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LAND MANAGEMENT
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LAND MANAGEMENT IN CENTRAL ASIA

12.- Sensors and Remote Sensing Platforms

Spatial, Spectral, Temporal, and Radiometric Resolution

LM-W12-V83

Spatial, Spectral, Temporal, and Radiometric Resolution

SPATIAL

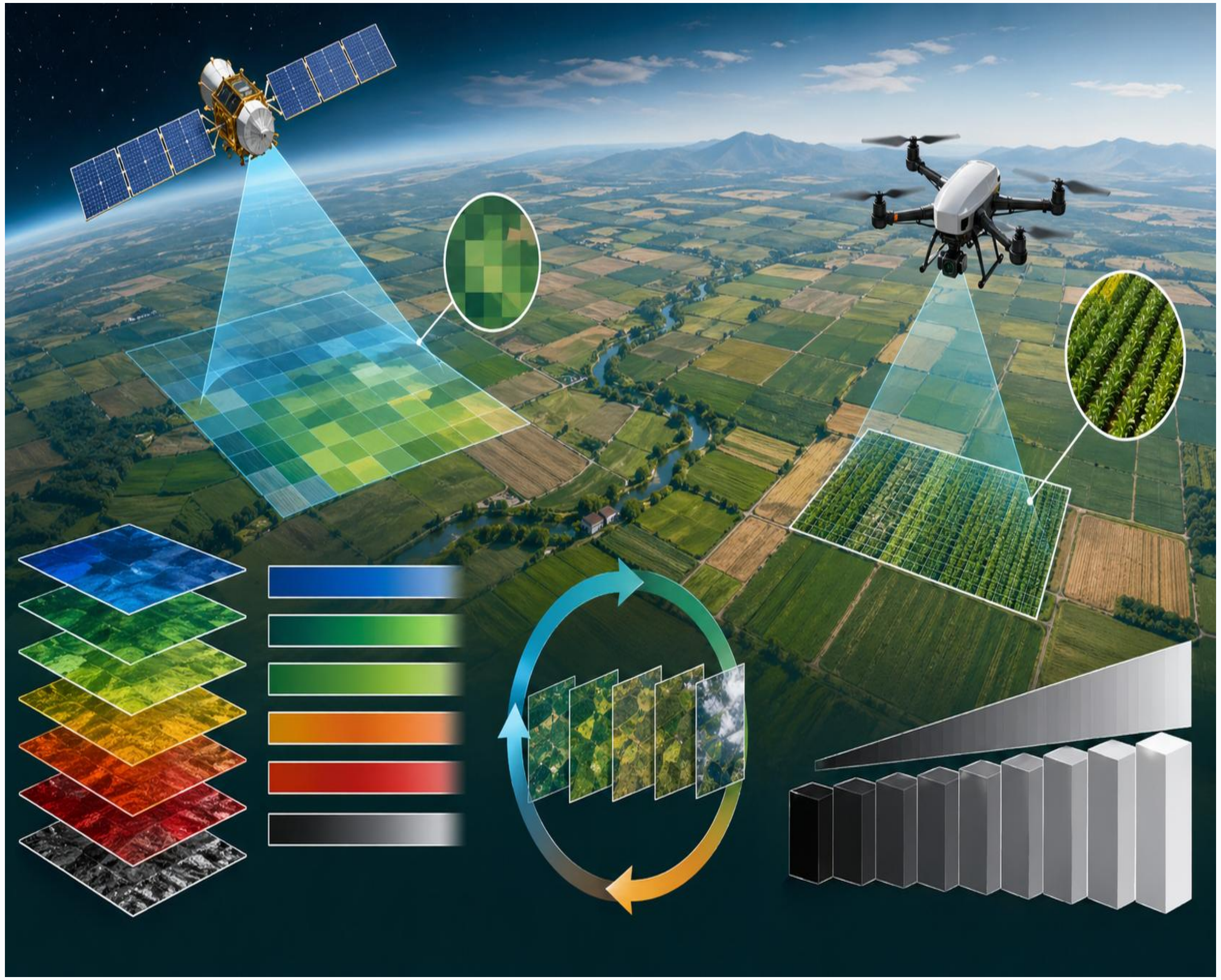
pixel size

SPECTRAL

band detail

TEMPORAL

revisit time



Why does resolution matter?

