Machine learning for remote sensing applications

Practice: Land cover classification

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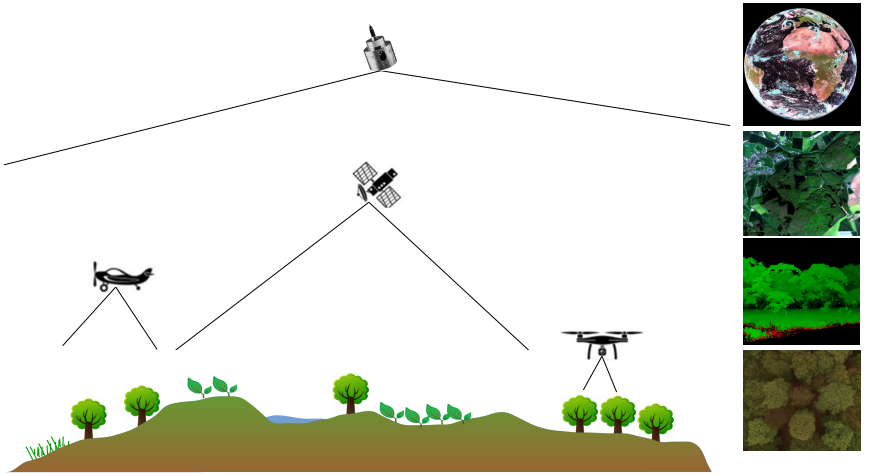
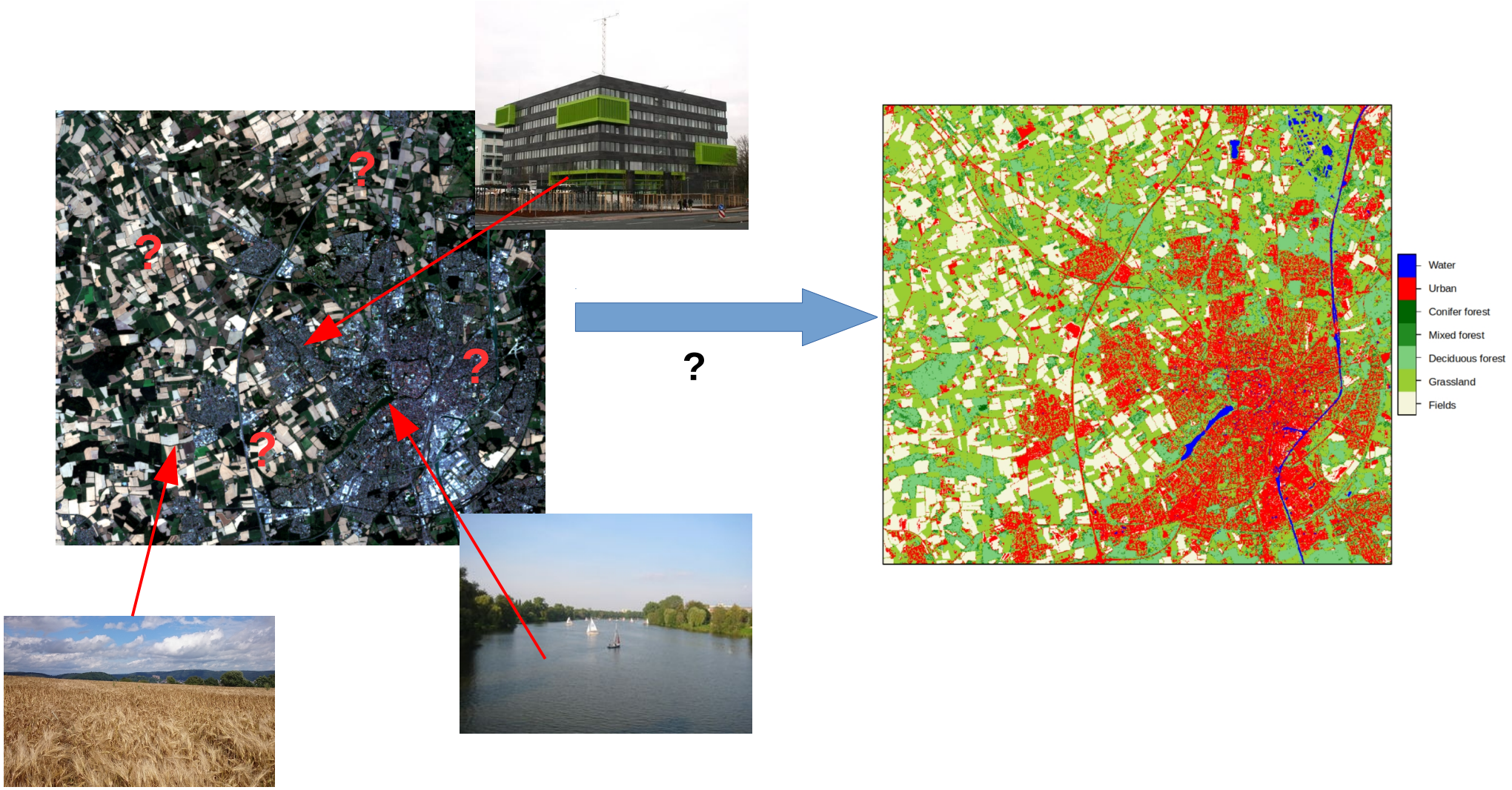
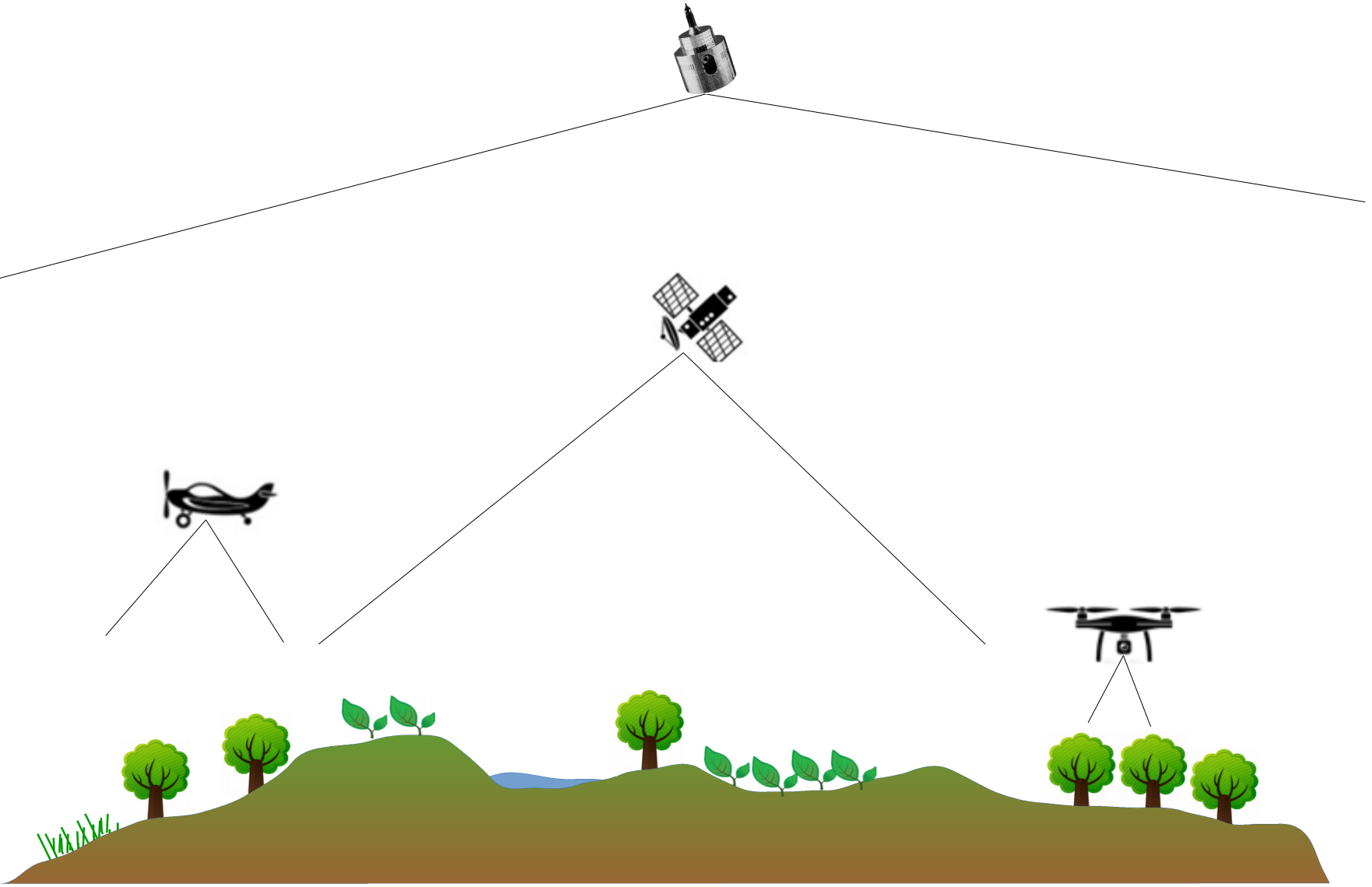


