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Image classification

Grundlagen Fernerkundung, Geo 123.1, FS 2014
Lecture 7b

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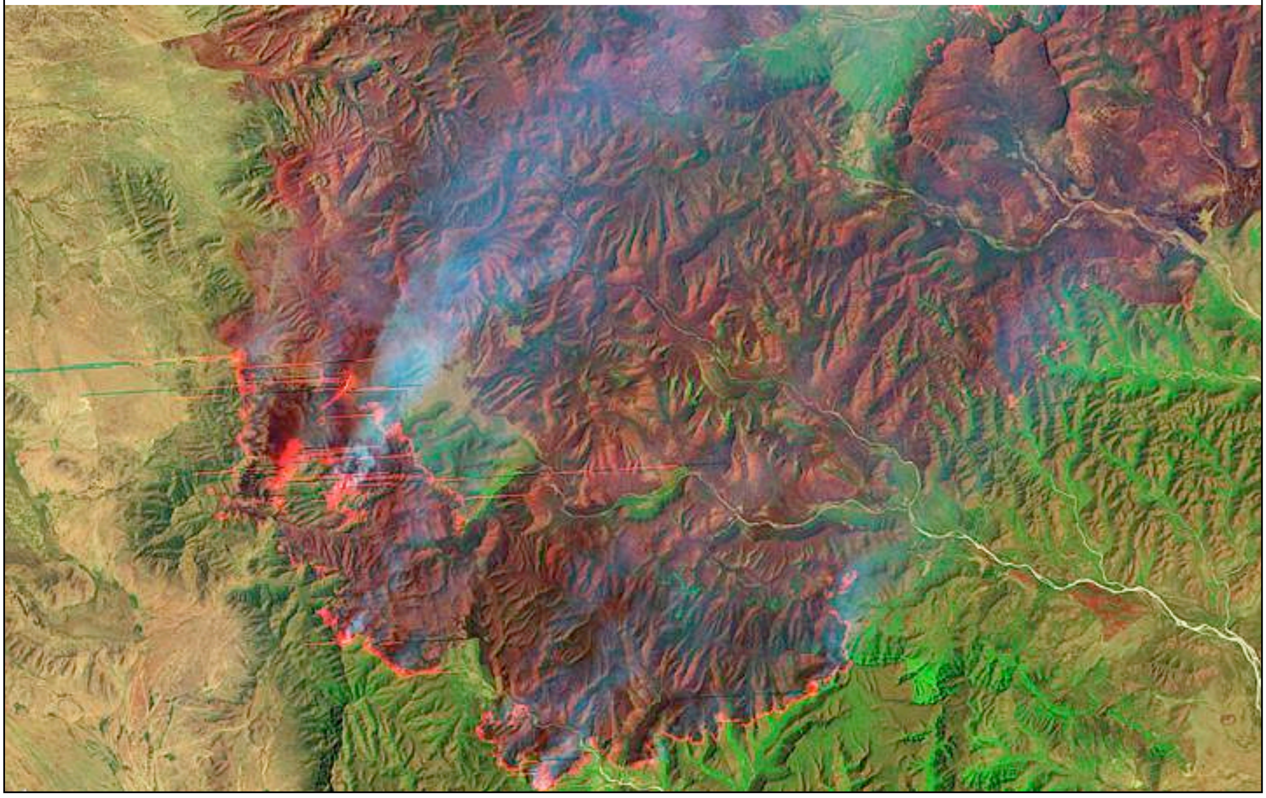

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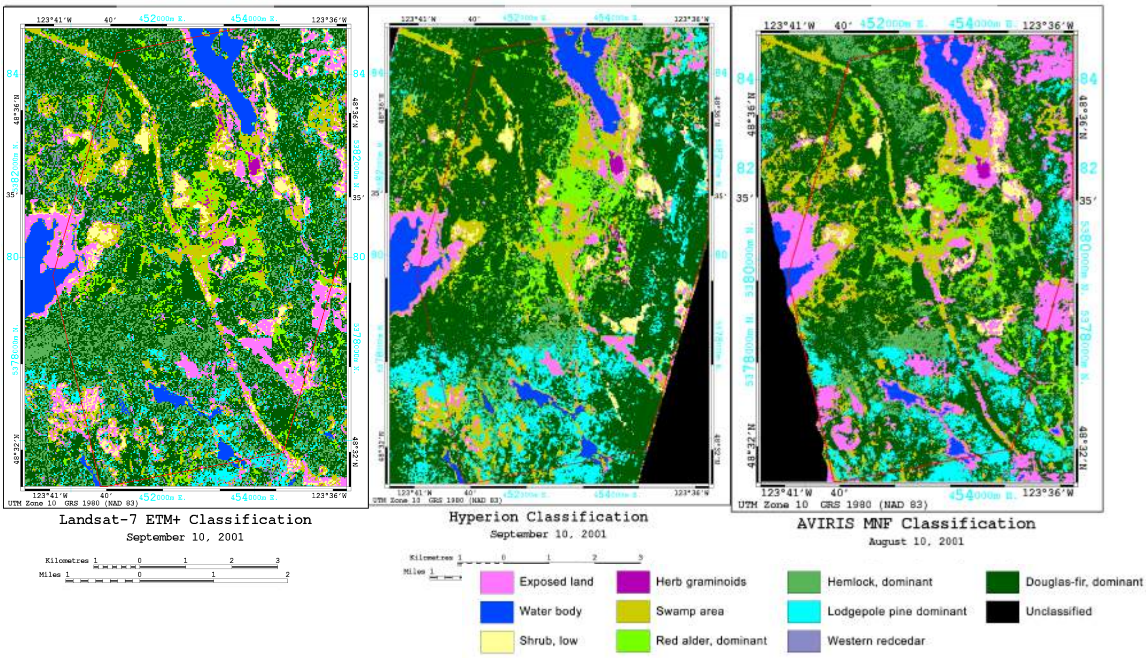
Landcover Classification Improvement