Resolution controls what we can see, distinguish, monitor, and measure.

Learning outcomes

Define the four main resolution types in remote sensing.

Explain spatial, spectral, temporal, and radiometric resolution with examples.

Recognize trade-offs among resolution types.

Select suitable data for different land, water, and agriculture tasks.

Avoid common interpretation errors caused by mixed pixels or poor timing.

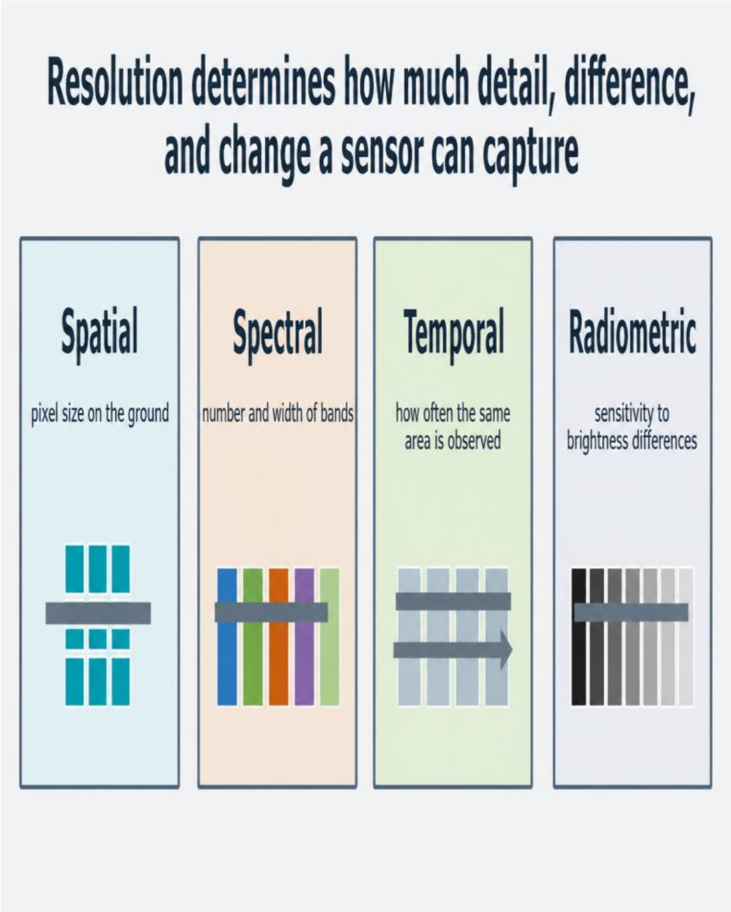
Key idea

Resolution is not only “image sharpness.”

It is a multi-dimensional description of sensor capability.

Practical question

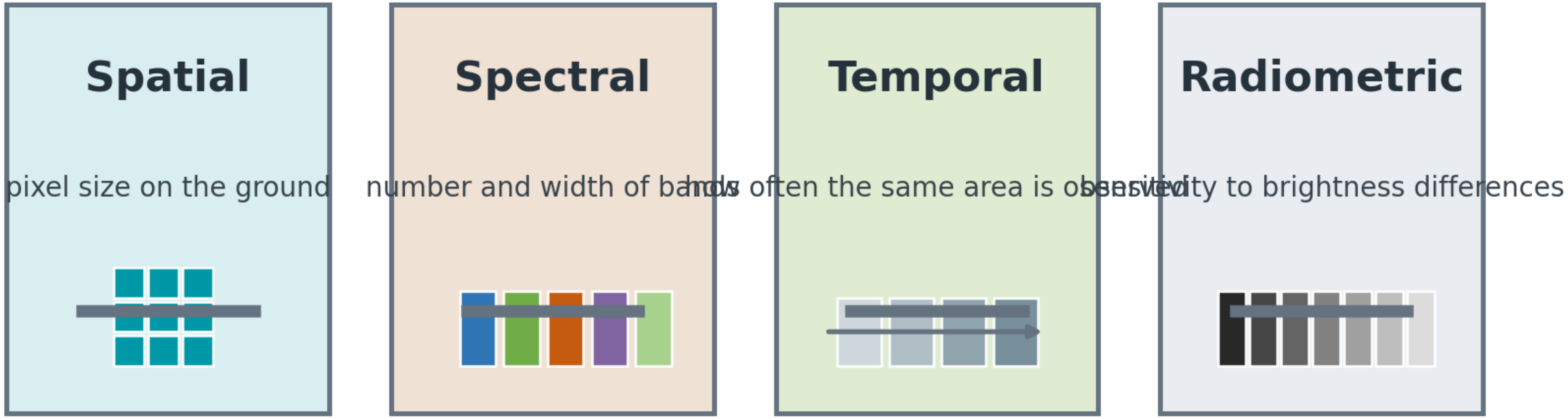
What resolution is required to answer the real management or research question?