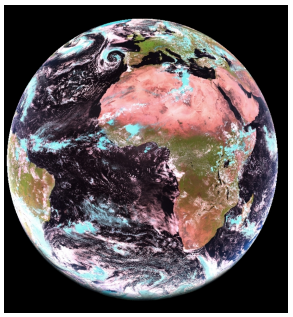
→ Slides and material: https://github.com/HannaMeyer/OpenGeoHub_2019

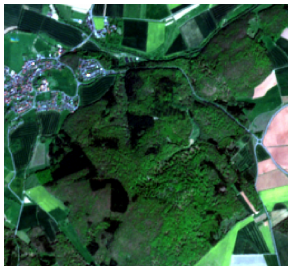
Problem: Moving from field observations to maps of environmental variables

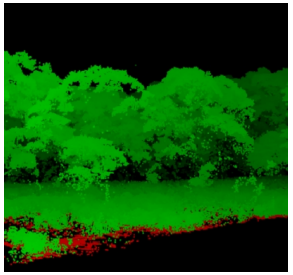


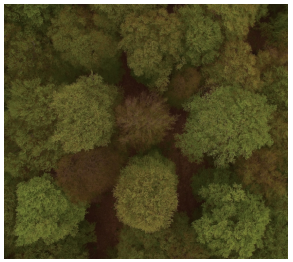
Remote sensing data



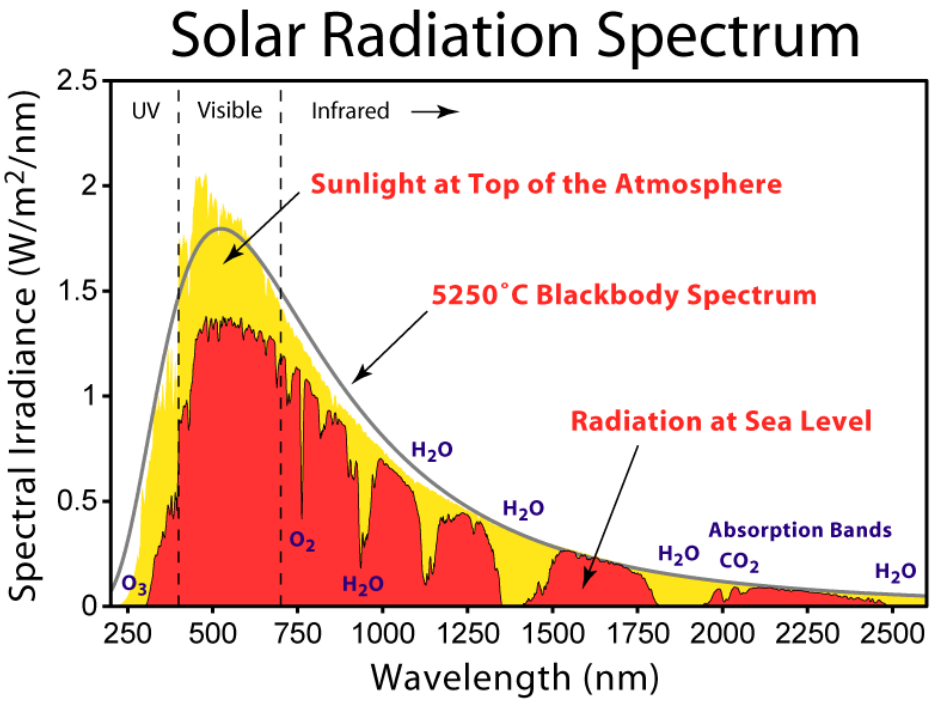




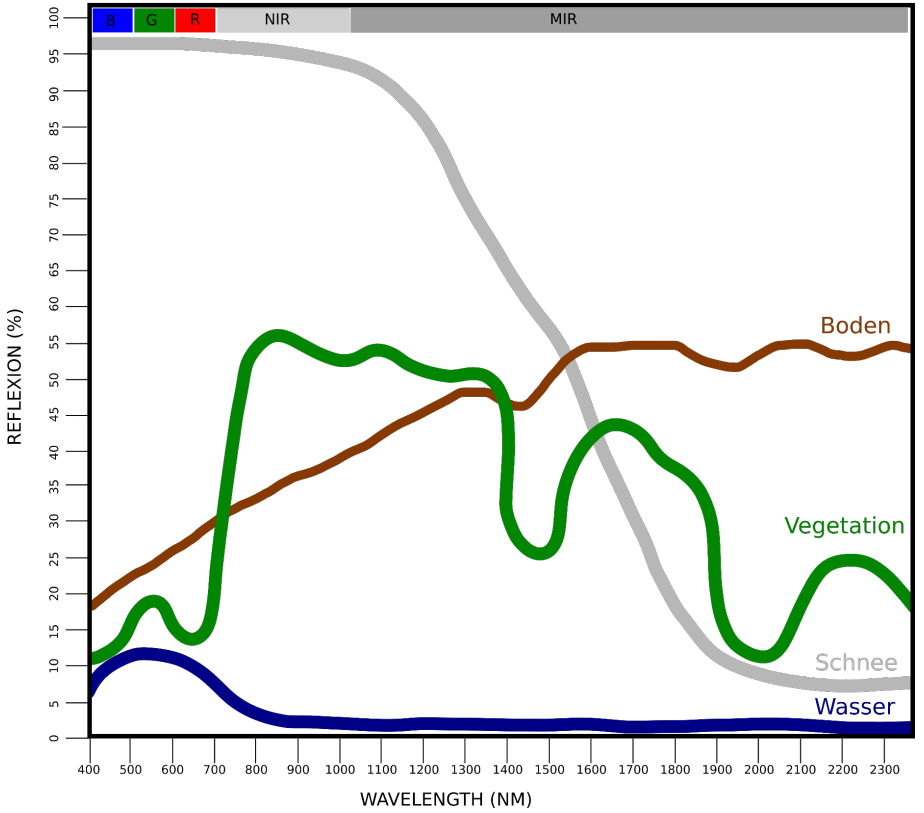




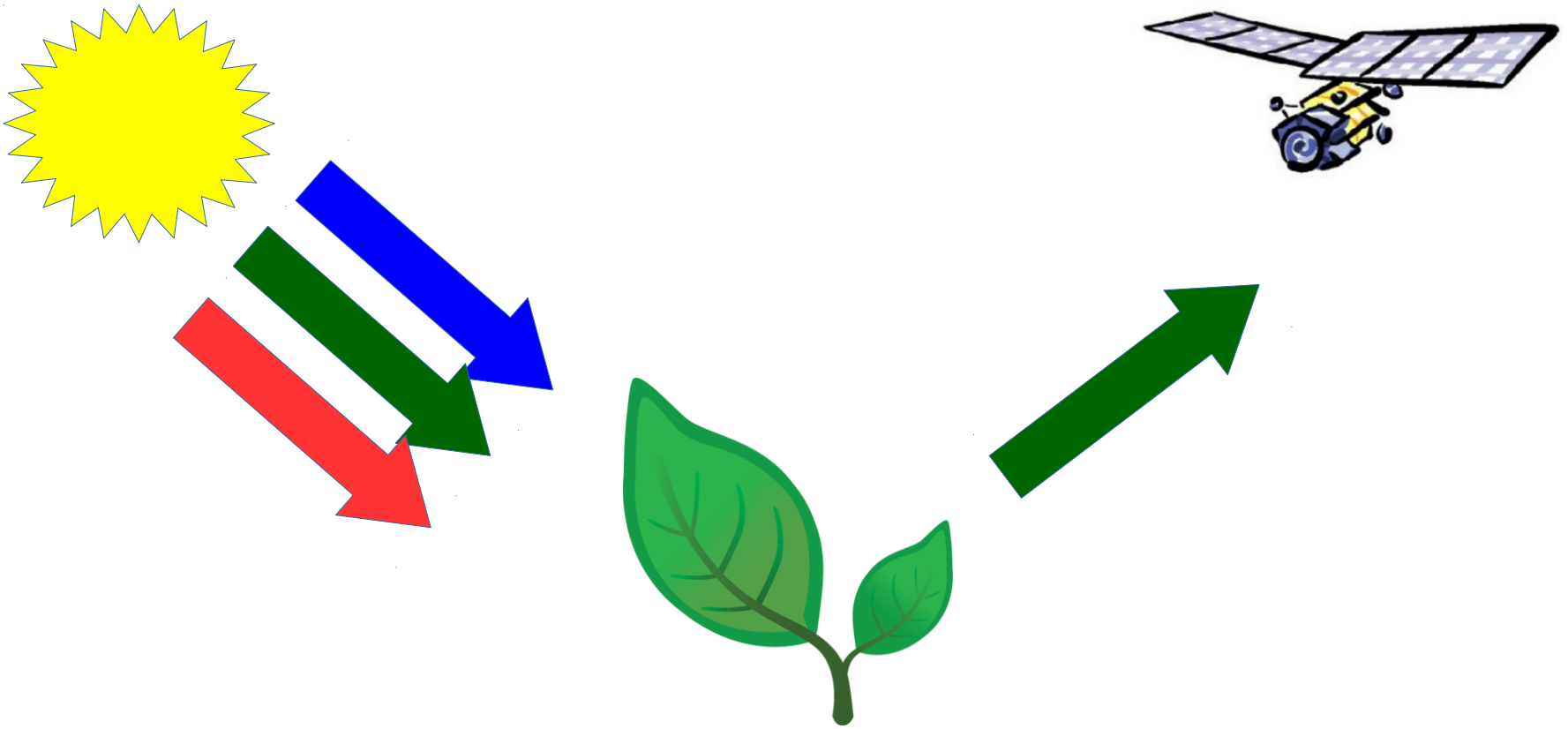
Solar radiation and reflection properties



