COURSE: SATELLITE IMAGE PROCESSING

LECTURE 10 – Image Classification Accuracy Assessment

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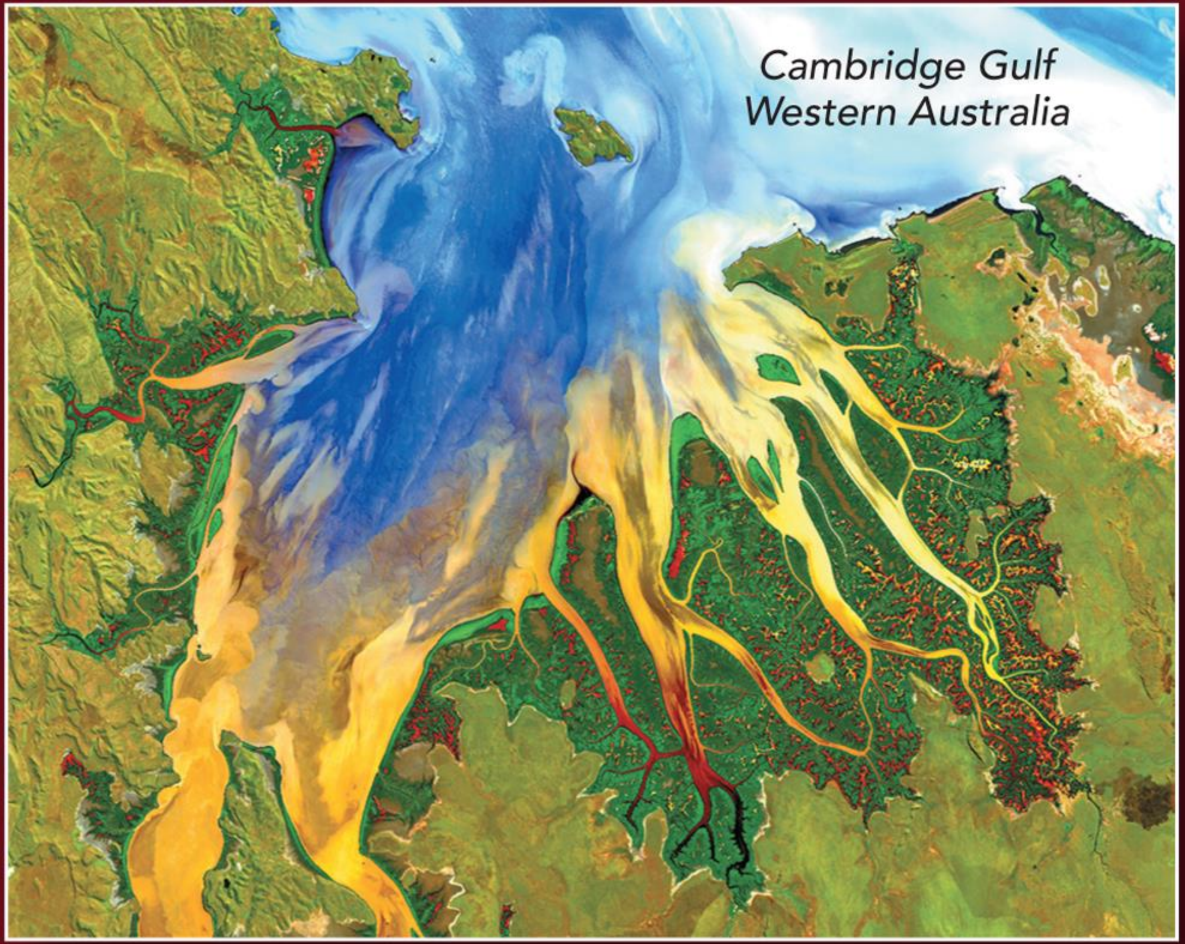
Remote Sensing Digital Imagery Pattern Recognition