75.0% 90.0% 92.1%



Today's topics

- Feature space
- Classification algorithms and user supervision

- Error matrix
- Accuracy measures

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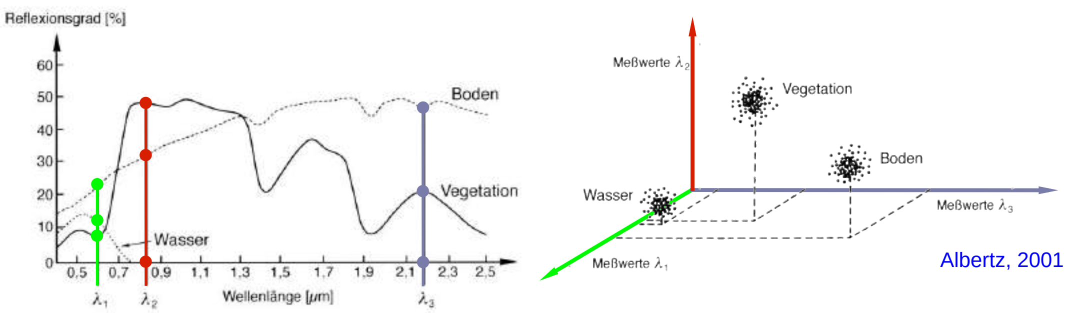
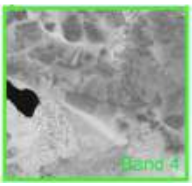
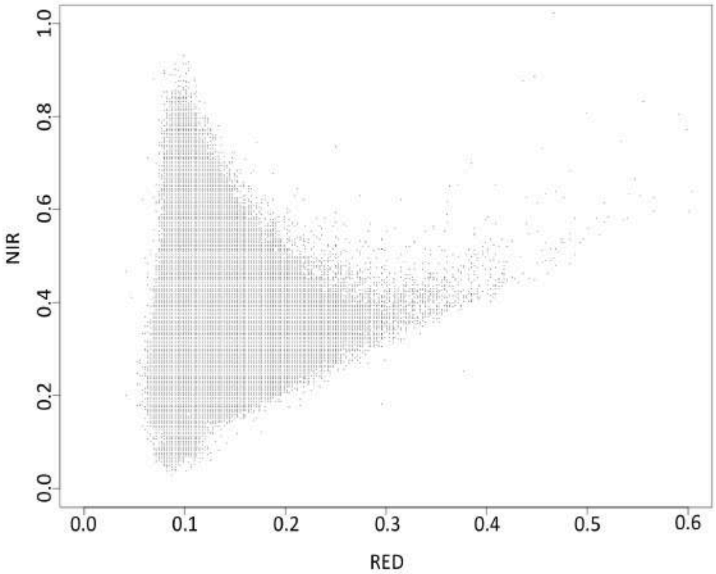
Feature Space (Eigenschaftsraum / Merkmalsraum)

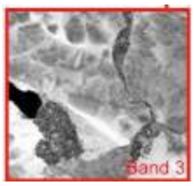


Albertz, 2001

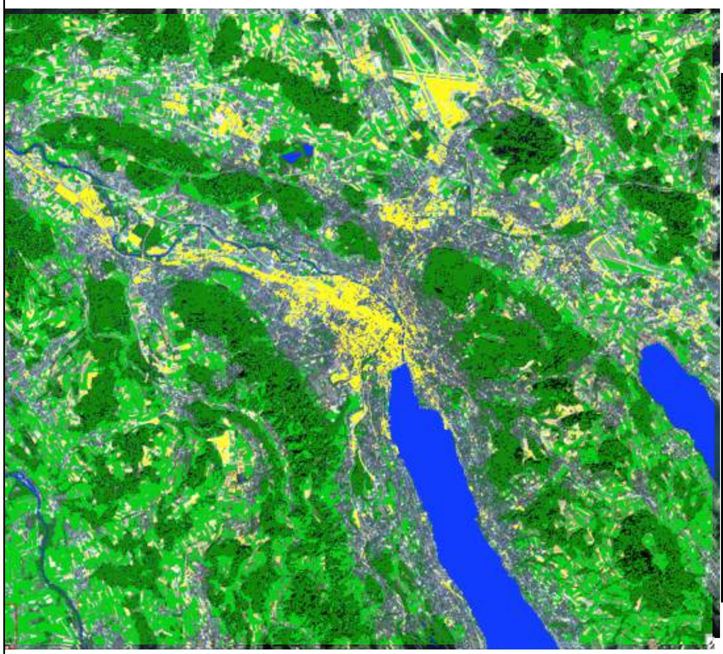
Feature space: NIR vs RED

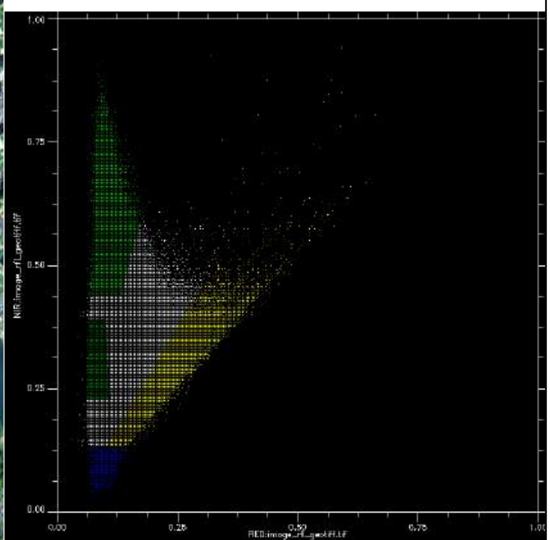






Feature space: NIR vs RED



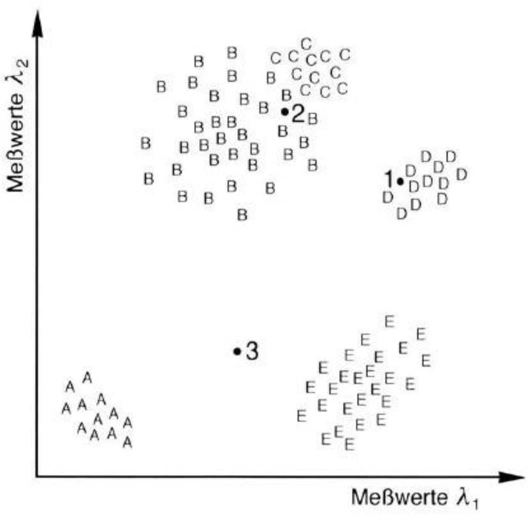


Statistical description of “spectral clusters”

- Histogram / distribution curve
- Min, Mean, Max values
- Standard deviations

Spectral clustering using the feature space

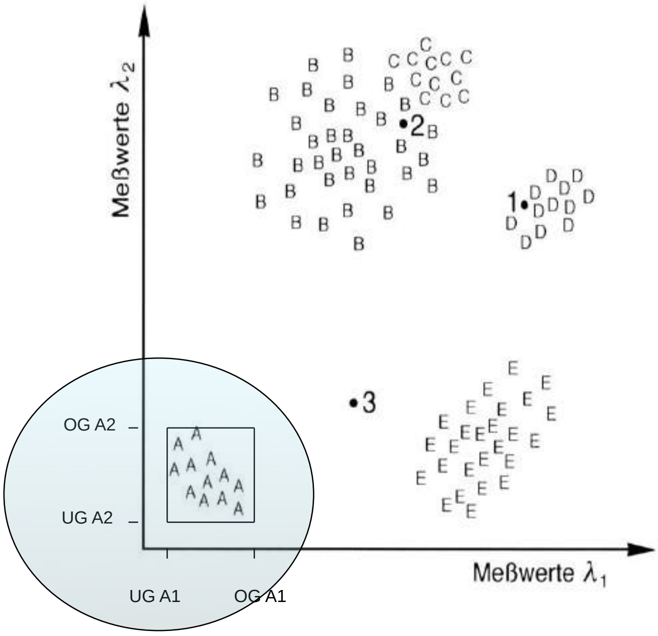
- Ground features are defined based on their spectral response
- Points 1-3 are unknown features that need to be assigned to A-E



λ = wavelength
Messwerte = reflectance

Method 1: Parallelepiped classification

OG = Obergrenze (upper limit)
UG = Untergrenze (lower limit)



