent with chlorophyll absorption and internal leaf scattering.”

7. Activity Part C: Match Bands to Land Surface Questions

Band selection should begin with the target property, not with software availability. Students should ask: What physical contrast am I trying to detect? Which wavelength region responds to that property? Which sensor provides a suitable band, spatial resolution, and revisit frequency?

Band Selection Practice

Land-management question	Recommended band or product	Physical reason	Student alternative
Crop vigor in irrigated fields	Red + NIR; optionally red-edge bands	Plants absorb red and reflect NIR strongly; red edge can improve crop analysis.	
Open water extent	NIR or SWIR contrast; NDWI/MNDWI	Water is usually dark in NIR and SWIR, while land is brighter.	
Leaf or soil moisture stress	SWIR; NDMI-type features	Water absorption affects SWIR reflectance in vegetation and soils.	
Snow cover versus bright soil or cloud	Green + SWIR; NDSI	Snow is bright in visible bands but much lower in SWIR.	
Urban/bare surface separation	Visible + NIR + SWIR, plus context	Built materials and dry soils can overlap, so multiple bands and context are needed.	
Flood mapping under clouds	Microwave radar, plus optical before/after when available	Radar can operate day/night and through cloud in many conditions.	

Task C1. Complete the “student alternative” column. Students may propose a different sensor or band combination, but they must justify it physically.

Task C2. Choose one question relevant to Central Asian land and water management and write a three-sentence explanation of the band selection.

8. Activity Part D: Calculate Simple Indices from Spectral Values

Spectral indices compress a contrast between bands into one layer. They are useful because they summarize a known physical relationship, but they do not replace interpretation. Students must understand why the formula works and when it may fail.

Index Formulas Used in This Activity

Index	Formula	Main use	Physical logic
NDVI	(NIR - Red) / (NIR + Red)	Green vegetation and vigor	Healthy plants absorb red and reflect NIR.
NDWI	(Green - NIR) / (Green + NIR)	Open water emphasis	Water is darker in NIR than many land surfaces.
NDMI	(NIR - SWIR1) / (NIR + SWIR1)	Vegetation or surface moisture proxy	Water content changes SWIR response.
NDSI	(Green - SWIR1) / (Green + SWIR1)	Snow mapping	Snow is bright in green but much lower in SWIR.
Simple NIR/SWIR contrast	NIR - SWIR1	Moisture or material contrast	Large or small differences indicate changing absorption/scattering.

Index Calculation Table

Object	Red	Green	NIR	SWIR1	NDVI	NDWI	NDMI
A	0.05	0.12	0.55	0.34			
B	0.03	0.04	0.01	0.00			
C	0.27	0.23	0.36	0.48			
D	0.14	0.12	0.17	0.18			
E	0.84	0.88	0.68	0.20			
F	0.23	0.20	0.30	0.36			

Task D1. Calculate NDVI, NDWI, and NDMI for each object. Round results to two decimal places. Then compare whether the numerical results support the visual curve labels.

Task D2. Explain one case where an index helps clearly and one case where an index may be misleading without context.

9. Activity Part E: Write an Interpretation Paragraph

The final output of the activity is a short interpretation paragraph. It should be written like a scientific explanation, not like a guess. Students must refer to the observed curve, the likely physical cause, and the practical land-management meaning.

Recommended Paragraph Structure

12. Start with the likely class and the main spectral evidence.
13. Explain the physical reason for the pattern using correct terms.
14. Identify the band region or index that would be most useful for mapping this target.
15. State one uncertainty or condition that could affect the interpretation.
16. Connect the interpretation to an applied use such as crop monitoring, water mapping, salinity assessment, or snow observation.

Model Paragraph

Object A is likely healthy vegetation. The evidence is low reflectance in the red band, high reflectance in the NIR band, and a clear red-to-NIR jump. This pattern is consistent with chlorophyll absorption in the visible red region and strong scattering by internal leaf structure in the near infrared. NDVI or a red-edge/NIR band combination would therefore be useful for mapping its vigor. The interpretation should still consider crop type, growth stage, canopy density, soil background, and whether the values represent corrected surface reflectance. In a land-management context, this pattern could support monitoring of irrigated crop condition or identification of fields with reduced vegetation vigor.

Student Writing Space

10. Optional GIS Extension in ArcGIS Pro or Google Earth Engine

This extension is designed for students who will later work with real satellite imagery. The same activity can be implemented in ArcGIS Pro, QGIS, SNAP, or Google Earth Engine. The key principle is unchanged: students extract band values from known surface samples and compare the resulting spectral profiles.