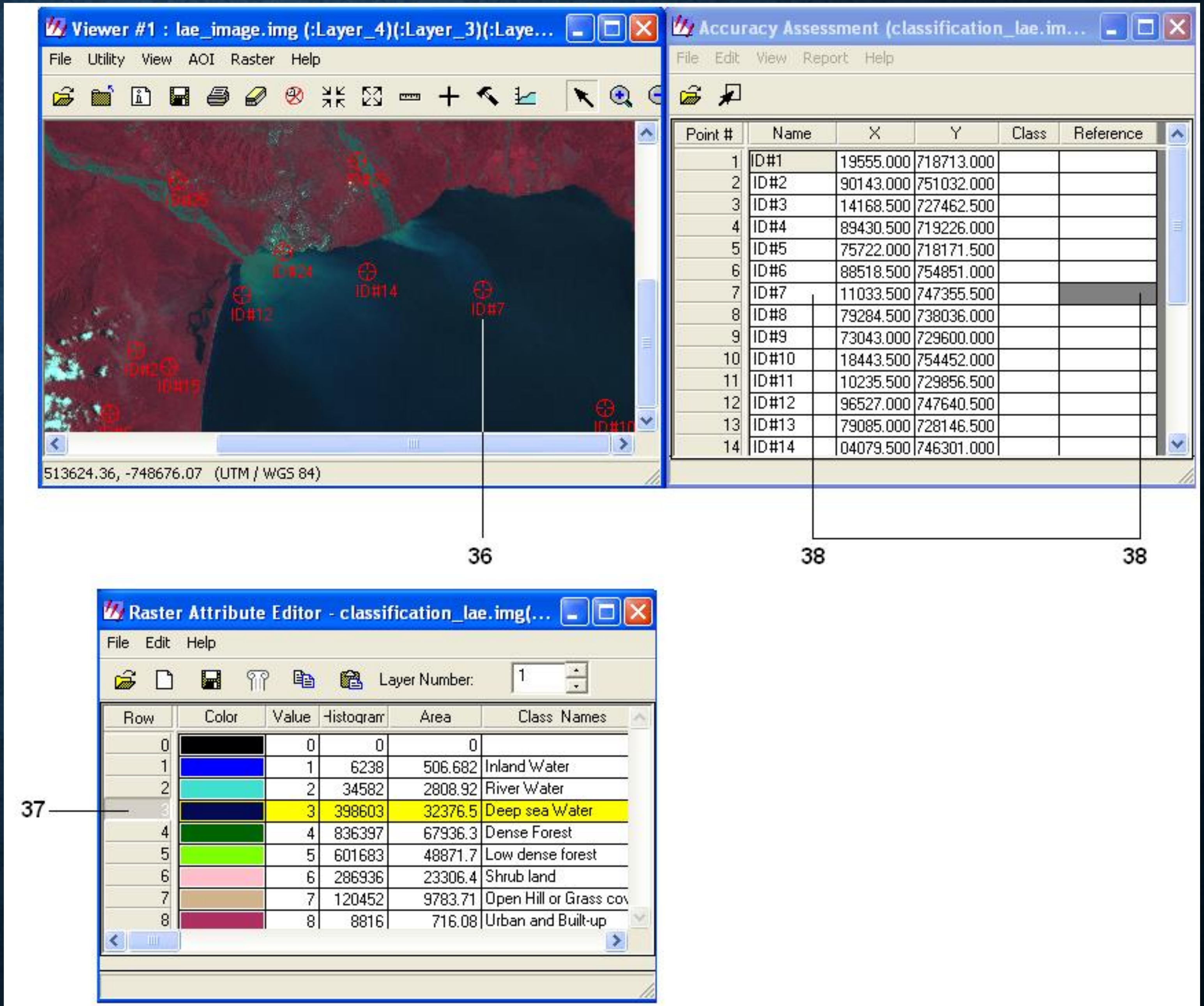


Source: John R. Jesen, 4th Ed, Landsat 8 artist rendition: NASA, 2014

Feature Classification and Extraction

Source: John R. Jesen, 4th Ed,

Software use for Accuracy Assessment



Source: RSGIS Course Module, SSLS

Thematic Layer Contains Error

- Information derived from remotely sensed data is becoming increasingly important for planning, ecosystem monitoring, food security and human health assessment, and police/military reconnaissance at local, regional, and global scales.

- The remote sensing–derived thematic information must be accurate because important decisions are made throughout the world using the geospatial information

Source: John R. Jesen, 4th Ed; Jensen and Jensen, 2013; Wickham et al., 2013).