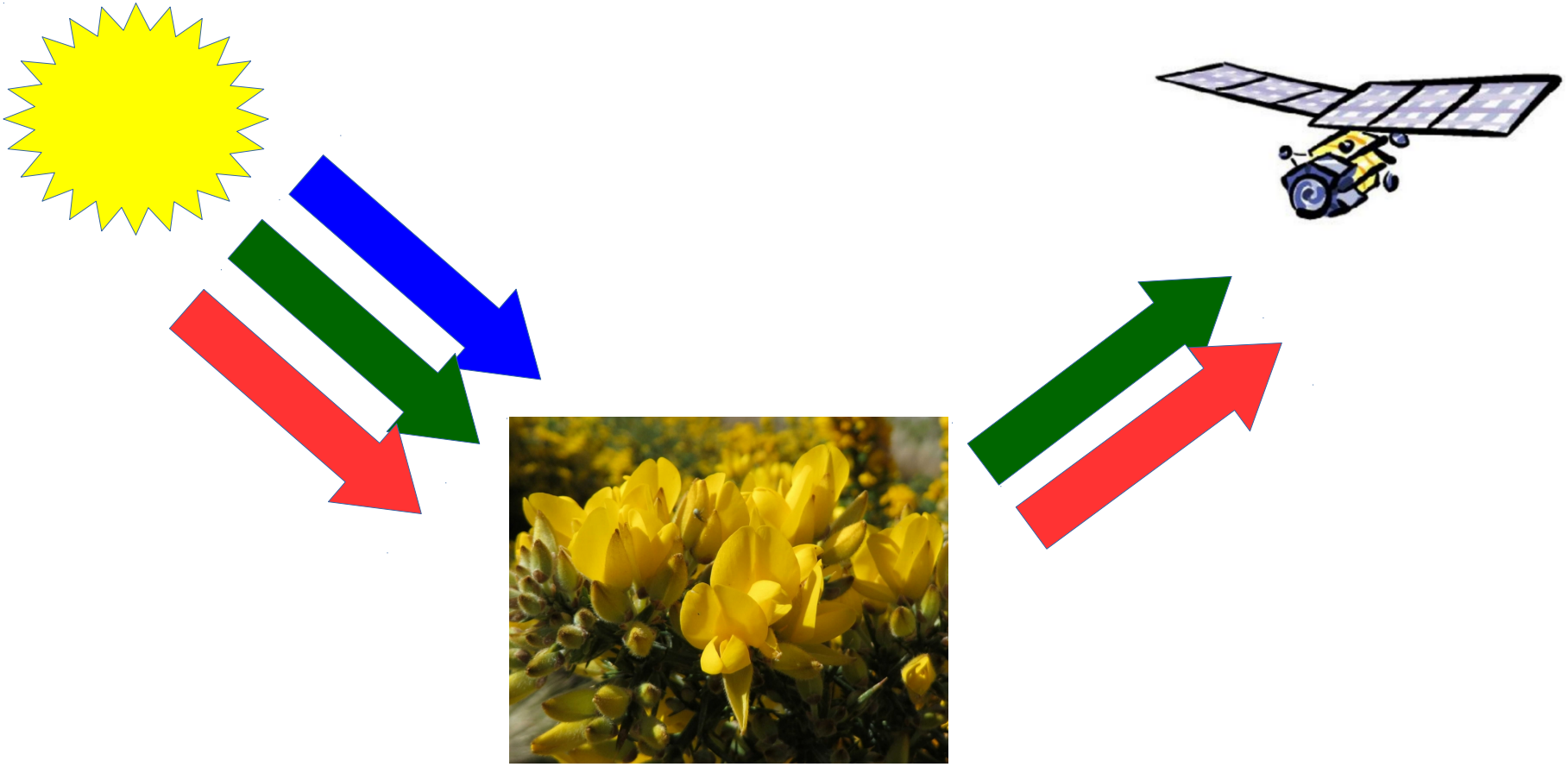
https://commons.wikimedia.org/wiki/File:Solar_Spectrum.png