The four dimensions of resolution

Each dimension describes a different kind of detail in remote sensing data.

Resolution determines how much detail, difference, and change a sensor can capture

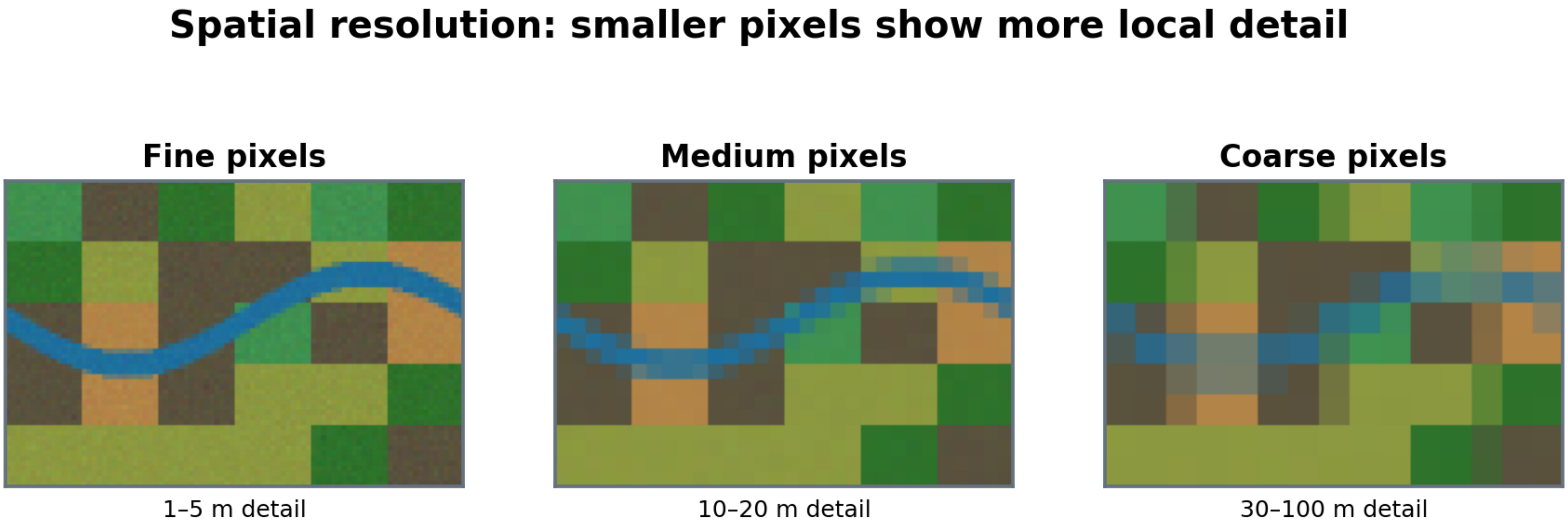


Take-away

A dataset can be excellent in one resolution type and weaker in another; good analysis starts by matching resolution to the task.

Spatial resolution: pixel size on the ground

Smaller pixels usually show finer detail, but also increase data volume.