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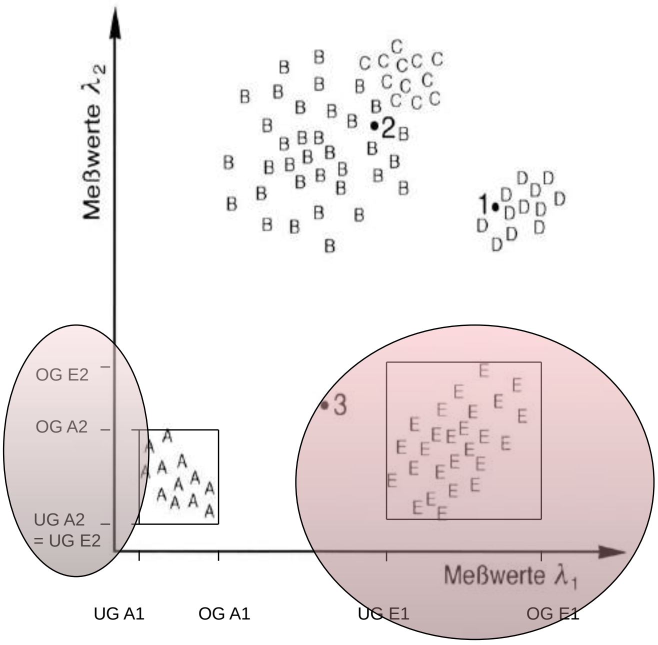
Method 1: Parallelepiped classification

OG = Obergrenze (upper limit)
UG = Untergrenze (lower limit)



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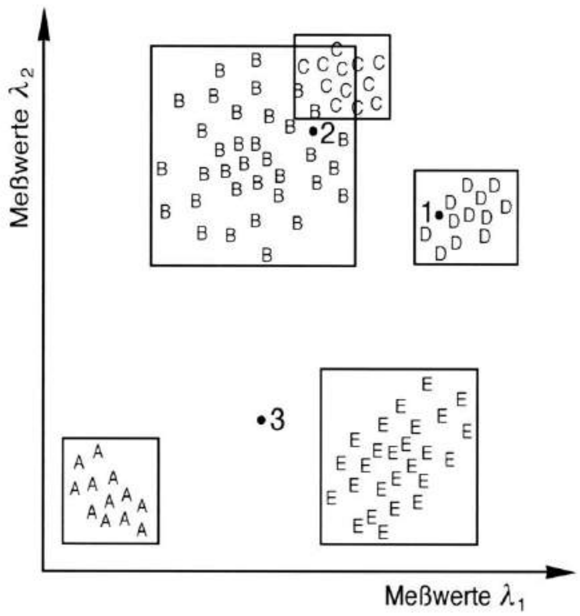
Method 1: Parallelepiped classification



- Features B and C cannot be distinguished. You'll need to try other spectral channels for this purpose.
- Point 2 is therefore the most uncertain but with only this information classified as B

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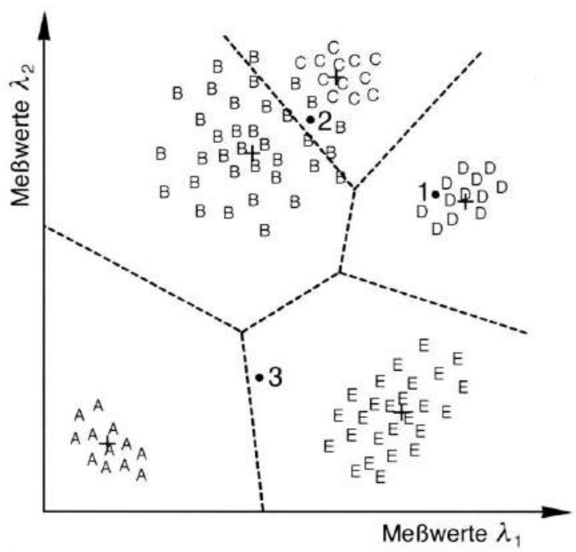
Method 2: Minimum-distance classification

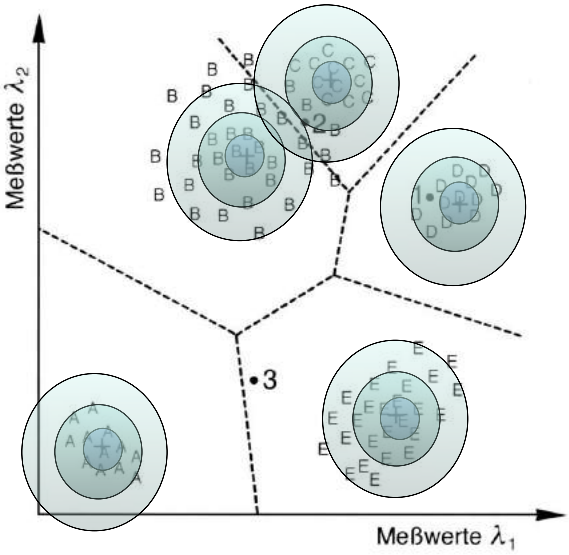
- Criterium: smallest Euclidean distance to the mean value of the class (+)
- Boundaries are perpendiculars ("Mittelsenkrechte")



λ = wavelength
Messwerte = reflectance

Method 2: Minimum-distance classification

- Without a “max-distance threshold”, point 3 changed from unclassified to E
- Point 2 has changed from B to C
- Less overlap between class B and C but more misclassifications of Bs as Cs?



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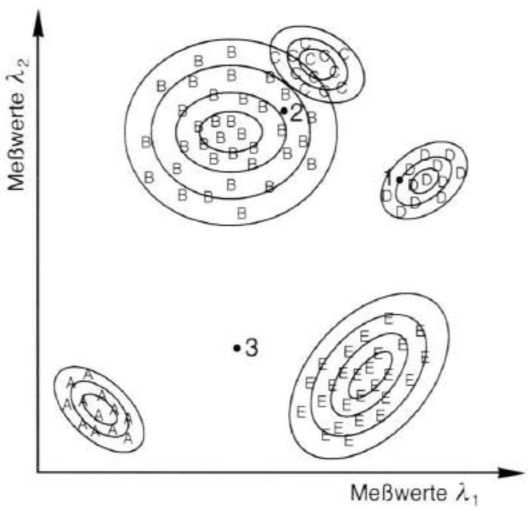
Method 3: Maximum-likelihood classification

- Criterium: maximum likelihood (“Mutmasslichkeit”) according to a probability-density function (“Wahrscheinlichkeits-dichte-Funktion”)
- Boundaries: number of standard deviations (sigma)



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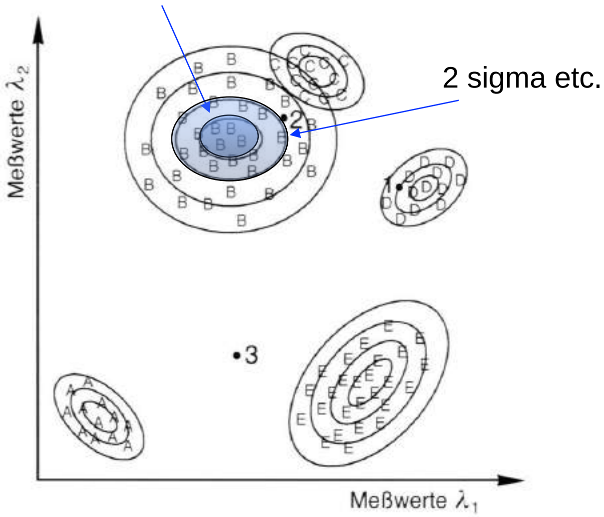
Method 3: Maximum-likelihood classification

- Point 3: more than x sigma distance and thus unclassified
- Point 2: class B with 2 sigma distance