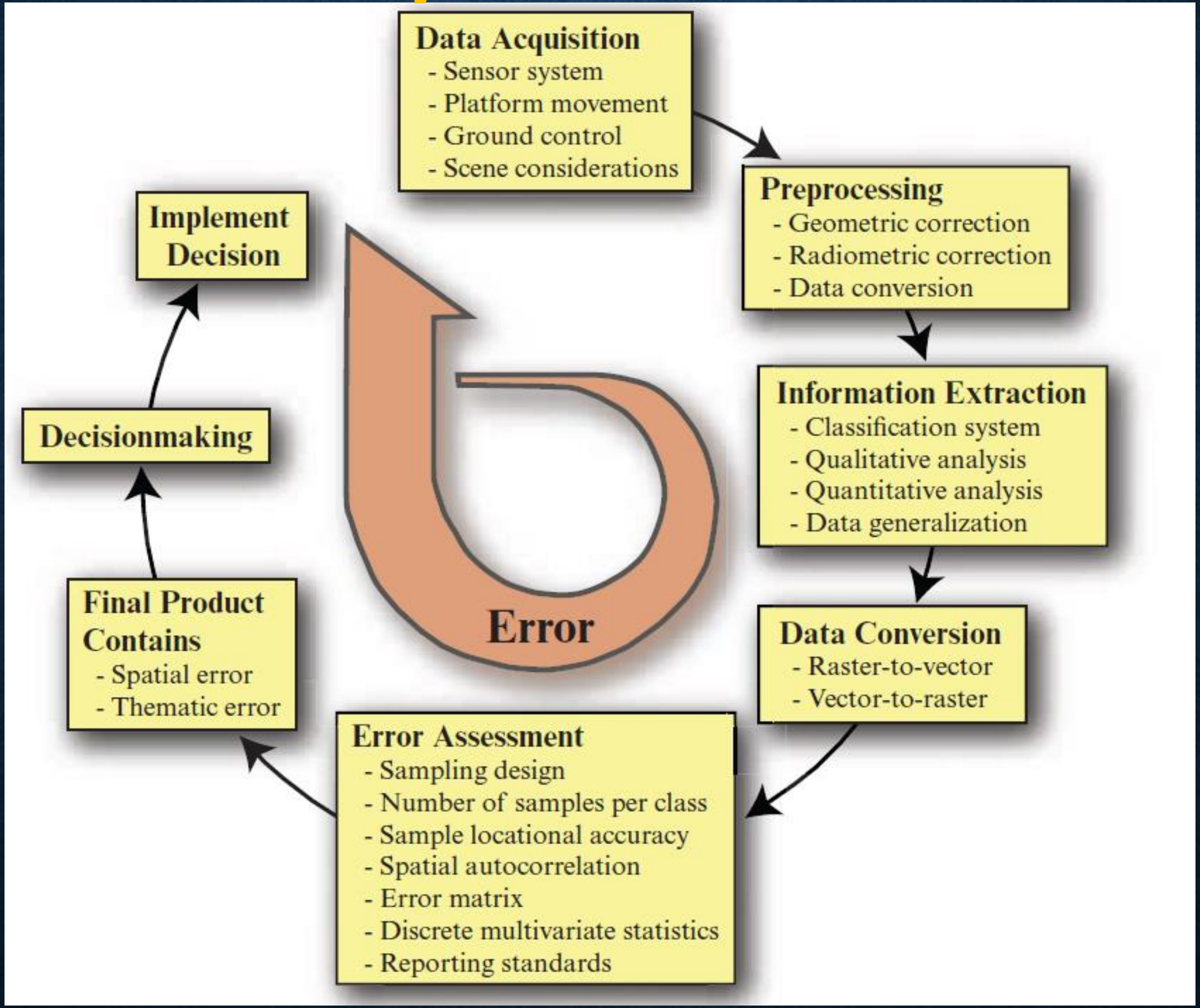
Thematic Layer Contains Error

- Remote sensing–derived thematic information contains error.

- Analysts who create remote sensing–derived thematic information should recognize the sources of the error, minimize it as much as possible, and inform the user how much confidence he or she should have in the thematic information.

Source: John R. Jesen, 4th Ed; Jensen and Jensen, 2013; Wickham et al., 2013).

Thematic Layer Contains Error



Source: John R. Jesen, 4th Ed;

Accuracy Assessment for Remote Sensing derived Thematic Layer

- Remote sensing–derived thematic maps should normally be subjected to a thorough accuracy assessment before being used in subsequent scientific investigations and policy decision-making.

- This also includes assessing the accuracy of remote sensing–derived change detection maps.

Source: John R. Jesen, 4th Ed; Borengasser et al., 2008; Congaltonand Green, 2009
).

Steps for Accuracy Assessment

1. State the nature of the thematic accuracy assessment problem:

- State what the accuracy assessment is expected to accomplish.
- Identify classes of interest (discrete or continuous).
- Specify the sampling frame within the sampling design:

  - area frame (the geographic region of interest)
  - list frame (consisting of points or areal sampling units)

Source: John R. Jesen, 4^{th} Ed;
).

Steps for Accuracy Assessment

2. Select method(s) of thematic accuracy assessment.

- Confidence-building assessment:

  - Qualitative

- Statistical measurement:

  - Model-based inference (concerned with image processing methods)
  - Design-based statistical inference of thematic information

Source: John R. Jesen, 4th Ed;

Steps for Accuracy Assessment

3. Compute total number of observations required in the sample:

* Observations per class.