ArcGIS Pro Workflow

17. Open a cloud-free multispectral image, preferably a surface reflectance product such as Landsat Collection 2 Surface Reflectance or Sentinel-2 Level-2A.
18. Display a natural-color composite and a false-color composite to identify candidate samples.
19. Create point samples or small polygon samples for vegetation, water, dry soil, moist soil, snow if available, and built surfaces.
20. Use Extract Multi Values to Points, Zonal Statistics as Table, or a similar tool to extract band values.
21. Export the table to Excel or CSV and plot reflectance by wavelength.
22. Calculate indices such as NDVI, NDWI, NDMI, and NDSI where appropriate.
23. Compare the extracted curves with the conceptual reference sheet and write interpretation notes.

Google Earth Engine Workflow

24. Select an area of interest and a date range that matches the land-cover condition being studied.
25. Filter a Sentinel-2 or Landsat surface reflectance collection by date, cloud cover, and location.
26. Apply cloud masking if needed and create a median or best-pixel composite.
27. Add sample geometries for known land surface objects.
28. Use reduceRegion or sampleRegions to extract band values.
29. Export the sample table or plot charts directly in the code editor.
30. Interpret differences in visible, NIR, and SWIR response using the worksheet questions.

Important GIS Cautions

- Do not compare digital numbers from different sensors unless values are calibrated or converted correctly.
- Avoid cloud, shadow, haze, snow contamination, and mixed boundary pixels unless the task is specifically about those effects.
- Use sample polygons away from class edges to reduce mixed-pixel problems.
- Record the acquisition date because vegetation and soil moisture change through the season.
- Check whether band values are scaled integers and whether a scale factor must be applied.

11. Student Worksheet Package

Name: ______________________________________ Group: __________ Date: ________________

Worksheet 1. Curve Identification

Object code	Likely class	Strongest evidence	Most useful band region	Confidence 1-5
A				
B				
C				
D				
E				
F				

Worksheet 2. Physical Explanation

Class	Observed spectral behavior	Physical cause	Possible confusion or uncertainty
Healthy vegetation			
Open water			
Dry soil			
Moist soil			
Snow			
Built surface			

Student Worksheet Package Continued

Worksheet 3. Index Calculations

Object	Red	Green	NIR	SWIR1	NDVI	NDWI	NDMI	Interpretation
A	0.05	0.12	0.55	0.34				
B	0.03	0.04	0.01	0.00				
C	0.27	0.23	0.36	0.48				
D	0.14	0.12	0.17	0.18				
E	0.84	0.88	0.68	0.20				
F	0.23	0.20	0.30	0.36				

Worksheet 4. Band Selection for Applied Questions

Question	Selected band/index	Physical reason	Limitation
Crop vigor			
Water extent			
Moisture stress			
Snow mapping			
Urban/bare soil separation			
Cloudy-season flood mapping			

12. Discussion Prompts for Group Work

The instructor may use these prompts for a 10- to 15-minute group discussion after the worksheet is completed. The purpose is to test whether students can defend their interpretation and recognize uncertainty.

31. Why is vegetation usually easier to identify in NIR than in a true-color image?
32. Why can water be simple to map as an extent but difficult to interpret as a quality variable?
33. Why can dry soil and built surfaces be confused in some multispectral images?
34. How does soil moisture change a spectral curve, and why does this matter for irrigated agriculture?
35. Why is SWIR useful for separating snow from many bright surfaces?
36. How can atmosphere, haze, or cloud shadow change the curve that students extract from an image?
37. Why is field validation still required even when the curve looks convincing?
38. Which spectral curve would be most useful for a land-management decision in Central Asia? Explain why.

Short Group Presentation Format

- One sentence: identify the object.
- Two sentences: explain the spectral evidence.
- One sentence: connect the interpretation to a land-management application.
- One sentence: state a limitation or uncertainty.

This concise presentation format encourages students to explain evidence instead of only giving labels.

13. Instructor Guide and Suggested Answers

The suggested answers below are intended for instructor use. They should not be treated as the only acceptable wording. Student answers can receive full credit if they correctly connect observed spectral evidence to physical reasoning and state appropriate limitations.