Fine detail

Useful for parcels, roads, small canals, trees.

Medium detail

Useful for fields, land cover, reservoirs.

Coarse detail

Useful for regional trends and broad monitoring.

Spatial resolution and mixed pixels

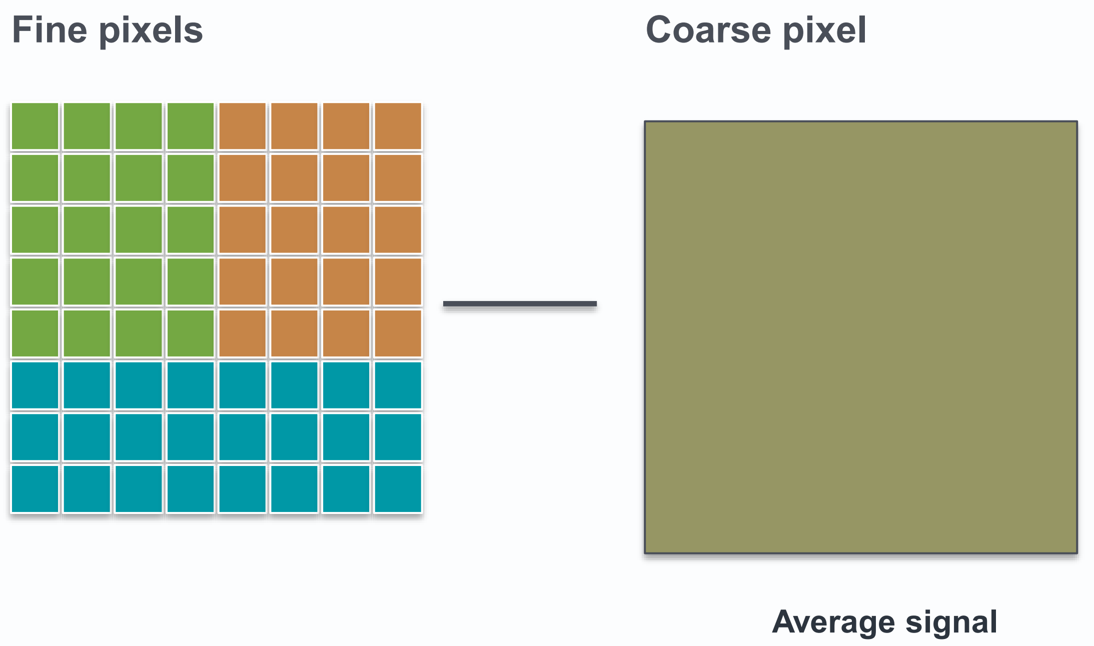
A mixed pixel contains more than one land-cover type.

Why mixed pixels matter

If a pixel covers crop + soil + water, its value is an average signal.