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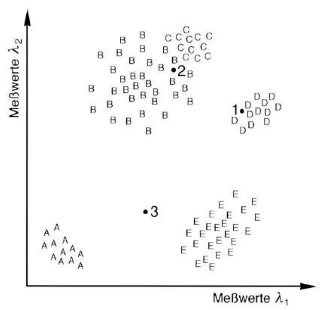
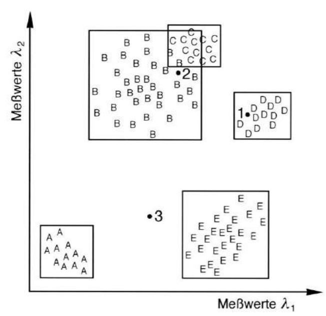
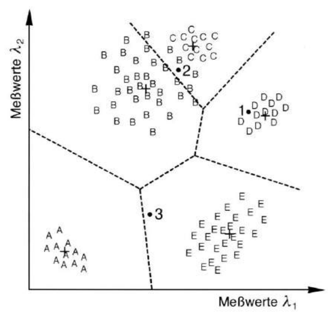
Common classification algorithms: overview



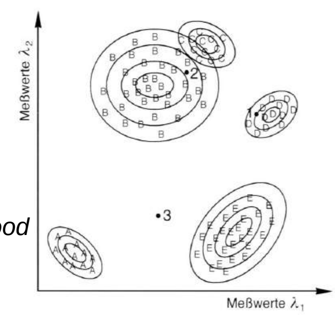
Parallelepiped



Minimum Distanz



Maximum Likelihood



User supervision (“Überwachung”)

Unsupervised classification

- The user does not provide information with respect to the classes
- Classes are defined based on statistical properties
- Given the same dataset and same method, each user obtains the identical result

Supervised classification

- The user defines training classes to which unclassified pixels are being compared
- The result depends on the definition of the training classes and is therefore likely to change between users

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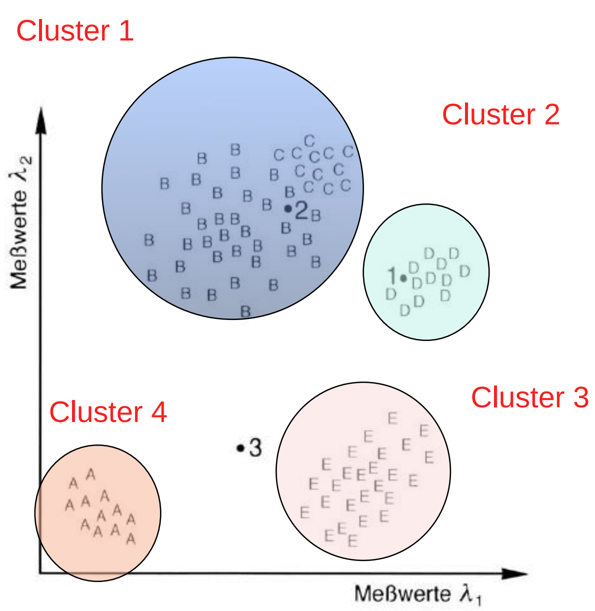
Method 4: Unsupervised clustering

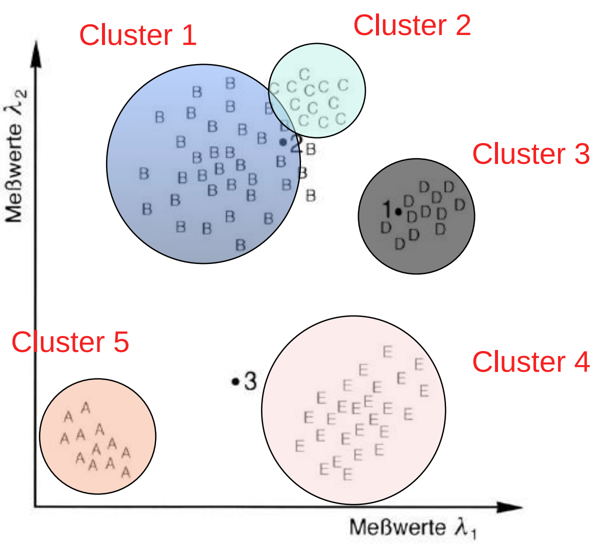
- Option 1:
  no a-priori information at all, (number of) clusters are estimated from statistics



Method 4: Unsupervised clustering

- Option 2:
  the user defines (only) the number of classes, i.e. 5

- After classification (option 1 or 2), clusters may be assigned to features of interest based on user knowledge



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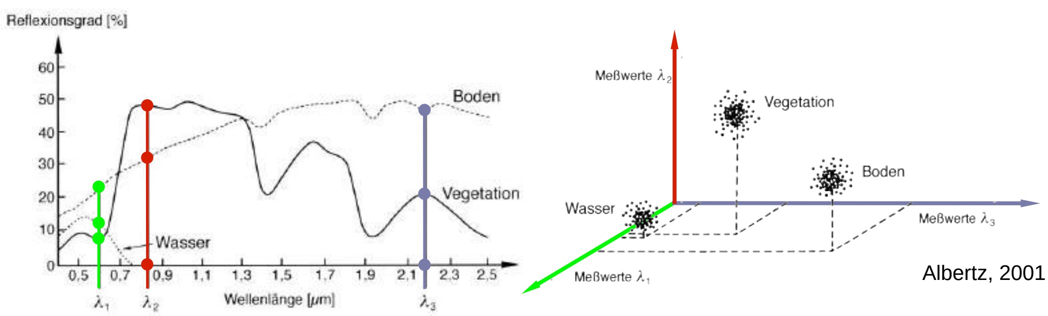
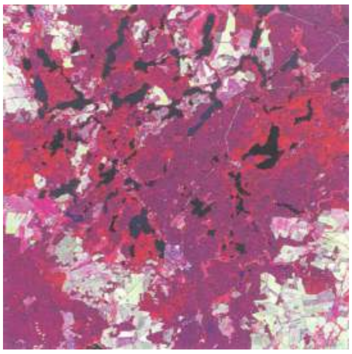
Classification methods



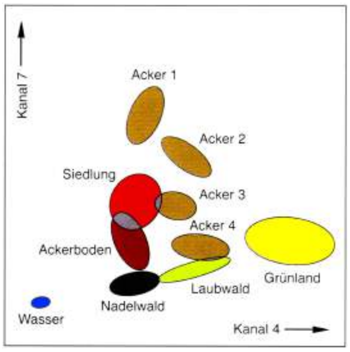
Albertz, 2001

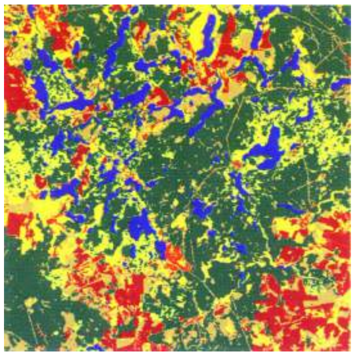
Unsupervised classification	Supervised classification
Clustering, (Segmentation) . . .	Parallelepiped, Minimum distance, Maximum likelihood . . .

How accurate is your classification?



Landsat *Thematic Mapper*, K 2,4,7





- Looks good!
- Seems plausible!
- Is that enough though?

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A classification is not complete until it has been assessed.