Object	Suggested class	Key evidence	Physical explanation	Typical uncertainty
A	Healthy vegetation	Low red, high NIR, moderate SWIR	Chlorophyll absorbs red; leaf structure reflects NIR; water affects SWIR	Crop stage, species, canopy density, soil background
B	Open water	Very dark in NIR and SWIR	Water absorbs strongly beyond visible wavelengths	Turbidity, depth, glint, shadow, floating vegetation
C	Dry soil	Gradual increase from visible to SWIR	Dry mineral surface reflects more; low moisture absorption	Soil type, salinity, roughness, built materials
D	Moist soil	Darker than dry soil, low gradual curve	Water lowers reflectance and masks mineral features	Could be shadow, dark soil, wet built surface
E	Snow	Very bright visible, lower SWIR	Snow reflects visible strongly but absorbs more in SWIR	Cloud confusion, snow age, grain size, mixed pixels
F	Built surface	Moderate smooth curve, no vegetation red edge	Urban materials often have broad moderate reflectance	Concrete/asphalt/roof mixtures, shadows, dry soil confusion

Index Calculation Answer Key

Object	NDVI	NDWI	NDMI	Likely class	Interpretation note	Check
A	0.83	-0.64	0.24	Healthy vegetation	High NDVI supports vegetation.	
B	-0.50	0.60	1.00	Open water	Negative NDVI and high relative water darkness support water.	
C	0.14	-0.22	-0.14	Dry soil	Low index separation; interpret with curve shape.	
D	0.10	-0.17	-0.03	Moist soil	Moist soil may be darker but index values need context.	
E	-0.11	0.13	0.55	Snow	NDSI would be more diagnostic than NDVI.	
F	0.13	-0.20	-0.09	Built surface	Indices alone may not separate built surface from dry soil.	

14. Common Mistakes and How to Correct Them

Common mistake	Why it is a problem	Correction
Calling a curve “vegetation” only because it is green	Visible green alone is not enough; many surfaces can appear greenish	Use red absorption and NIR reflectance evidence.
Using one band as final proof	Single-band brightness can be ambiguous	Compare at least visible, NIR, and SWIR behavior.
Ignoring surface moisture	Moisture strongly changes soil and vegetation curves	Use SWIR and acquisition-date context.
Comparing uncorrected values from different dates	Atmosphere and illumination can change apparent reflectance	Use surface reflectance products or careful correction.
Confusing snow with cloud or bright soil	All can be bright in visible bands	Check SWIR and context.
Assuming an index is a final answer	Indices summarize band contrast but can be misleading	Interpret index values with spectral curves and validation.

The best correction strategy is to ask students to return to the physical mechanism. For example, if a student says “water is blue,” ask them what happens to water reflectance in NIR and SWIR, and how suspended sediment or shallow bottoms might change the visible response.

15. Assessment Rubric

Criterion	Excellent	Good	Satisfactory	Needs improvement
Curve identification	All or nearly all classes labeled correctly with evidence	Most labels correct with minor uncertainty	Several correct labels but weak evidence	Labels mostly guessed or unsupported
Physical explanation	Clearly links curve shape to absorption, reflection, scattering, moisture, and structure	Mostly correct physical explanation	Basic explanation but limited mechanism	No clear physical reasoning
Band selection	Band choices are physically justified and application-specific	Band choices mostly reasonable	Band choices listed but weakly justified	Band choices random or incorrect
Index calculation	Calculations accurate and interpretation cautious	Minor calculation or interpretation issues	Some formulas used but several mistakes	Cannot calculate or interpret indices
Uncertainty awareness	Explicitly discusses atmosphere, mixed pixels, season, and validation	Mentions at least two uncertainties	Mentions one uncertainty superficially	No uncertainty or overclaims
Written interpretation	Clear, concise, evidence-based paragraph	Mostly clear and evidence-based	Understandable but descriptive only	Unclear or unsupported

Suggested scoring: 5 points per criterion, 30 points total. The instructor may convert the score to a grade or use it as formative feedback.

16. Activity Variations for Different Class Levels

Beginner Version

- Use only four classes: vegetation, water, soil, and snow.
- Use the conceptual curves rather than real image-derived values.
- Ask students to write one evidence sentence for each label.
- Focus on red, NIR, and SWIR rather than all bands.

Intermediate Version

- Use six classes and require index calculations.
- Use one real Sentinel-2 or Landsat image to extract sample values.
- Require students to compare true-color and false-color composites.
- Ask for a 150-word interpretation with limitations.

Advanced Extension

- Compare spectral curves across two dates to identify seasonal change or irrigation effects.
- Use parcel polygons and calculate mean reflectance per parcel instead of single point samples.
- Add classification testing using Random Forest, XGBoost, or another model after spectral feature extraction.
- Assess accuracy using field observations or high-resolution reference imagery.

For PhD-oriented preparation, this activity can become the first step of a field/parcel-based crop classification workflow. Students first learn to interpret spectral response, then extract parcel-level features, then train and validate a supervised model.