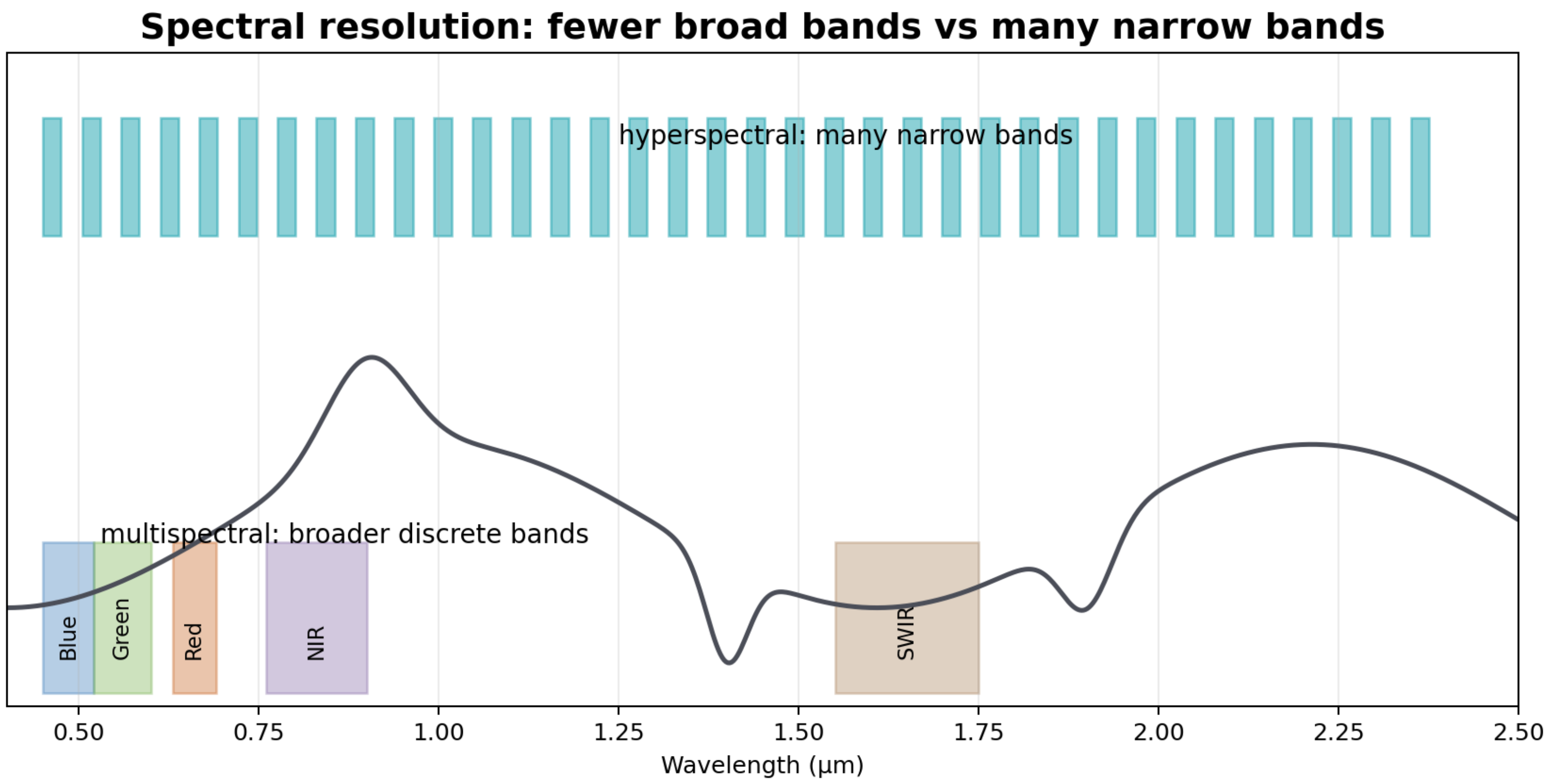
Small objects may disappear when pixel size is too large.

Classification accuracy often decreases when field boundaries are smaller than pixel size.



Spectral resolution: number and width of bands

Narrower and more numerous bands can reveal more material differences.



Interpretation message

Broad bands are efficient and easy to use; narrow bands help detect subtle absorption features and improve material identification.

Spectral resolution in practice

Different spectral systems fit different analytical goals.

Panchromatic

One broad band.

Often high spatial detail.

Useful for sharpening and visual interpretation.

Multispectral

Several broad bands.

Very common in land, vegetation, and water mapping.

Examples include Landsat and Sentinel-2 style data.