Source: John R. Jesen, 4th Ed;

Steps for Accuracy Assessment

4. Select sampling design (scheme):

- Random.
- Systematic.
- Stratified random.
- Stratified systematic unaligned sample.

* Cluster sampling.

Source: John R. Jesen, 4th Ed;

Steps for Accuracy Assessment

5. Obtain ground reference data at observation locations using a response design:

- Evaluation protocol.
- Labeling protocol.

Source: John R. Jesen, 4th Ed;

Steps for Accuracy Assessment

6. Error matrix creation and analysis:

* Creation:
- Ground reference test information (columns)
- Remote sensing classification (rows)

* Univariate statistical analysis:
- Producer's accuracy
- User's accuracy
- Overall accuracy

* Multivariate statistical analysis:
- Kappa coefficient of agreement; conditional Kappa
- Fuzzy

Source: John R. Jesen, 4th Ed;

Steps for Accuracy Assessment

7. Accept or reject the previously stated hypothesis.

8. Distribute results if accuracy is acceptable.

- Accuracy assessment report.
- Digital products.
- Analog (hard-copy) products.
- Image and map lineage report.

Source: John R. Jesen, 4th Ed;

The Error Matrix

- To determine the accuracy of a remote sensing–derived thematic map, it is necessary to systematically compare two sources of information:

1. pixels or polygons in the remote sensing–derived classification map, and

2. ground reference test information obtained at the same x, y location (which may in fact contain error).

Source: John R. Jesen, 2015, 4th Ed;

Accuracy Assessment Error Matrix

- Sample-based error matrix where there are k classes in the remote sensing derived thematic map and N ground reference test samples that are used to assess its accuracy.

		Ground Reference Test Information Class 1 to *k* (*j* columns)					
		1	2	3		*k*	Row total x_{i+}
Map Class 1 to *k* (*i* rows)	1	$x_{1,1}$	$x_{1,2}$	$x_{1,3}$	....	$x_{1,k}$	x_{1+}
	2	$x_{2,1}$	$x_{2,2}$	$x_{2,3}$	. . . .	$x_{2,k}$	x_{2+}
	3	$x_{3,1}$	$x_{3,2}$	$x_{3,3}$	. . . .	$x_{3,k}$	x_{3+}
	.	.	.	.	. . . .	.	.
	k	$x_{k,1}$	$x_{k,2}$	$x_{k,3}$	. . . .	$x_{k,k}$	x_{k+}
	Column total x_{+j}	x_{+1}	x_{+2}	x_{+3}	. . . .	x_{+k}	*N*

where:

- Cell entry, x_{ij}, is the proportion of area mapped as class *i* and labeled class *j* in the reference data.
- The *row marginal*, x_{i+}, is the sum of all x_{ij} values in row *i* and represents the proportion of area classified as class *i*.
- The *column marginal*, x_{+j}, is the sum of all x_{ij} values in column *j* and represents the proportion of area that is truly class *j*.
- The *diagonal*, x_{ii}, summarizes correctly classified pixels.
- All off diagonal cells represent misclassified pixels.

Source: John R. Jesen, 2015, 4th Ed;

Sample Size

- The number of ground reference test samples to be used to determine the accuracy of individual categories in a remote sensing classification map is an important consideration:

1. Some analysts use an equation based on the *binomial Distribution* to compute the required sample size.

2. Others suggest that a *multinomial distribution* be used to determine the sample size because we are usually investigating the accuracy of multiple classes of information on a land-cover map

Source: John R. Jesen, 2015, 4th Ed;

Sample Size Based on Binomial Probability Theory

1. Some analysts use an equation based on the *binomial Distribution* to compute the required sample size.

where p is the expected percent accuracy of the entire map,

$$N = \frac{Z^2(p)(q)}{E^2}$$

q = 100 – p,

E is the allowable error,

and Z = 2 from the standard normal deviate of 1.96 for the 95% two-sided confidence level

Source: John R. Jesen, 2015, 4th Ed;

Sample Size Based on Binomial Probability Theory

- For a sample for which the expected accuracy is 85% at an allowable error of 5%, the number of points necessary for reliable results is:

$$N = \frac{2^2(85)(15)}{5^2} = \text{a minimum of 204 points}$$

Source: John R. Jesen, 2015, 4th Ed; McCoy, 2005

Sample Size Based on Binomial Probability Theory

- The lower the expected percent accuracy (*p*), and the greater the allowable error (*E*), the fewer ground reference test samples that need to be collected to evaluate the classification accuracy.

Source: John R. Jesen, 2015, 4th Ed; McCoy, 2005

Sampling Design (Scheme)

- Once the total sample size (‘N’) and the number of samples required per class (strata) are determined, it is necessary to determine the geographic location (x, y) of these ‘N’ samples in the real world so that we can visit them and obtain ground reference test information.

