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LAND MANAGEMENT IN CENTRAL ASIA

13.- Image Interpretation and Digital Image Processing

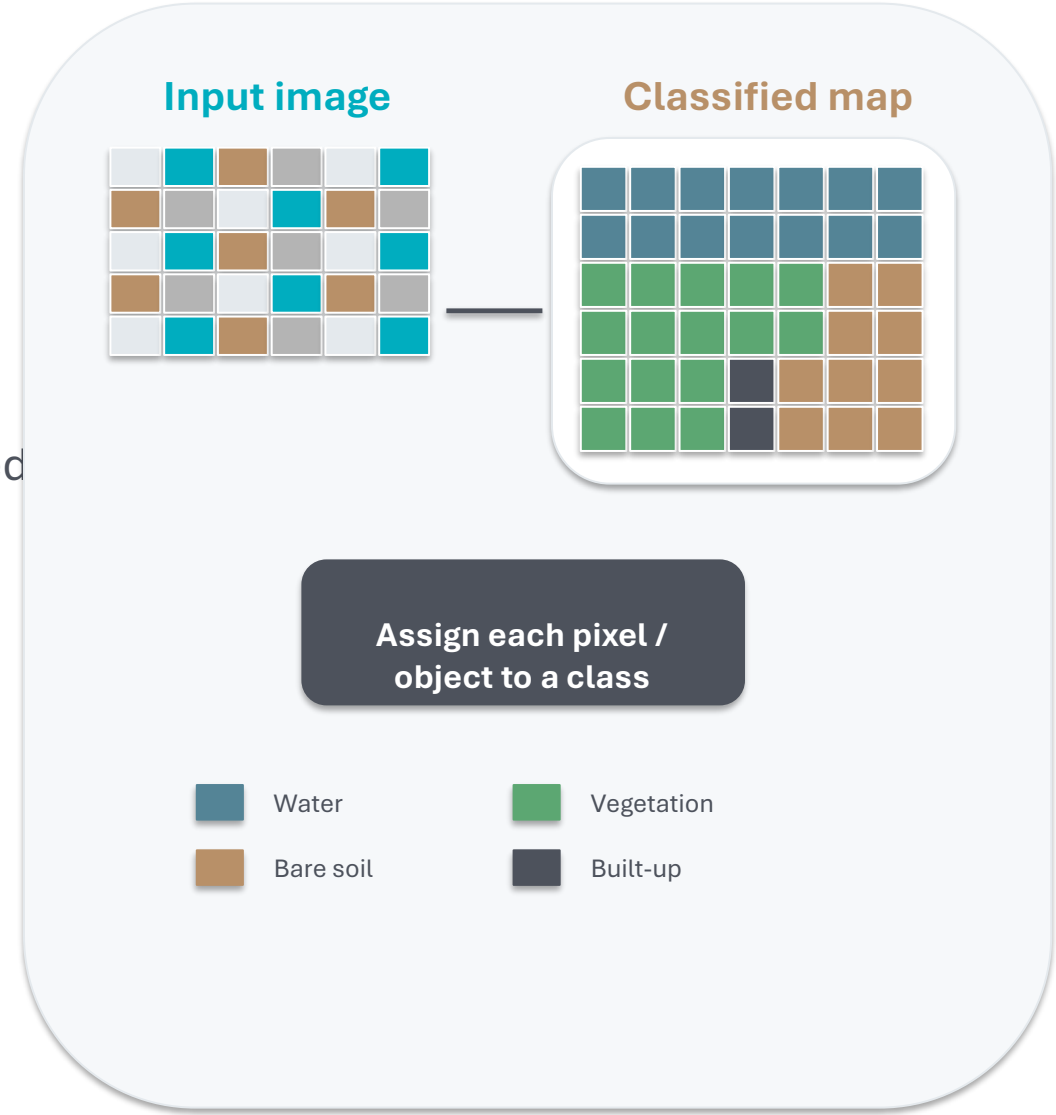
Image Classification Methods

LM-W13-V89

Image Classification Methods

An introductory overview of how digital images are grouped into meaningful land-cover classes using supervised, unsupervised, and object-based approaches.

Focus: training data, algorithms, decision rules, accuracy assessment, and practical applications



Designed for undergraduate students in remote sensing

Learning objectives and lesson roadmap

Learning objectives

Define image classification and explain why it is important in remote sensing.
Distinguish between supervised, unsupervised, and object-based classification.
Recognize common classification algorithms and their basic logic.
Understand the roles of training data, feature selection, and validation.
Interpret simple accuracy assessment results such as a confusion matrix.

Roadmap

Concept → Workflow → Methods → Validation → Applications

Supervised

Uses known training samples.

Unsupervised

Groups pixels automatically.

Object-based

Classifies image segments.

Accuracy

Checks how reliable the map is.