Hyperspectral

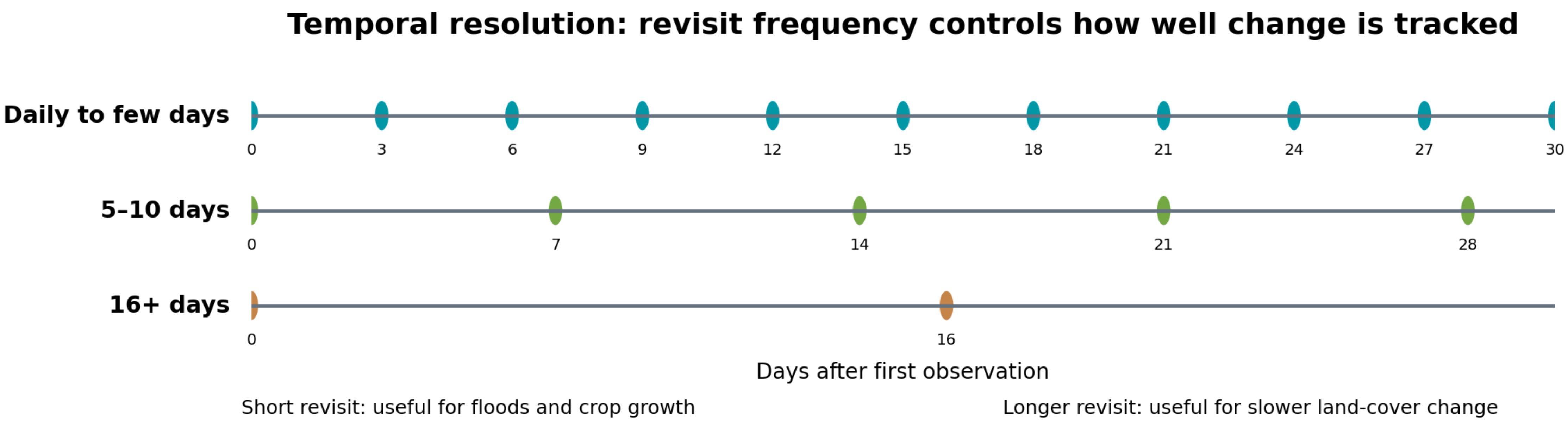
Many narrow bands.

Strong for minerals, crop traits, and detailed spectral signatures.

Requires careful processing and larger storage.

Temporal resolution: revisit time

Temporal resolution determines how often the same area can be observed.



Fast events

Floods, fires, and storms need frequent observations.

Seasonal processes

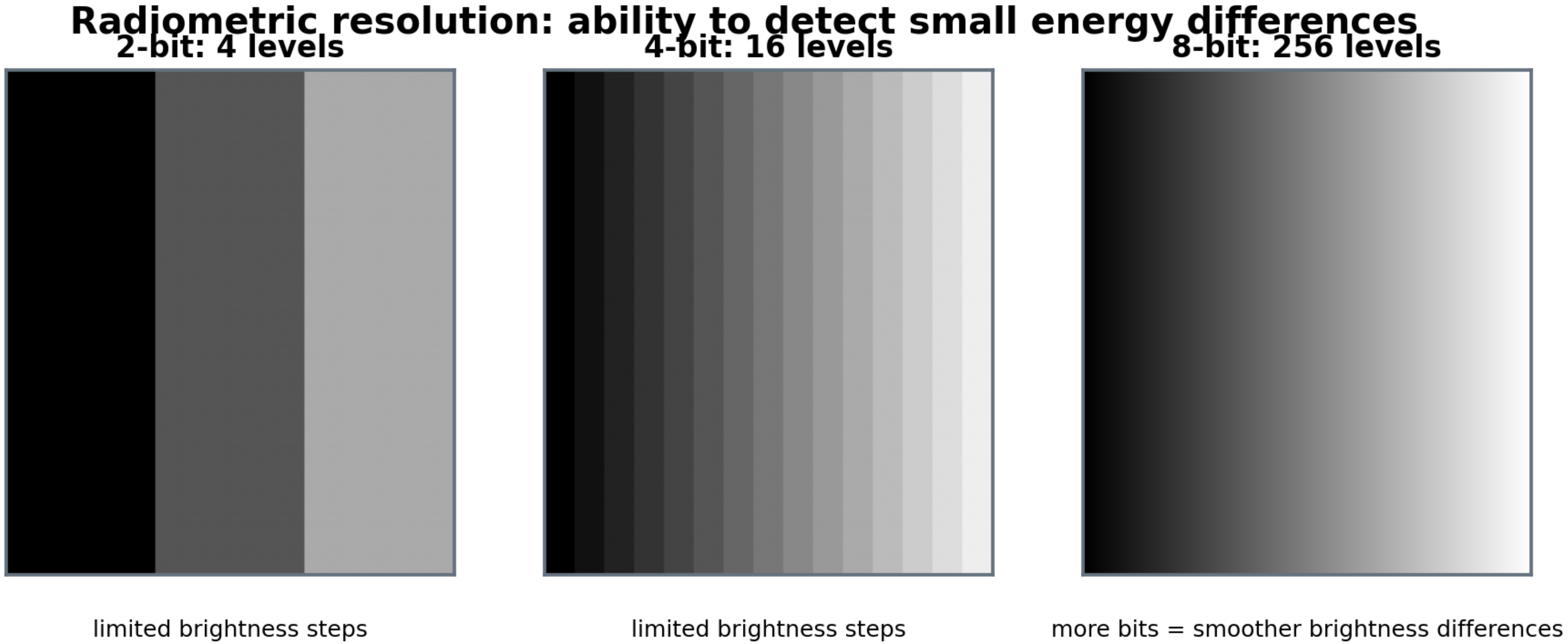
Crop growth and pasture dynamics need repeated dates.