Reflection properties



Reflection properties



How can we make use of the different reflectance properties to map land cover?

So let's get some satellite data

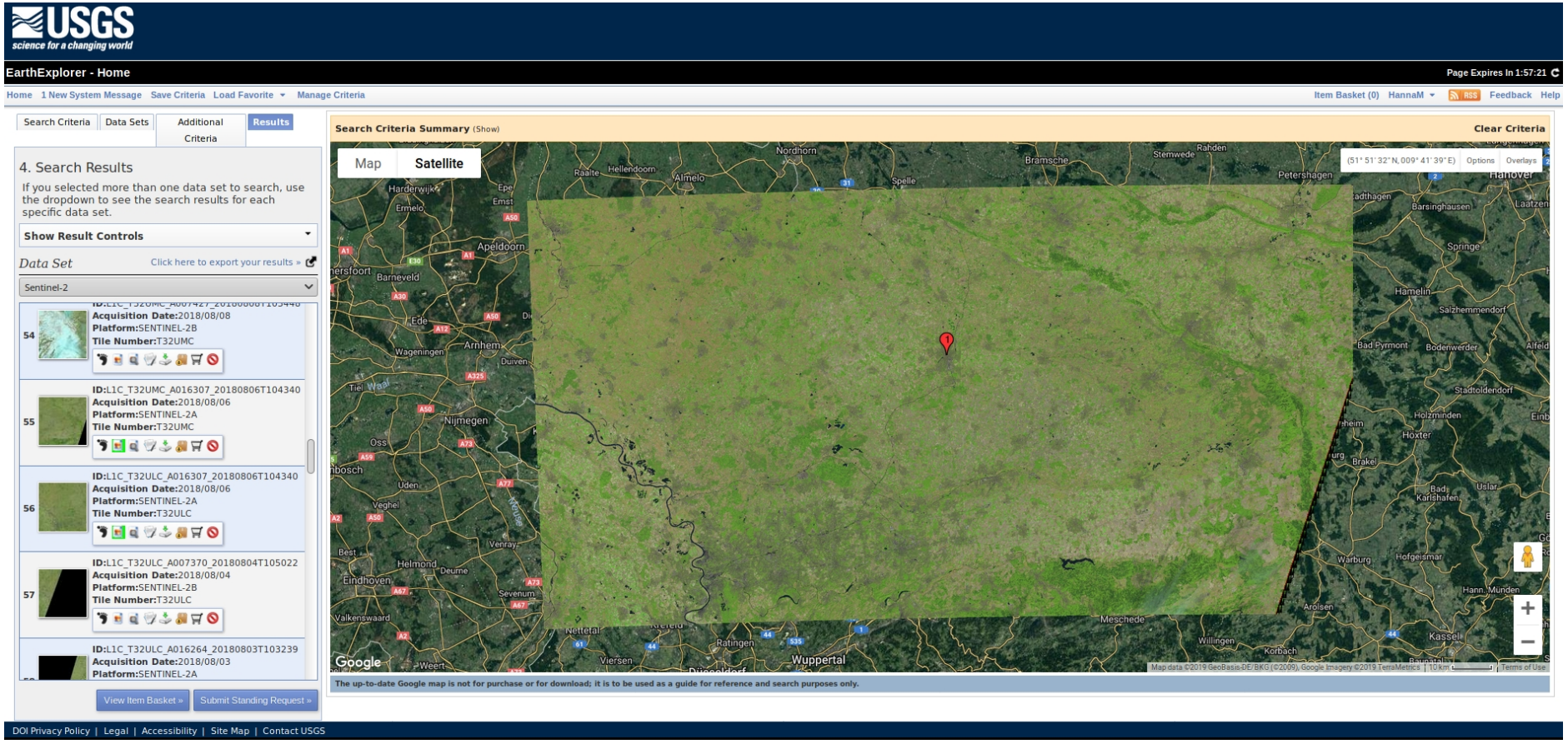
Platform/Sensor	Spatial resolution (m)	Temporal resolution	Availability
Landsat MSS	79	16 days	since 1972
Landsat TM	30	16 days	since 1982
Landsat ETM+	30	16 days	since 1999
Landsat 8 (OLI)	30	16 days	since 2013
Sentinel-2	10	5/10 days	since 2014
MODIS Terra/Aqua	250-1000	4 per day	since 2000
Meteosat Second Generation	3000	15 minutes	since 2002