(R.G. CONGALTON 1991:35)

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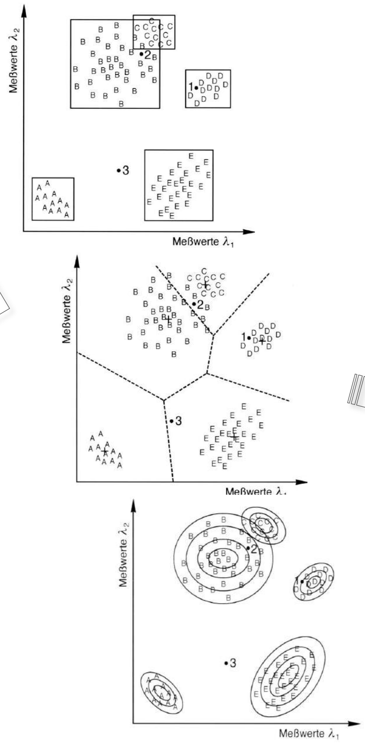

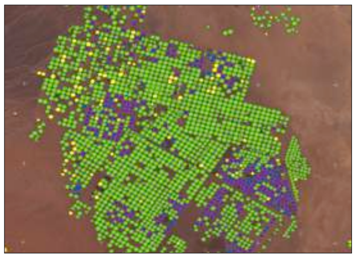

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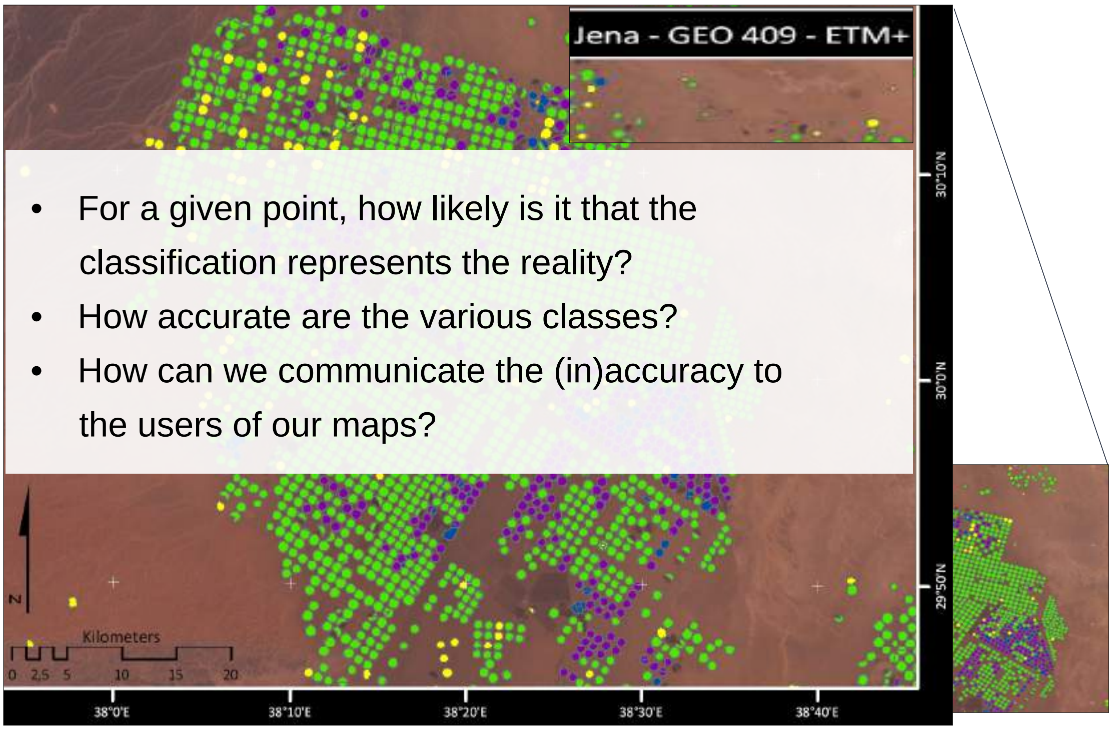


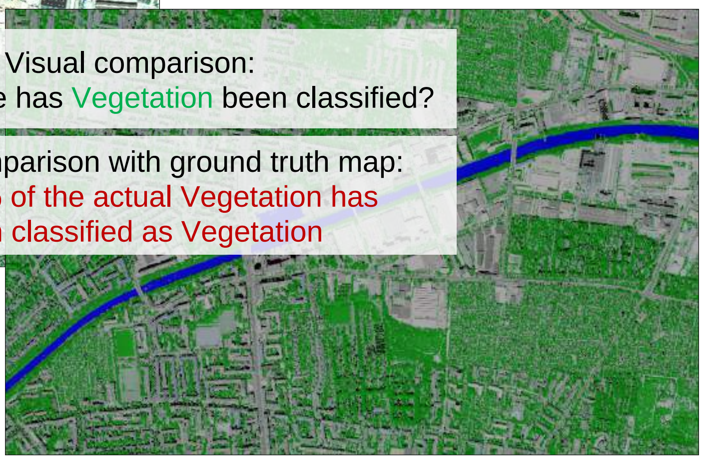
- For a given point, how likely is it that the classification represents the reality?
- How accurate are the various classes?
- How can we communicate the (in)accuracy to the users of our maps?

Options for accurcay assessment

Vergleich mit Bild (visuell)	-> sehr unzuverlässig, **nicht-quantitativ**
Vergleich mit Karte (visuell)	-> unzuverlässig, **nicht-quantitativ**
Vergleich mit *ground truth* (visuell)	-> bedingt abschätzbar, **nicht-quantitativ**
Vergleich mit *ground truth* (digital)	-> zuverlässig, häufig angewendet, **quantitativ**
Unabhängige Verwendung von *ground truth* für Training des Klassifikators und Validierung (digital)	-> zuverlässig, häufig angewendet, **quantitativ**
Vergleich mit unabhängiger/ statistisch basierter Referenz (digital)	-> „*best practice*“, sehr zuverlässig, **quantitativ**

Accuracy assessment

Aerial image – HRSC-AX

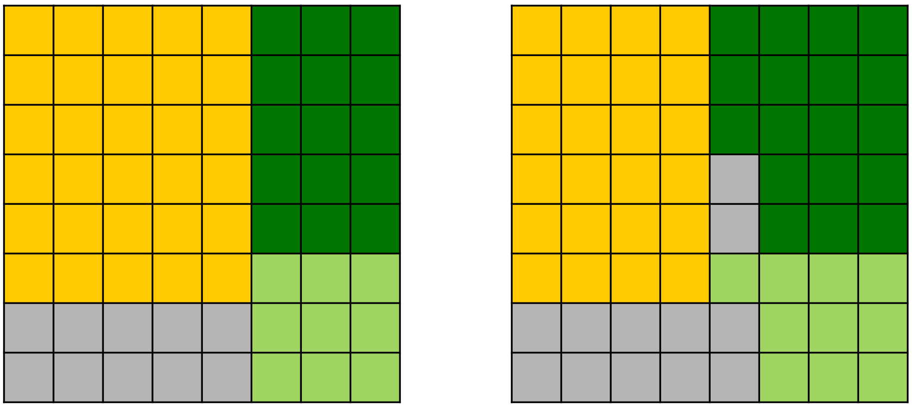


Classes:
Water, Vegetation, Bare / built-up

Error matrix („Fehlermatrix“)