Slow change

Urban expansion and land degradation can be monitored less frequently.

Radiometric resolution: brightness sensitivity

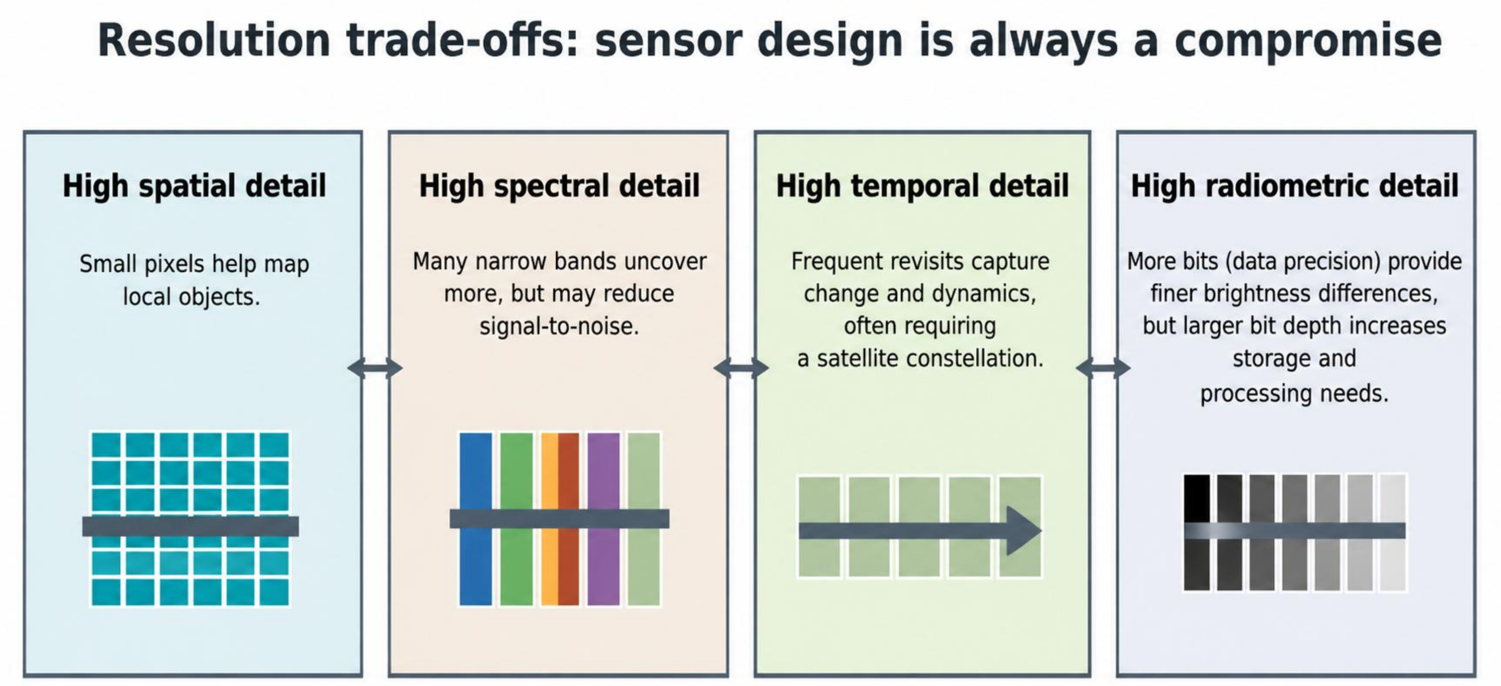
Higher bit depth allows the sensor to store more levels of measured energy.