17. Application Notes for Central Asian Land and Water Management

Central Asia provides many strong examples for spectral-curve analysis because irrigated agriculture, bare soil, salinity, waterlogging, reservoirs, wetlands, rangelands, snow, and urban growth often occur close to each other. These mixed landscapes make spectral interpretation useful but also challenging.

Application	Relevant spectral contrast	Possible product	Caution
Irrigated crop monitoring	Red absorption and NIR reflectance	NDVI, red-edge indices, parcel mean reflectance	Crop calendar and field boundaries matter.
Salinity and bare soil mapping	Bright soil, SWIR behavior, moisture context	Bare soil indices, SWIR composites	Salts, dry soil, and built surfaces can overlap.
Reservoir and canal mapping	Water darkness in NIR/SWIR	NDWI, MNDWI, NIR/SWIR masks	Turbidity, aquatic vegetation, and shadow matter.
Waterlogging	Wet soil darkening and thermal patterns	NDMI, SWIR composites, thermal data	Irrigation timing and mixed pixels matter.
Snow and runoff context	High visible reflectance but lower SWIR	NDSI, snow masks, time series	Cloud and old snow can complicate mapping.
Rangeland degradation	Vegetation decline and exposed soil increase	NDVI time series, bare soil fraction	Rainfall variability must be considered.

A strong applied answer should not say only that a product can “monitor agriculture.” It should state which spectral property is measured, why that property relates to the land-management issue, and what reference data are needed to validate the conclusion.

18. Reflection Questions for Independent Study

Why does a false-color composite often make vegetation easier to identify than a natural-color composite?

____

How can two objects that look similar in RGB be separated using NIR or SWIR?

____

Why is water usually dark in NIR and SWIR, and when might this rule be less reliable?

____

Why is soil more difficult to interpret spectrally than healthy vegetation?

____

How can soil moisture create confusion in land-cover classification?

____

Why do students need to know whether an image is surface reflectance or top-of-atmosphere reflectance?

____

What is the difference between using a spectral curve for interpretation and using it for supervised classification?

____

How would you design a field data collection plan to validate spectral curve labels?

____

Why might parcel-based averages be better than individual pixels for crop classification?

____

Which spectral bands would be most important for distinguishing potato, tomato, carrot, onion, cabbage, and other vegetable crops? What additional time-series information would be needed?

____

19. Short Glossary

Absorption: The process by which energy is taken into a material, often reducing reflectance at specific wavelengths.

Atmospheric correction: Processing intended to reduce atmospheric effects and estimate surface reflectance or another surface property.

Band: A selected wavelength interval measured by a remote sensing sensor.

False-color composite: An image display in which non-visible bands such as NIR are assigned to visible display colors.

Mixed pixel: A pixel containing more than one surface material, common near field boundaries, canals, roads, and urban edges.

NDVI: Normalized Difference Vegetation Index, commonly used to represent vegetation greenness or vigor.

NIR: Near infrared, a spectral region strongly reflected by healthy vegetation and strongly absorbed by water.

Reflectance: The fraction of incoming radiation reflected by a surface.

Spectral curve: A graph showing response, often reflectance, as a function of wavelength.

Spectral signature: A characteristic spectral response pattern used to distinguish materials or conditions.

SWIR: Shortwave infrared, useful for moisture, mineral, burn, snow, and dry-surface analysis.

Validation: Checking interpreted results against independent evidence such as field observations, high-resolution imagery, or trusted maps.

20. References and Recommended Sources

Core Week 11 teaching materials used as the internal course base

- LM-W11-V71. Nature of Electromagnetic Radiation. LESLIE micro-credential slide deck.
- LM-W11-V72. Electromagnetic Spectrum. LESLIE micro-credential slide deck.
- LM-W11-V73. Radiation-Matter Interaction. LESLIE micro-credential slide deck.
- LM-W11-V74. Spectral Characteristics of Natural Objects. LESLIE micro-credential slide deck.
- LM-W11-V75. Reflection, Absorption, and Transmission. LESLIE micro-credential slide deck.
- LM-W11-V76. Spectral Behavior of Vegetation, Soil, and Water. LESLIE micro-credential slide deck.
- LM-W11-V77. Electromagnetic Energy Review. LESLIE micro-credential slide deck.