(synonym: confusion matrix, matching matrix, contingency table)

Classification | **Reference / ground truth**



Forest
Arable
Other vegetation
Bare / built-up

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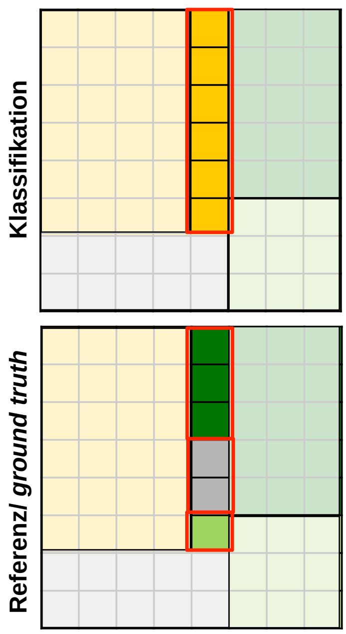
Error matrix

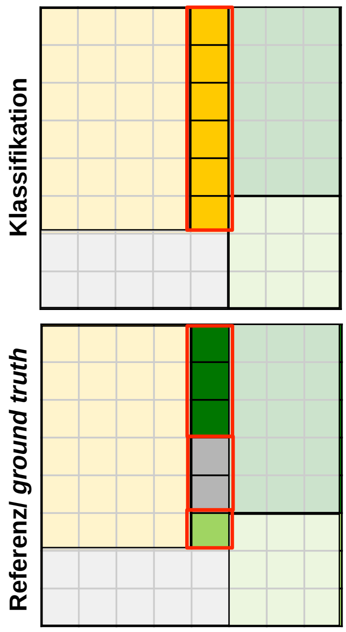


Referenz/ *ground truth* (columns) / **Klassifikation** (rows)

	A	B	C	D	Σ
A	15	0	0	0	15
B	0	9	0	0	
C	3	1	24	2	
D	0	0	0	10	
Σ	18				

Forest
Arable
Other vegetation
Bare / built-up

Error matrix



Referenz/ *ground truth*

Klassifikation	A	B	C	D	Σ
A	15	0	0	0	15
B	0	9	0	0	9
C	3	1	24	2	30
D	0	0	0	10	10
Σ	18	10	24	12	64

Forest
Arable
Other vegetation
Bare / built-up

Error matrix

Referenz/ *ground truth*

Klassifikation	A	B	C	D	Σ
A	n_{AA}	$\cancel{n_{AB}}$	$\cancel{n_{AC}}$	$\cancel{n_{AD}}$	n_{A+}
B	$\cancel{n_{BA}}$	n_{BB}	$\cancel{n_{BC}}$	$\cancel{n_{BD}}$	n_{B+}
C	$\cancel{n_{CA}}$	$\cancel{n_{CB}}$	n_{CC}	$\cancel{n_{CD}}$	n_{C+}
D	$\cancel{n_{DA}}$	$\cancel{n_{DB}}$	$\cancel{n_{DC}}$	n_{DD}	n_{D+}
Σ	n_{+A}	n_{+B}	n_{+C}	n_{+D}	n_{++}

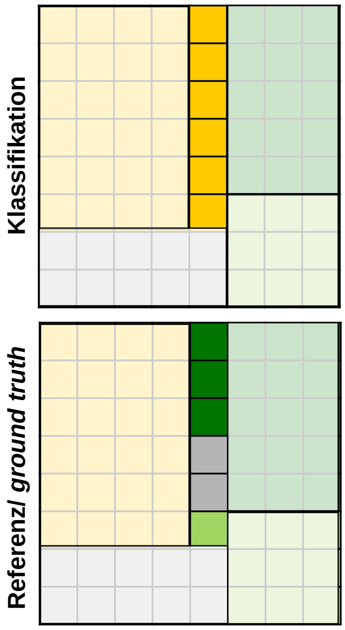
N_{A+} Number of pixels *classified* as A
N_{+A} Number of pixels found to be A in *reference*

Correctly classified
(classification == reference)

Incorrectly classified
(classification ≠ reference)

Grand total (total pixel count)

Error matrix



Klassifikation	Referenz/ *ground truth* A	B	C	D	Σ
A	15	0	0	0	15
B	0	9	0	0	9
C	3	1	24	2	30
D	0	0	0	10	10
Σ	18	10	24	12	64

Correctly classified classification == reference

Incorrectly classified classification ≠ reference

Forest
Arable
Other vegetation
Bare / built-up

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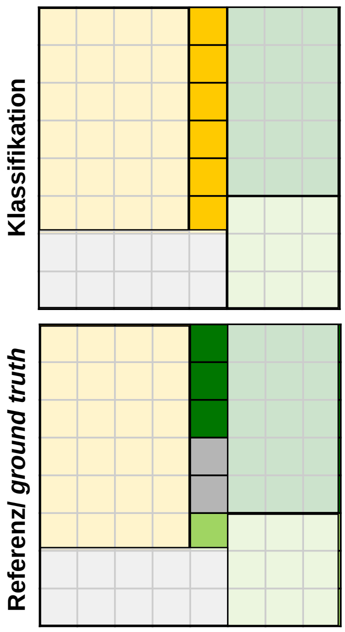
Type 1 (commission) and type 2 (omission) error



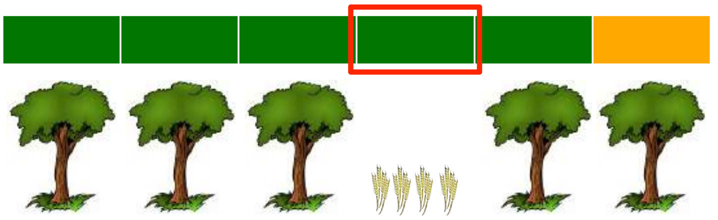
Klassifikation	Referenz/ *ground truth* A	B	C	D	Σ
A	15	0	0	0	15
B	0	9	0	0	9
C	3	1	24	2	30
D	0	0	0	10	10
Σ	18	10	24	12	64

Incorrectly classified classification ≠ reference

- Type 1:
  Commission Error
  Pixels were included in the class, although they should not have been
- Type 2:
  Omission Error
  Pixels were not included in the class, although they should have been

Type 1 (commission) and type 2 (omission) error

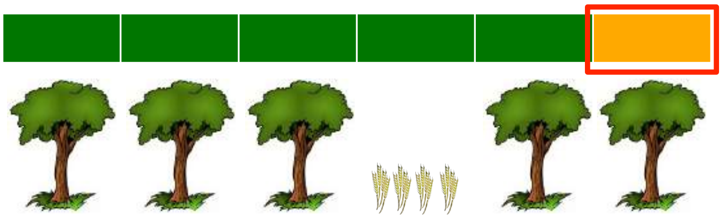
Type 1 (commission error) – example for class **Forest**



Klassifikation

Referenz/ *ground truth*

Type 2 (ommission error) – example for class **Forest**



Klassifikation

Referenz/ *ground truth*

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Accuracy metrics (or: error metrics)