- The sample locations must be determined randomly without bias.

- Any bias will cause the statistical analysis of the error matrix to over- or underestimate the true accuracy of the thematic map.

Source: John R. Jesen, 2015, 4th Ed

Sampling Design (Scheme)

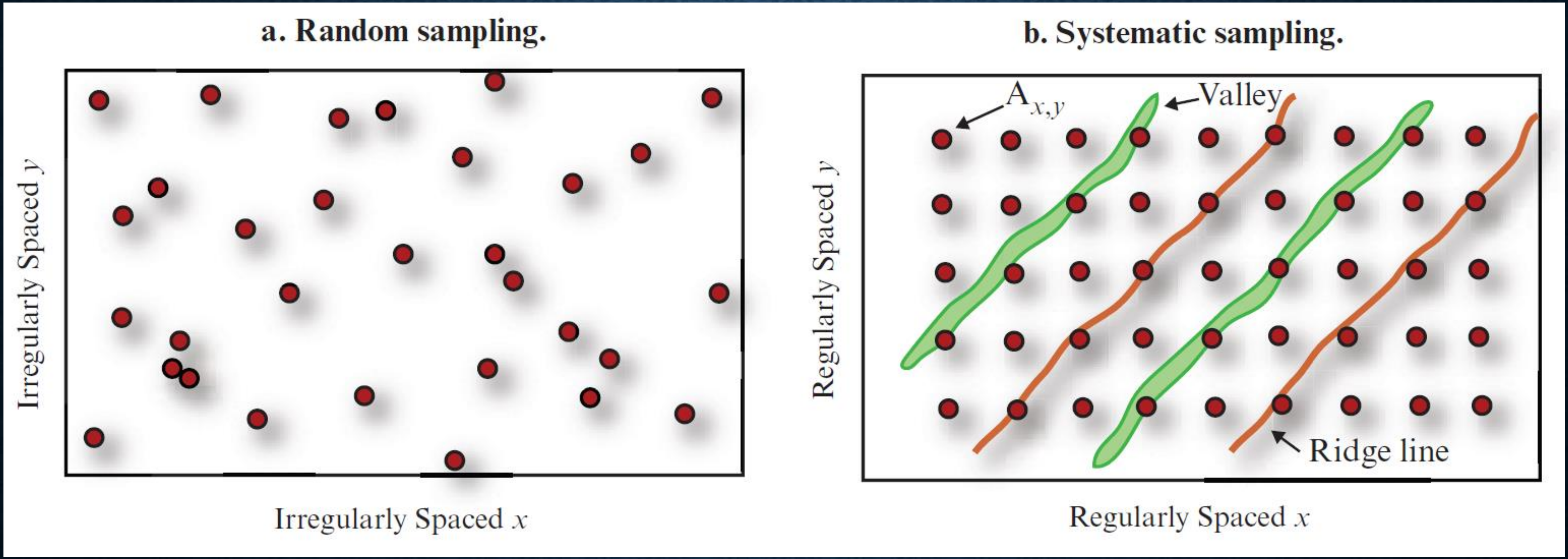
- There are numerous sampling designs that can be used to collect ground reference test data for assessing the accuracy of a remote sensing–derived thematic map.

. Some of the most commonly used include:

- random sampling,
- systematic sampling,
- stratified random sampling,
- stratified systematic unaligned sampling, and
- cluster sampling.