Image classification converts image data into thematic categories that support mapping and decision-making.

What is image classification?

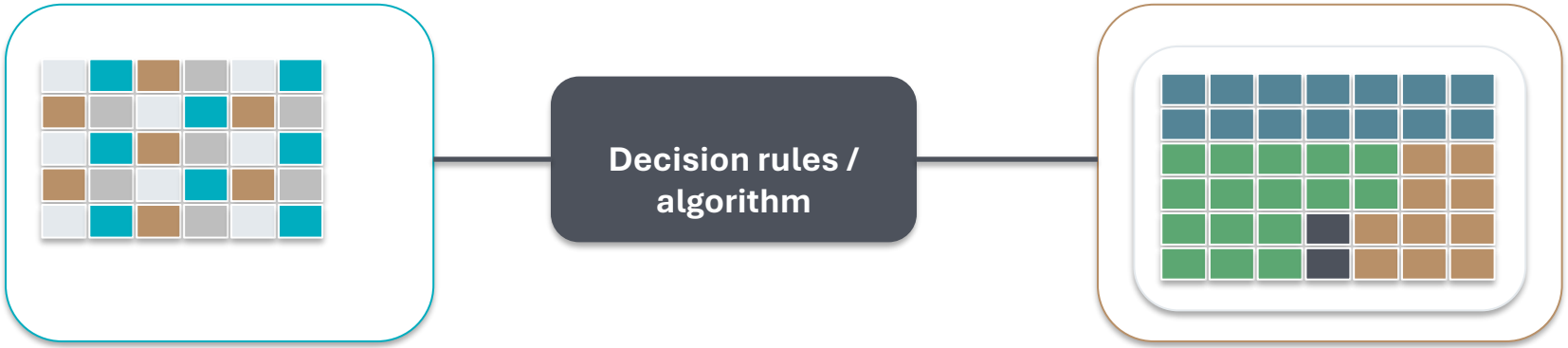


Image pixels / objects

Thematic map

Input features

Pixel values, texture, shape, indices, and contextual information.

Output classes

Examples: water, vegetation, soil, urban area, crop type.

Purpose

To transform image values into meaningful categories for interpretation and analysis.

Classification assigns every pixel or image object to a land-cover or land-use class.

General classification workflow

1. Select image

Choose suitable spatial, spectral, and temporal resolution.

2. Prepare data

Apply preprocessing and create useful bands or indices.

3. Define classes

Decide the land-cover categories needed for the study.

4. Run classifier

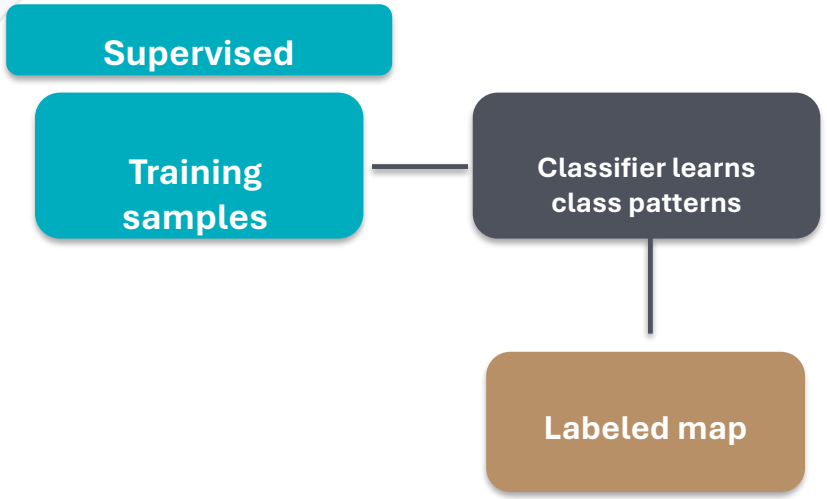
Apply a method such as supervised or unsupervised classification.

5. Validate result

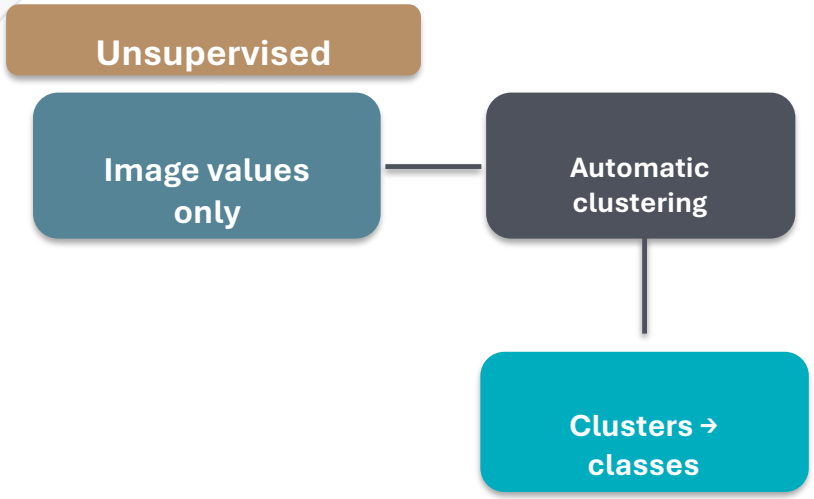
Compare with reference data and calculate accuracy.