Referenz/ *ground truth*

Klassifikation

	A	B	C	D	Σ
A	n_{AA}	X $\cancel{n_{AB}}$	X $\cancel{n_{AC}}$	X $\cancel{n_{AD}}$	n_{A+}
B	X $\cancel{n_{BA}}$	n_{BB}	X $\cancel{n_{BC}}$	X $\cancel{n_{BD}}$	n_{B+}
C	X $\cancel{n_{CA}}$	X $\cancel{n_{CB}}$	n_{CC}	X $\cancel{n_{CD}}$	n_{C+}
D	X $\cancel{n_{DA}}$	X $\cancel{n_{DB}}$	X $\cancel{n_{DC}}$	n_{DD}	n_{D+}
Σ	n_{+A}	n_{+B}	n_{+C}	n_{+D}	n_{++}

N_{A+} Number of pixels *classified* as A
N_{+A} Number of pixels found to be A in *reference*

Correctly classified
(classification == reference)

Incorrectly classified
(classification ≠ reference)

Grand total (total pixel count)

Accuracy **metrics**: measures for classification accuracy based on the error **matrix**

Accuracy metrics

English	*Deutsch*
Overall Accuracy	**Gesamtgenauigkeit**
Producer Accuracy	**Produzenten-Genauigkeit**
User Accuracy	**Nutzer-Genauigkeit**
Average Accuracy	durchschnittliche Genauigkeit
Mean Accuracy	mittlere Genauigkeit
Kappa Coefficient	Kappa Koeffizient

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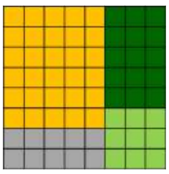
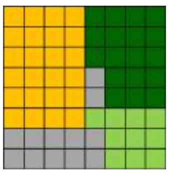
Overall/ Total Accuracy (OA)



Klassifikation



Referenz

Referenz/ *ground truth* (columns); Klassifikation (rows)

	A	B	C	D	Σ
A	**15**	**0**	**0**	**0**	**15**
B	**0**	**9**	**0**	**0**	**9**
C	**3**	**1**	**24**	**2**	**30**
D	**0**	**0**	**0**	**10**	**10**
Σ	**18**	**10**	**24**	**12**	**64**

$$\text{Overall Accuracy} = \frac{\text{Count of correctly classified pixels}}{\text{Grand total (total pixel count)}} = \frac{58}{64} = 0.90625$$

(~90.6%)

Genauigkeitsmasse – Overall/ Total Accuracy (OA)

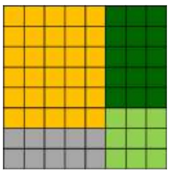
Die **Overall Accuracy** ist ein einfaches Genauigkeitsmass,
aber **wenig aussagekräftig**!

Fehler 1. Art (Commission) und **Fehler 2. Art** (Omission)
werden **nicht berücksichtigt**!

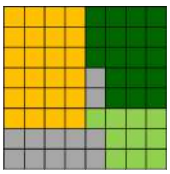
$$\text{Overall Accuracy} = \frac{\text{die Summe der richtig klassifizierten Pixel}}{\text{Gesamtanzahl aller Pixel/ Grundgesamtheit}} = \frac{58}{64} = 0.90625$$

(~90.63%)

Producer‘s Accuracy (PA)



Klassifikation



Referenz

Referenz/ *ground truth* (columns); Klassifikation (rows)

	A	B	C	D	Σ
A	**15**	**0**	**0**	**0**	**15**
B	**0**	**9**	**0**	**0**	**9**
C	**3**	**1**	**24**	**2**	**30**
D	**0**	**0**	**0**	**10**	**10**
Σ	**18**	**10**	**24**	**12**	**64**
PA	83.33	90	100	83.33	

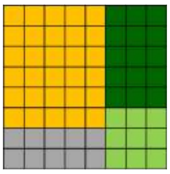
The **producer** needs to know how well her/his classification (e.g. for **class A**) matches with the reference

== Omission Error
How many pixels should have been in the class but were not

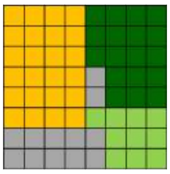
$$\text{Producer‘s Accuracy} = \frac{\text{count of correctly classified pixels in class}}{\text{count of pixels in same reference class}} = \frac{15}{18} = 0.8333$$

(~83.3%)

User's Accuracy (UA)



Klassifikation



Referenz

Referenz/ *ground truth* (columns) – Klassifikation (rows)

	A	B	C	D	Σ	UA
A	15	0	0	0	15	100
B	0	9	0	0	9	100
C	3	1	24	2	30	80
D	0	0	0	10	10	100
Σ	18	10	24	12	64	

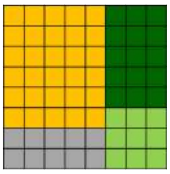
The **user** needs to know how well a class (e.g. **A**) matches with the reality

== Commission Error
How many pixels are in the class but should not have been

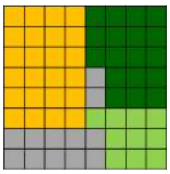
$$\text{User's Accuracy} = \frac{\text{count of correctly classified pixels in class}}{\text{count of all pixels in that class}} = \frac{15}{15} = 1$$

(100%)

Accuracy metrics – OA, PA, UA



Klassifikation



Referenz

Referenz/ *ground truth* (columns) – Klassifikation (rows)

	A	B	C	D	Σ	UA [%]
A	15	0	0	0	15	100
B	0	9	0	0	9	100
C	3	1	24	2	30	80
D	0	0	0	10	10	100
Σ	18	10	24	12	64	
PA [%]	83.33	90	100	83.33		

OA [%] 90.63

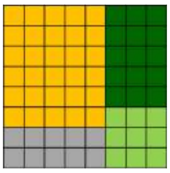
If I classified a pixel as forest (A), there is in 100% of the cases indeed forest at that location

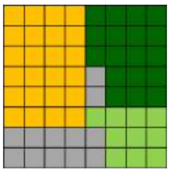
I have captured 100% of the existing arable land (C) with my classification

But: 20% of the classified arable land (C) pixels has another land cover in reality

But: 16.67% of the existing forest (A) was not captured

Accuracy metrics – OA, PA, UA


Klassifikation


Referenz

Klassifikation \ Referenz/ *ground truth*	A	B	C	D	Σ	UA [%]
A	15	0	0	0	15	100
B	0	9	0	0	9	100
C	3	1	24	2	30	80
D	0	0	0	10	10	100
Σ	18	10	24	12	64	
PA [%]	83.3	90	100	83.3		

OA [%] 90.63

90.63% of all classified pixels matches with the reference / reality

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Hands-on!