Numerical example

8-bit data can store $2^8 = 256$ brightness levels; 12-bit data can store $2^{12} = 4096$ levels, which improves sensitivity to subtle differences.

A sensor rarely maximizes all resolution dimensions at the same time.



Practical rule

Choose the dataset based on the research question, not only because it has the “highest resolution” in one dimension.

The best dataset depends on the object, timing, and analysis objective.

Choosing the right resolution for the task

Task	lost important resolutio	Why it matters
Mapping small field boundaries	Spatial	Pixels must be smaller than the field features.
Distinguishing crop types	Spectral + temporal	Bands and seasonal patterns both matter.
Tracking flood expansion	Temporal + spatial	Frequent repeat images and adequate detail are needed.
Detecting subtle stress	Radiometric + spectral	Small brightness and band differences become important.
[illegible]	[illegible]	[illegible]

Decision support message

Start with the smallest object you need to map, the fastest change you need to detect, and the spectral/brightness differences you need to separate.

Typical resolution profiles of common data sources

These examples show why different sensors are used for different purposes.

Data type	Spatial	Spectral	Temporal	Radiometric	Typical use
UAV imagery	cm-level to meter	RGB / multi	on demand	varies	parcel mapping, field inspection
Sentinel-2 style	10–60 m	multispectral	few days	high	agriculture, water, land cover
Landsat style	15–100 m	multi + thermal	about weeks	high	long-term change analysis
MODIS style	hundreds of meters	multispectral	daily	moderate/high	regional to global monitoring
Hyperspectral data	varies	many narrow bands	mission dependent	high	materials, minerals, crop traits

Note

Exact values differ by mission and product level; the goal here is to understand relative trade-offs.

Case examples: how resolution affects decisions

Good resolution choice improves scientific accuracy and practical decision-making.

Crop parcels

Need spatial resolution smaller than field features.

Temporal resolution should match the crop calendar.

Water bodies

Spatial resolution affects shoreline accuracy.

Temporal resolution matters during floods and irrigation seasons.

Urban heat

Thermal data is needed, often at coarser spatial resolution.

Radiometric sensitivity helps identify subtle temperature differences.

Land degradation

Multi-year temporal consistency is critical.

Spectral bands help distinguish vegetation, bare soil, and moisture conditions.

Review summary

Key points to remember

Four resolution types

Spatial: pixel size and object detail.

Spectral: bands and material discrimination.

Temporal: revisit time and change monitoring.

Radiometric: sensitivity to brightness differences.

Practical message

Higher resolution is not automatically better for every task.

Mixed pixels, poor timing, and insufficient spectral detail can all reduce accuracy.

The best dataset is the one that matches the study question and ground reality.

References

Selected introductory and authoritative sources

Lillesand, T., Kiefer, R. W., & Chipman, J. (2015). Remote Sensing and Image Interpretation. Wiley.

Jensen, J. R. (2016). Introductory Digital Image Processing: A Remote Sensing Perspective. Pearson.

Campbell, J. B., & Wynne, R. H. (2011). Introduction to Remote Sensing. Guilford Press.

NASA Earthdata. Educational materials on spatial, spectral, temporal, and radiometric resolution.

USGS Landsat Missions. Educational materials on Landsat resolution and data products.

ESA Sentinel Online. Sentinel mission documentation and sensor descriptions.

FAO and USGS educational resources on Earth observation and land monitoring.

Independent study suggestion

Students are encouraged to compare the same area in UAV, Sentinel-2, Landsat, and MODIS-style imagery to see how resolution changes interpretation.

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