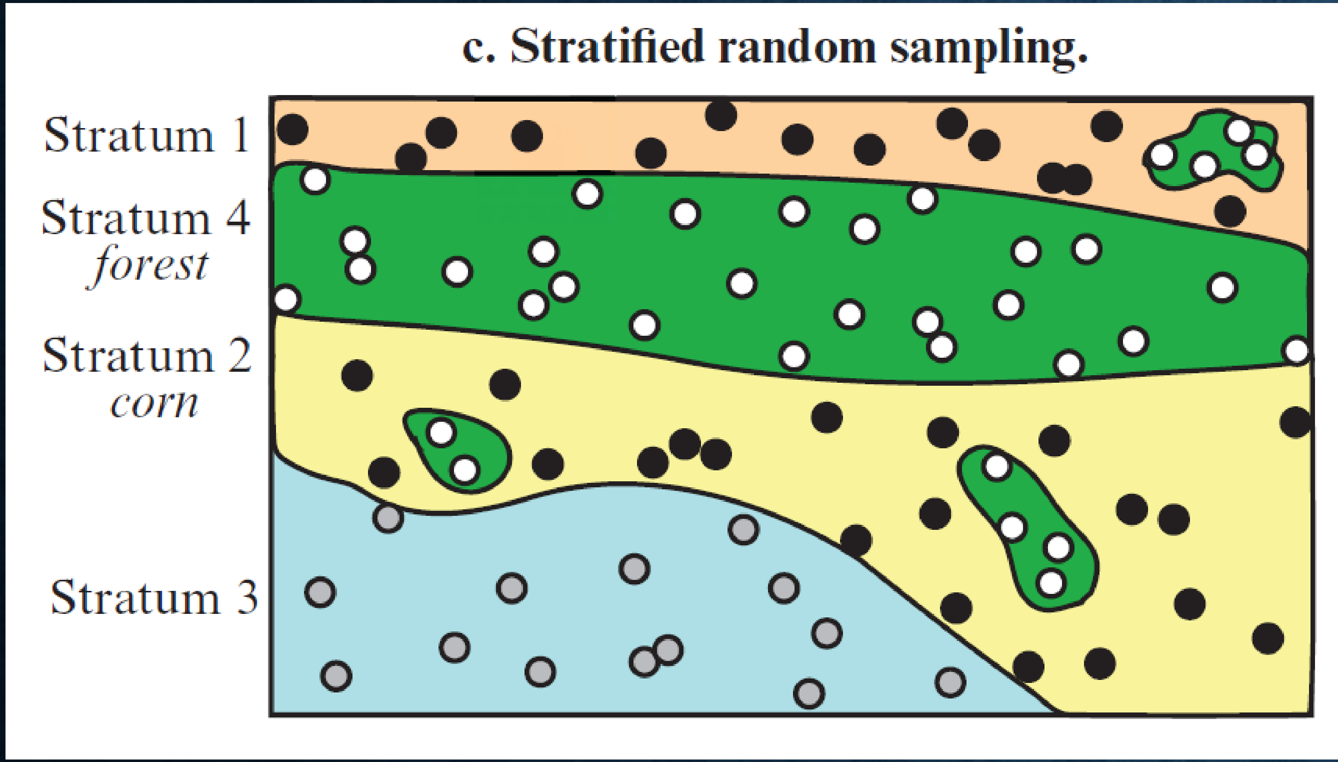
Source: John R. Jesen, 2015, 4th Ed; (McCoy, 2005; Congalton and Green, 2009; Stehman, 2009