A	A	A	B	B
A	A	A	B	B
A	A	A	B	B
B	B	B	B	B

Klassifikation

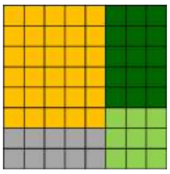
A	A	A	A	B
A	A	A	B	B
A	A	A	B	B
B	B	B	B	B

Referenz/ *ground truth*

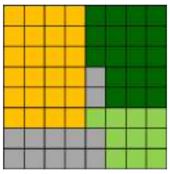
Klassifikation \ Referenz	A	B	Σ	UA [%]
A				
B				
Σ			20	
PA [%]				

OA [%]

Mean UA (or: average accuracy)



Klassifikation



Referenz

Referenz/ *ground truth*

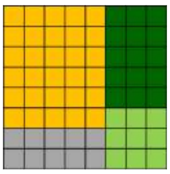
Klassifikation	A	B	C	D	Σ	UA [%]
A	15	0	0	0	15	100
B	0	9	0	0	9	100
C	3	1	24	2	30	80
D	0	0	0	10	10	100
Σ	18	10	24	12	64	
PA [%]	83.33	90	100	83.33		

Overall Accuracy
90.63 %

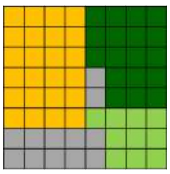
Mean UA
95.00 %

$$\text{Average Accuracy} = \frac{\text{sum of all user accuracies}}{\text{number of classes}} = \frac{380\%}{4} = 95\%$$

Mean classification accuracy



Klassifikation



Referenz

Referenz/ *ground truth*

Klassifikation	A	B	C	D	Σ	UA [%]
A	15	0	0	0	15	100
B	0	9	0	0	9	100
C	3	1	24	2	30	80
D	0	0	0	10	10	100
Σ	18	10	24	12	64	
PA [%]	83.33	90	100	83.33		

Overall Accuracy
90.63 %

Mean UA
95.00 %

Mean Accuracy
92.82 %

$$\text{Mean Accuracy} = \frac{\text{Overall Accuracy + Mean UA}}{2} = \frac{185.63}{2} = 92.82\%$$

Accuracy assessment – summary

Referenz (columns) / **Klassifikation** (rows)

	A	B	C	D	Σ
A	n_{AA}	n_{AB}	n_{AC}	n_{AD}	n_{A+}
B	n_{BA}	n_{BB}	n_{BC}	n_{BD}	n_{B+}
C	n_{CA}	n_{CB}	n_{CC}	n_{CD}	n_{C+}
D	n_{DA}	n_{DB}	n_{DC}	n_{DD}	n_{D+}
Σ	N_{+A}	N_{+B}	N_{+C}	N_{+D}	n

$$\textit{Overall Accuracy} = \frac{\sum_{i=1}^{q} n_{ii}}{n} \qquad PA = \frac{n_{ii}}{n_{+i}} \qquad UA = \frac{n_{ii}}{n_{i+}}$$

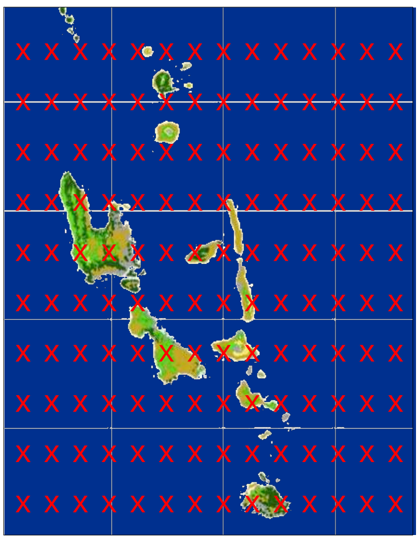
$$\textit{Mean UA Accuracy} = \frac{\sum_{i=1}^{q} UA}{n}$$

$$\textit{Mean Accuracy} = \frac{OA + \textit{Mean UA Accuracy}}{2}$$

q = *Anzahl an Klassen*
n = *Grundgesamtheit*
n_{ii} = *Anzahl übereinstimmender Pixel*
n_{i+} = *Summe der Zeilenwerte*
n_{+i} = *Summe der Spaltenwerte*

Accuracy metrics – applying them correctly

Accuracy metrics depend on the sampling scheme of the reference



OA = 95.6%

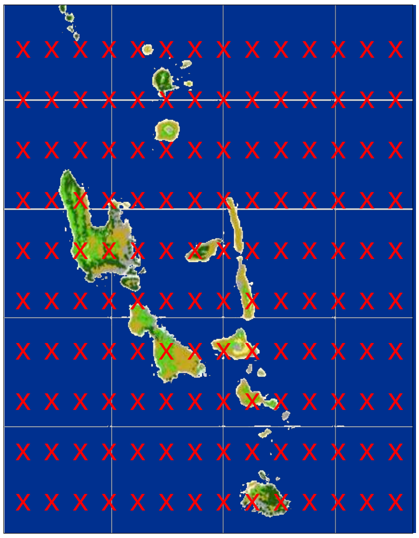
Forest (≥20%)
Forest (< 20%)
Grassland
Water

Referenz/ *ground truth* (columns) / **Klassifikation** (rows)

	A	B	C	D	Σ
A	2	1	0	0	3
B	2	3	1	0	6
C	0	2	5	0	7
D	0	0	0	124	124
Σ	4	6	6	124	140

Accuracy metrics – applying them correctly

Accuracy information depend on the choice of metric



OA = 95.6%

Mean user accuracy = 72.0%
Mean classification accuracy = 83.9%

	PA	UA
Forest (≥20%)	0.5	0.7
Forest (< 20%)	0.5	0.5
Grassland	0.8	0.7
Water	1.0	1.0

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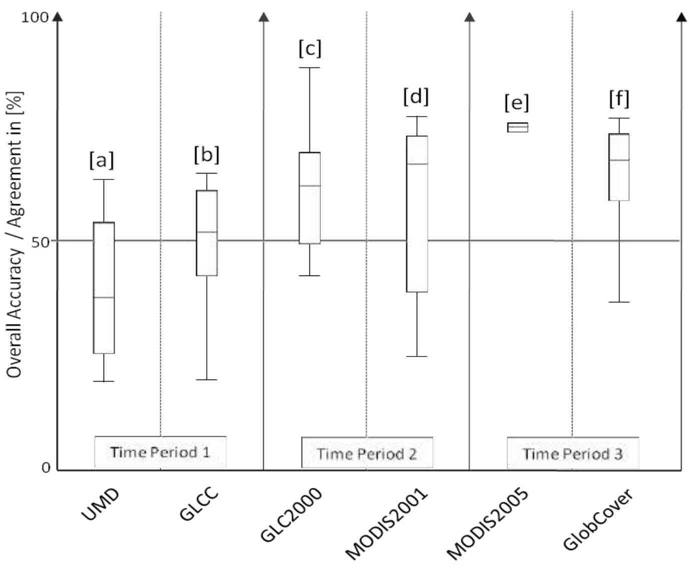
Accuracy metrics – applying them correctly

Accuracy information depend on the interpretation of the metric



Accuracy – Take-Home Messages

- "A classification is not complete until it has been assessed."
- You need multiple accuracy metrics to get a good representation of the actual accuracy; a single metric may lead to an incorrect assessment
- The reference dataset must be representative for the classification
- Be critical when you communicate your classification to your users

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Requirements regarding *these two lectures*

Image analysis

- Understand the concepts of (visualizing) spectral bands
- Understand simple band operations and what they can be used for
- Know various change-detection techniques (concepts, no tech. details)
- Be able to describe and recognize low-pass and high-pass filters

Classification

- Know different (types of) algorithms (characteristics, pros and cons), be able to describe them and to conceptually apply them
- Be able to describe and apply the various accuracy metrics

Text book (note: only relevant parts for lectures 7a, 7b listed)

- Section 7.1, 7.3, 7.4, 7.5 (excl. Fourier Analysis), 7.6 (Spectral Ratioing: full understanding, rest: read), 7.7, 7.8, 7.9, 7.10 (read), 7.11, 7.16, 7.17 (kappa/KHAT only conceptual understanding), 7.18 (only Change Detection Procedures)

Thank you!

Grundlagen Fernerkundung, Geo 123.1, FS 2014
Lecture 7b

Rogier de Jong
Michael Schaepman