A reliable classification depends on both a good workflow and carefully chosen input data.

Supervised and unsupervised classification



Analyst provides known examples for each class.
Often more accurate when good training data are available.
Common in land-cover and crop mapping.

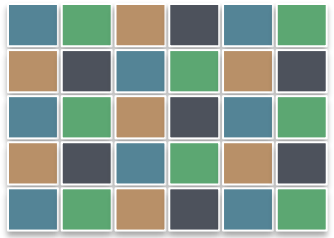


Pixels are grouped according to similarity without labeled samples.
Useful for exploration when classes are not yet fully known.
Clusters still need interpretation by the analyst.

The major difference is whether the algorithm starts with known training samples or finds groups automatically.

Pixel-based and object-based classification

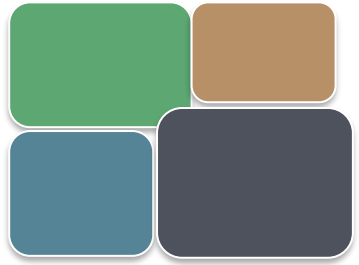
Pixel-based



Each pixel is classified individually using its spectral values.

Simple and widely used.
Works well with medium-resolution imagery.
May create a “salt-and-pepper” pattern in detailed scenes.

Object-based



Groups neighboring pixels into segments before classification.

Uses shape, texture, and context as well as spectral values.
Often useful with very high-resolution imagery.
Can improve mapping of buildings, fields, and urban features.

Pixel-based methods classify individual cells, while object-based methods classify meaningful image segments.

Common supervised classification algorithms

Minimum Distance

Supervised method

Assigns a pixel to the class with the nearest mean signature.

Maximum Likelihood

Supervised method

Uses class statistics and probability to choose the most likely class.

Decision Tree /

Supervised method

Splits data using decision rules; random forest combines many trees.

Support Vector

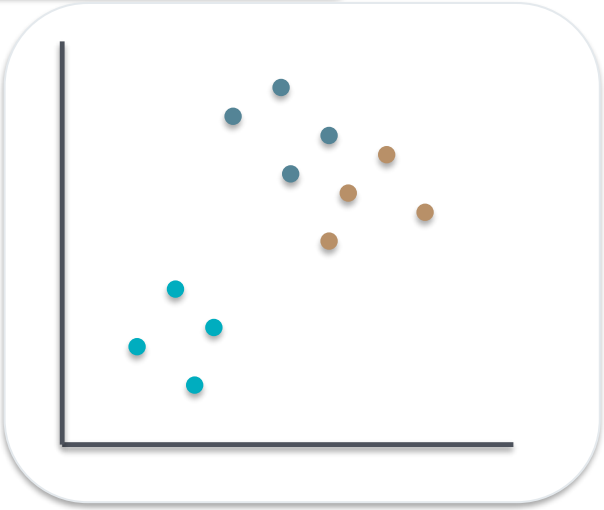
Supervised method

Finds separating boundaries between classes in feature space.

Different supervised algorithms use different decision rules, but all require labeled training data.

Unsupervised clustering methods

How clustering



Pixels are grouped by similarity in feature space.

Common examples: K-means and ISODATA.

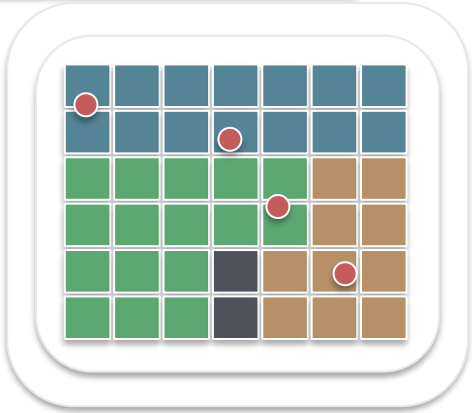
Advantages and limits

Useful for exploratory analysis when class labels are unavailable.
Can suggest patterns that may not be obvious at first.
The analyst must interpret each cluster after the algorithm runs.
Some clusters may combine different land-cover types if their spectral values are similar.

Unsupervised methods organize the data first; interpretation and labeling come afterward.

Training data and feature selection

Training samples



Sample points or polygons should represent each class well.