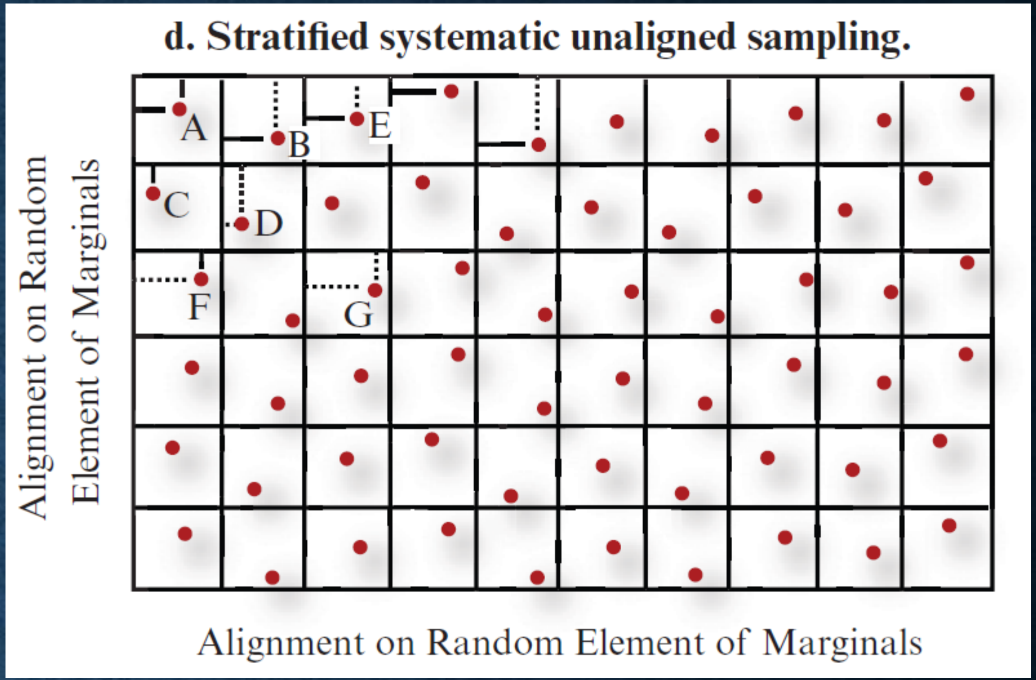
Sampling Methods

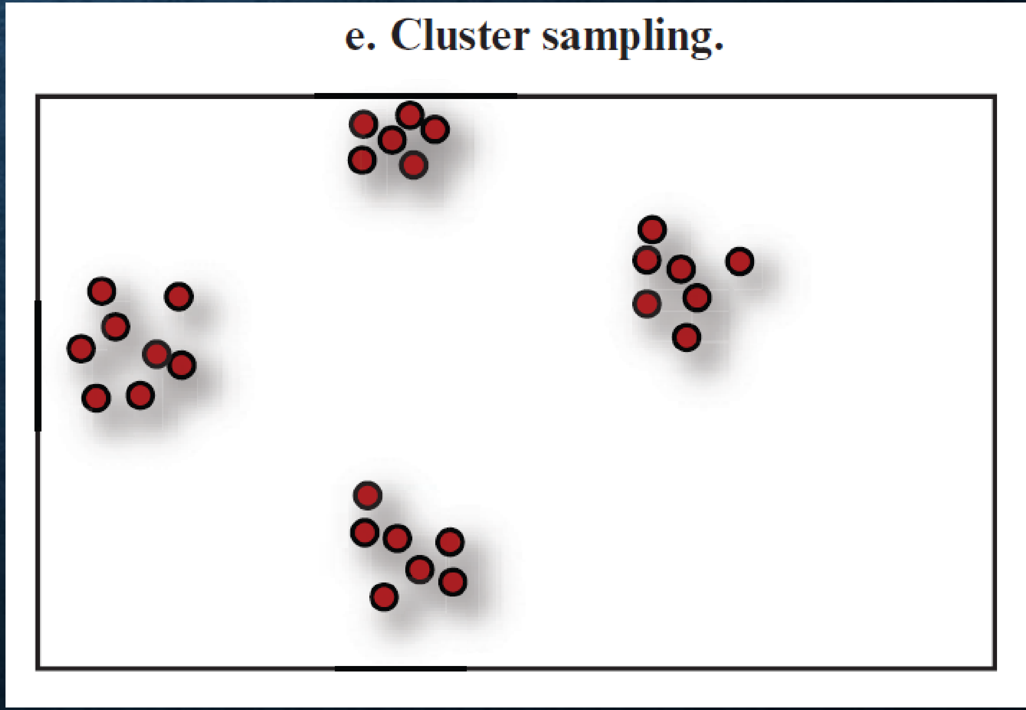


Source: John R. Jesen, 2015, 4th Ed

Sampling Methods



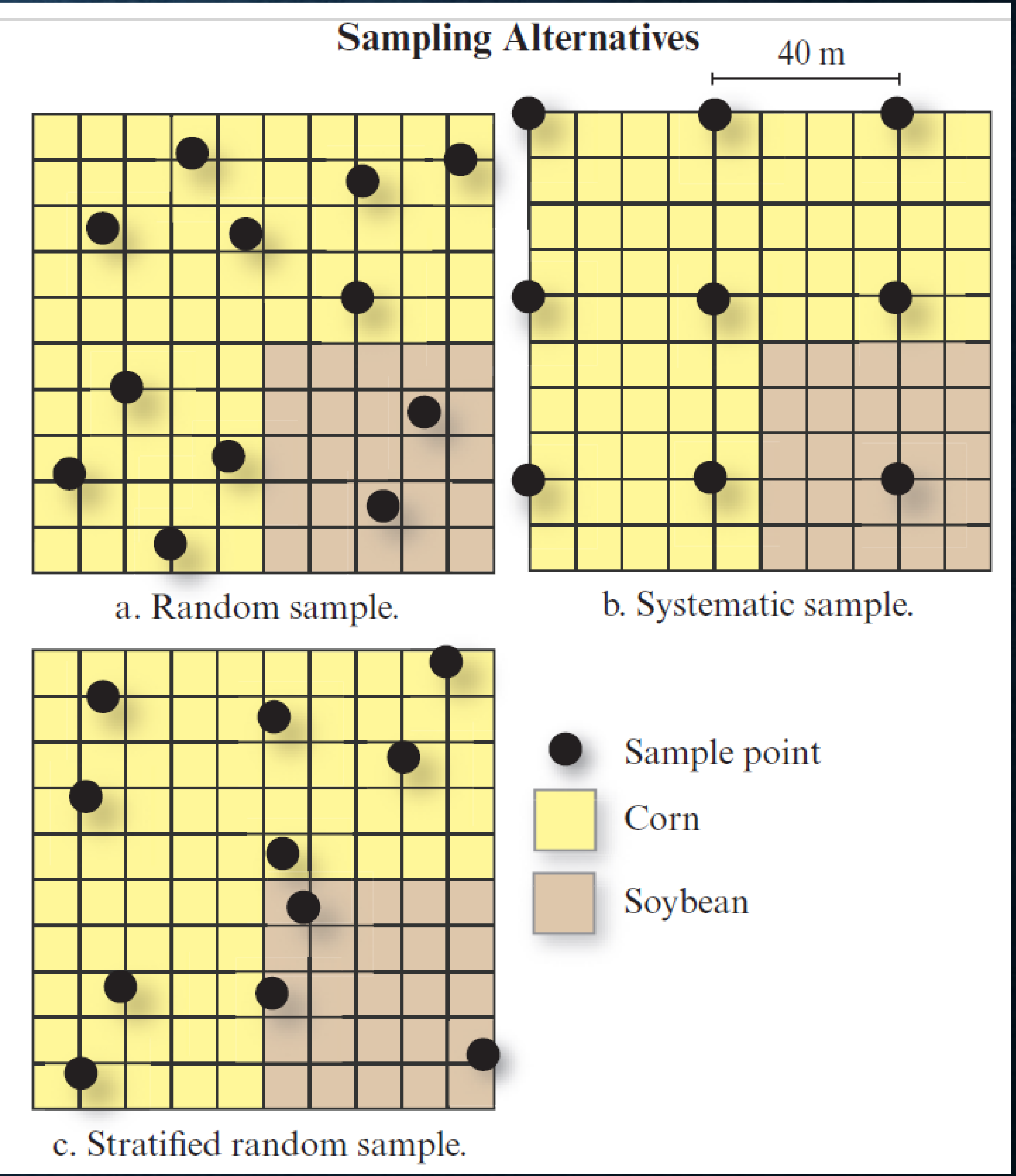




Source: John R. Jesen, 2015, 4th Ed

Sampling Alternatives

Hypothetical remote sensing–derived thematic map consisting of 100 pixels with 75% classified as corn and 25% classified as soybean



Source: John R. Jesen, 2015, 4th Ed

Accuracy Assessment from Stratified Random Sampling

- Stratified random sample-based error matrix associated with the land cover classification map derived from Landsat Thematic Mapper data

- The map has five classes and 407 ground reference samples were collected.

Source: John R. Jesen, 2015, 4th Ed;

Accuracy Assessment from Stratified Random Sampling

		Ground Reference Test Information Class 1 to *k* (*j* columns)					
		Residential	Commercial	Wetland	Forest	Water	Row total x_{i+}
Map Class 1 to *k* (*i* rows)	Residential	**70**	5	0	13	0	88
	Commercial	3	**55**	0	0	0	58
	Wetland	0	0	**99**	0	0	99
	Forest	0	0	4	**37**	0	41
	Water	0	0	0	0	**121**	121
	Column total x_{+j}	73	60	103	50	121	**407**

Overall Accuracy = 382/407 = 93.86%

Source: John R. Jesen, 2015, 4th Ed;

Accuracy Assessment from Stratified Random Sampling