External trustworthy references and teaching resources

- NASA Earthdata. The Electromagnetic Spectrum. Earth Observation Data Basics.
- NASA Applied Remote Sensing Training Program (ARSET). Fundamentals of Remote Sensing.
- NASA Science / Landsat. Spectral Bands and Applications.
- U.S. Geological Survey. Landsat Surface Reflectance and Landsat Surface Reflectance-derived Spectral Indices.
- European Space Agency. Sentinel-2 mission information.
- Copernicus Data Space Ecosystem. Sentinel-2 data collection and mission description.
- Penn State GEOG 480. Multispectral Remote Sensing Systems and image display principles.
- Penn State, The Nature of Geographic Information. Spectral Response Patterns.
- University of Twente / ITC. Principles of Remote Sensing and ITC Living Textbook material on spectral signatures.
- Natural Resources Canada. Fundamentals of Remote Sensing.
- Lillesand, T. M., Kiefer, R. W., & Chipman, J. W. Remote Sensing and Image Interpretation. Wiley.
- Jensen, J. R. Introductory Digital Image Processing: A Remote Sensing Perspective. Pearson.
- Campbell, J. B., & Wynne, R. H. Introduction to Remote Sensing. Guilford Press.
- Schowengerdt, R. A. Remote Sensing: Models and Methods for Image Processing. Academic Press.
- Rees, W. G. Physical Principles of Remote Sensing. Cambridge University Press.

Note for instructors: the conceptual curves in this activity are designed for teaching. They should not be used as calibrated spectral-library values. When using real imagery, always specify sensor, acquisition date, processing level, scale factor, and correction method.

Appendix A. Additional Blank Tables for Reuse

The following blank tables can be copied for other images, locations, or crop-classification exercises.

Sample ID	Class	Blue	Green	Red	NIR	SWIR1	SWIR2
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
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16							
17							
18							

Appendix B. Short Report Template

Title: Spectral Curve Analysis of Land Surface Objects

1. Study object and data source

2. Spectral curve observations

3. Physical interpretation

4. Band or index selection

5. Uncertainty and validation plan

6. Land-management meaning

Appendix C. Link to Parcel-Based Crop Classification

For students interested in machine learning or field/parcel-based classification, spectral curves can become input features. The workflow below connects this activity to a later classification exercise.

39. Collect field boundaries for vegetable crop parcels such as potato, tomato, carrot, onion, cabbage, or other crops.
40. Record crop type and field observation date for each parcel. Use accurate GPS or digitized field boundaries.
41. Download or access cloud-free Sentinel-2 or Landsat surface reflectance images that match crop growth stages.
42. Extract mean, median, standard deviation, minimum, and maximum reflectance for each band inside each parcel.
43. Calculate indices such as NDVI, NDWI, NDMI, red-edge indices, and simple SWIR contrasts.
44. Create a table where each row is one parcel and each column is a spectral or temporal feature.
45. Split the parcels into training and testing groups. Avoid using the same field in both groups when testing generalization.
46. Train a classifier such as Random Forest, XGBoost, CatBoost, or another supervised model.
47. Evaluate the model with independent validation data and report accuracy, class confusion, and limitations.
48. Interpret the model using spectral reasoning. Machine learning should not hide the physical meaning of the bands.

The key transition is from pixel thinking to object or parcel thinking. A parcel-based method summarizes many pixels inside a field boundary and can better represent the crop unit that farmers and land managers actually use.

Appendix D. Independent Exercise for Homework

Choose a local or regional landscape that contains at least four of the following: vegetation, water, dry soil, moist soil, built surfaces, snow, or wetland vegetation. Use an available multispectral image or the sample values in this manual.

Homework Tasks

49. Select six sample locations or use six given spectral profiles.
50. Plot the spectral curves and label each curve.
51. Calculate NDVI, NDWI, and NDMI for each sample.
52. Write one paragraph explaining the most distinct target and one paragraph explaining the most uncertain target.
53. Prepare a small table recommending bands or indices for one applied monitoring question.
54. State what field or reference data would be needed to validate your interpretation.

Homework Deliverable

Submit a 2-page report with one spectral-curve chart, one index table, and a 150- to 200-word interpretation. Include the data source, date, sensor, and any correction level if real imagery is used.

Closing Note

Spectral-curve analysis is one of the simplest but most powerful ways to connect remote sensing theory with land-management practice. It teaches students to ask what the sensor is measuring, why the target behaves that way, and how evidence can be used responsibly. This activity prepares students for more advanced work in band combinations, indices, image classification, crop monitoring, water mapping, salinity studies, and parcel-based machine learning.

Students are encouraged to repeat the activity with real Landsat or Sentinel-2 data, compare different seasons, and validate interpretations with field observations or reliable reference imagery.