Useful features

- Spectral bands
- Indices
- Texture
- Elevation / context

Good practice

Collect representative samples for all important classes.
Avoid mixed or uncertain pixels when possible.
Use features that separate classes clearly, such as NIR for vegetation or texture for urban areas.
Keep some reference data separate for validation.

The quality of training data and feature selection strongly influences classification accuracy.

Accuracy assessment and confusion matrix

Example confusion

	Water	Veg.	Soil	Urban
Water	18	1	0	1
Veg.	2	21	1	1
Soil	0	2	14	2
Urban	1	1	2	16

Rows = classified result
Columns = reference data

Key measures

Overall accuracy: proportion of all correctly classified samples.
Producer's accuracy: how well reference samples of a class were classified.
User's accuracy: how reliable a mapped class is for the map user.
Kappa coefficient: a traditional index of agreement beyond chance.

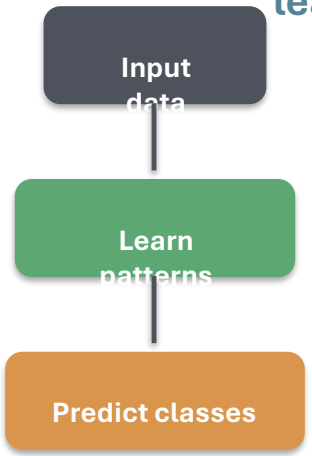
Accuracy assessment shows whether a classification is reliable enough for the intended application.

Rule-based methods and machine learning

Rule-based approach

Based on expert-defined thresholds or logical rules.
Easy to interpret.
Works well when the class behavior is simple and clear.

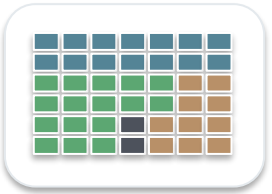
Machine learning



Examples: random forest, SVM, neural networks.
Can handle complex class boundaries.
Usually needs more training data and tuning.

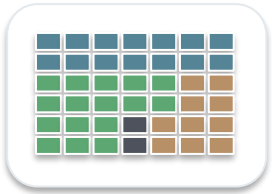
Some methods rely on explicit rules, while others learn patterns from training data.

Practical applications of classification



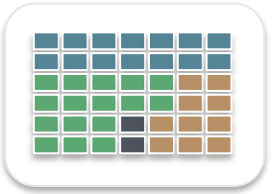
Land-cover mapping

Identify water, forest, cropland, bare land, and settlements.



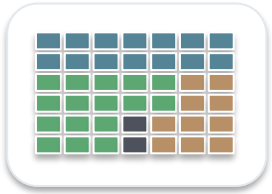
Crop type mapping

Separate agricultural fields such as wheat, cotton, rice, or vegetables.



Urban studies

Map buildings, roads, and urban expansion patterns.



Environmental monitoring

Track wetland change, erosion risk, or post-disaster damage.

Classification is widely used to turn remote sensing imagery into practical and policy-relevant information.

Choosing an appropriate classification method

Situation	Recommended direction	Reason
Known classes and good training data	**Supervised classification**	Usually provides stronger control and accuracy.
Little prior knowledge of the scene	**Unsupervised clustering**	Useful for exploratory grouping.
Very high-resolution image	**Object-based method**	Can use texture, shape, and context.
Complex class boundaries	**Machine learning approach**	Handles non-linear patterns more effectively.
Need a quick simple map	**Basic supervised method**	Fast and relatively easy to interpret.

There is no single best method for all situations; method choice depends on data, objectives, and available reference information.

Strengths, limitations, and best practice

Limitations

Spectrally similar classes may be difficult to separate.
Poor training data can produce weak results.
Mixed pixels can reduce accuracy, especially at coarser resolution.
Different algorithms may produce different maps from the same image.

Best practice tips

Preprocess carefully	Corrected and well-aligned imagery improves classification quality.
Design classes clearly	Class definitions should match the study goal.
Use good reference data	Representative training and validation samples are essential.
Validate and report	Always assess accuracy and mention uncertainty.

Good classification is not only about choosing an algorithm; it is also about data quality, class design, and validation.

References and further reading

Campbell, J. B., & Wynne, R. H. (2011). Introduction to Remote Sensing (5th ed.). Guilford Press.
Jensen, J. R. (2015). Introductory Digital Image Processing: A Remote Sensing Perspective (4th ed.). Pearson.
Lillesand, T., Kiefer, R. W., & Chipman, J. (2015). Remote Sensing and Image Interpretation (7th ed.). Wiley.
Richards, J. A. (2013). Remote Sensing Digital Image Analysis (5th ed.). Springer.
NASA Earth Observatory. Resources on land-cover mapping and classification from earth observation data.
USGS EROS Center. Landsat, land cover, and remote sensing tutorial resources.

Suggested activity: compare a supervised and an unsupervised classification of the same image and discuss which one better represents the land-cover pattern.

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