Producer's Accuracy (omission error)			User's Accuracy (commission error)		
Residential = 70/73 =	96%	4% omission error	Residential = 70/88 =	80%	20% commission error
Commercial = 55/60 =	92%	8% omission error	Commercial = 55/58 =	95%	5% commission error
Wetland = 99/103 =	96%	4% omission error	Wetland = 99/99 =	100%	0% commission error
Forest = 37/50 =	74%	26% omission error	Forest = 37/41 =	90%	10% commission error
Water = 20/22 =	100%	0% omission error	Water = 121/121 =	100%	0% commission error

Computation of K_{hat} Coefficient of Agreement:

$$\hat{K} = \frac{N \sum_{i=1}^{k} x_{ii} - \sum_{i=1}^{k} (x_{i+} \times x_{+j})}{N^2 - \sum_{i=1}^{k} (x_{i+} \times x_{+j})}$$

where $N = 407$

$$\sum_{i=1}^{k} x_{ii} = (70 + 55 + 99 + 37 + 121) = 382$$

$$\sum_{i=1}^{k} (x_{i+} \times x_{+j}) = (88 \times 73) + (58 \times 60) + (99 \times 103) + (41 \times 50) + (121 \times 121) = 36{,}792$$

therefore $\hat{K} = \frac{407(382) - 36792}{407^2 - 36792} = \frac{155474 - 36792}{165649 - 36792} = \frac{118682}{128857} = 92.1\%$

Source: John R. Jesen, 2015, 4th Ed;

References:

Jensen, John R., 2015- Introductory digital image processing : a remote sensing perspective / John R. Jensen, University of South Carolina.
pages cm. -- (Pearson series in geographic information science) 4th ed.