Sentinel-2 data

Spectral bands for the Sentinel-2 sensors[10]

Sentinel-2 bands	Sentinel-2A		Sentinel-2B		
	Central wavelength (nm)	Bandwidth (nm)	Central wavelength (nm)	Bandwidth (nm)	Spatial resolution (m)
Band 1 – Coastal aerosol	442.7	21	442.2	21	60
Band 2 – Blue	492.4	66	492.1	66	10
Band 3 – Green	559.8	36	559.0	36	10
Band 4 – Red	664.6	31	664.9	31	10
Band 5 – Vegetation red edge	704.1	15	703.8	16	20
Band 6 – Vegetation red edge	740.5	15	739.1	15	20
Band 7 – Vegetation red edge	782.8	20	779.7	20	20
Band 8 – NIR	832.8	106	832.9	106	10
Band 8A – Narrow NIR	864.7	21	864.0	22	20
Band 9 – Water vapour	945.1	20	943.2	21	60
Band 10 – SWIR – Cirrus	1373.5	31	1376.9	30	60
Band 11 – SWIR	1613.7	91	1610.4	94	20
Band 12 – SWIR	2202.4	175	2185.7	185	20

Getting satellite data



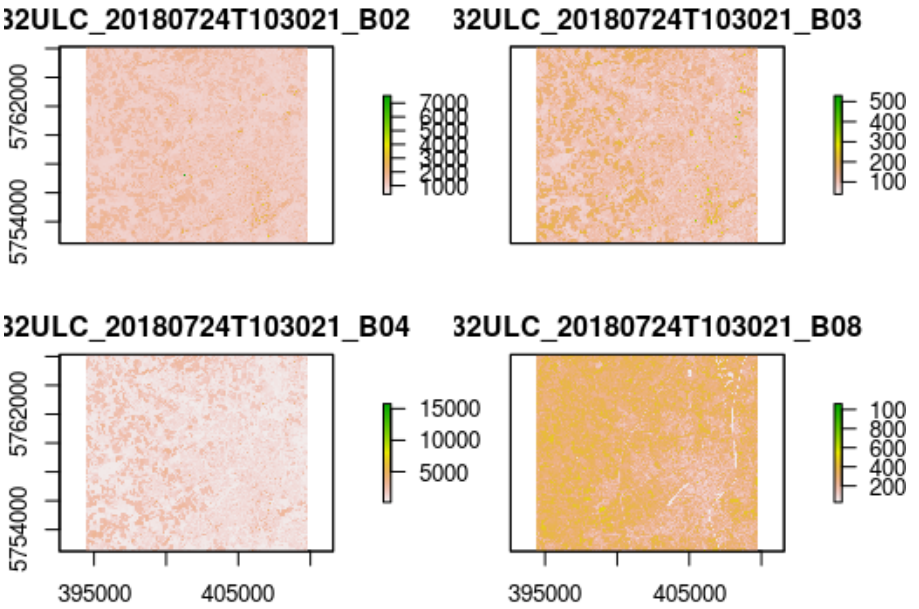
→ https://earthexplorer.usgs.gov/

Load satellite data in R

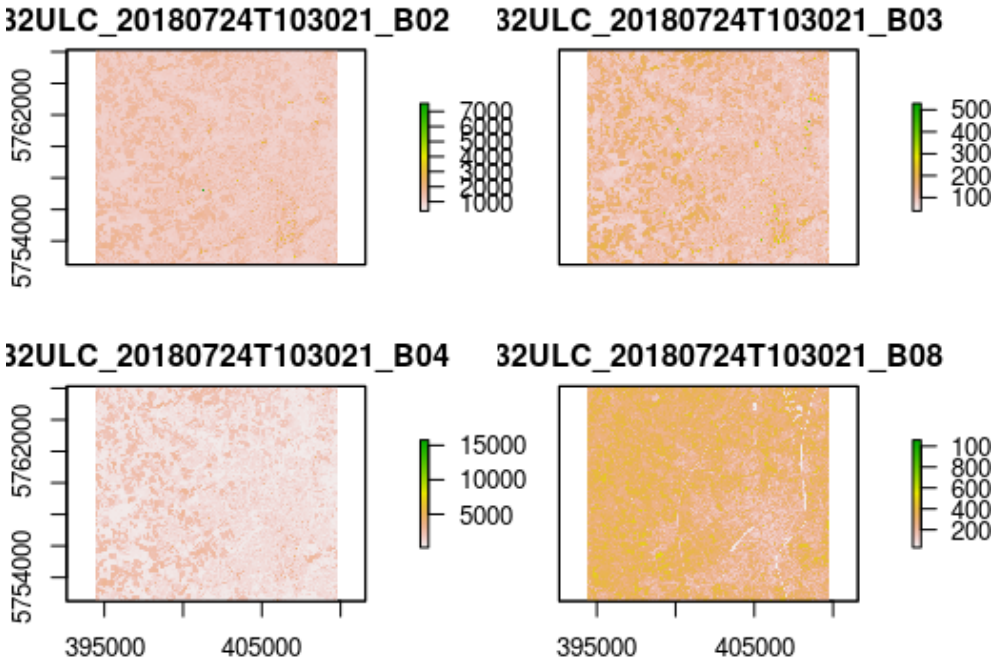
- Options: raster, stars, gdalcubes
- Focus for this session on raster

How to import satellite data into R

```
library(raster)
sen <- stack("blue.tif","green.tif",
             "red.tif","NIR.tif")
plot(sen)
```



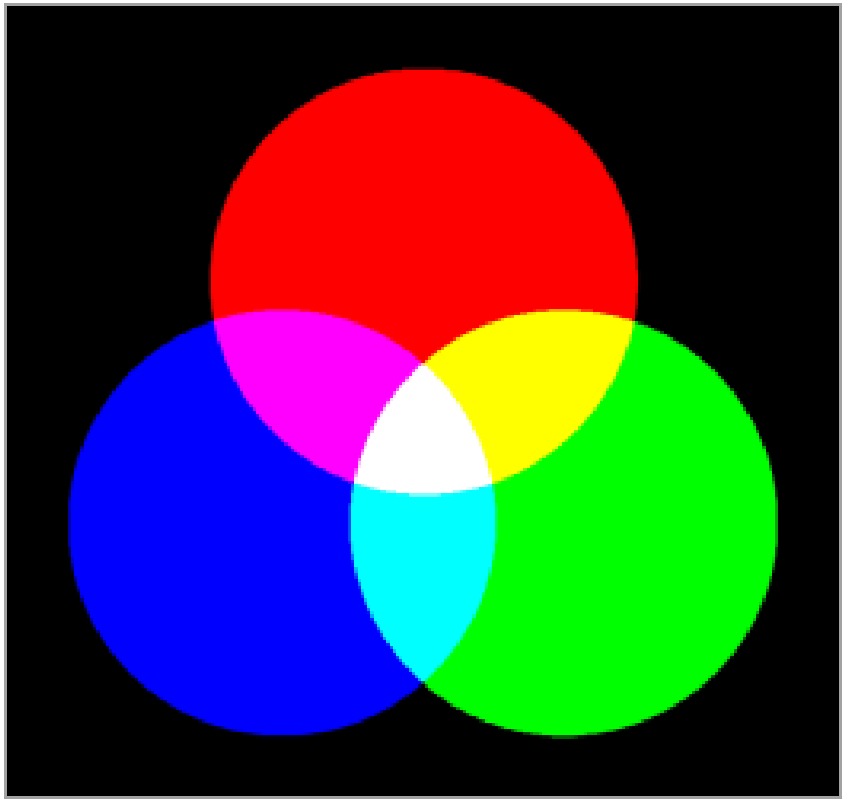
How do we get the “color” in the satellite data?



?

How do we get the “color” in the satellite data?

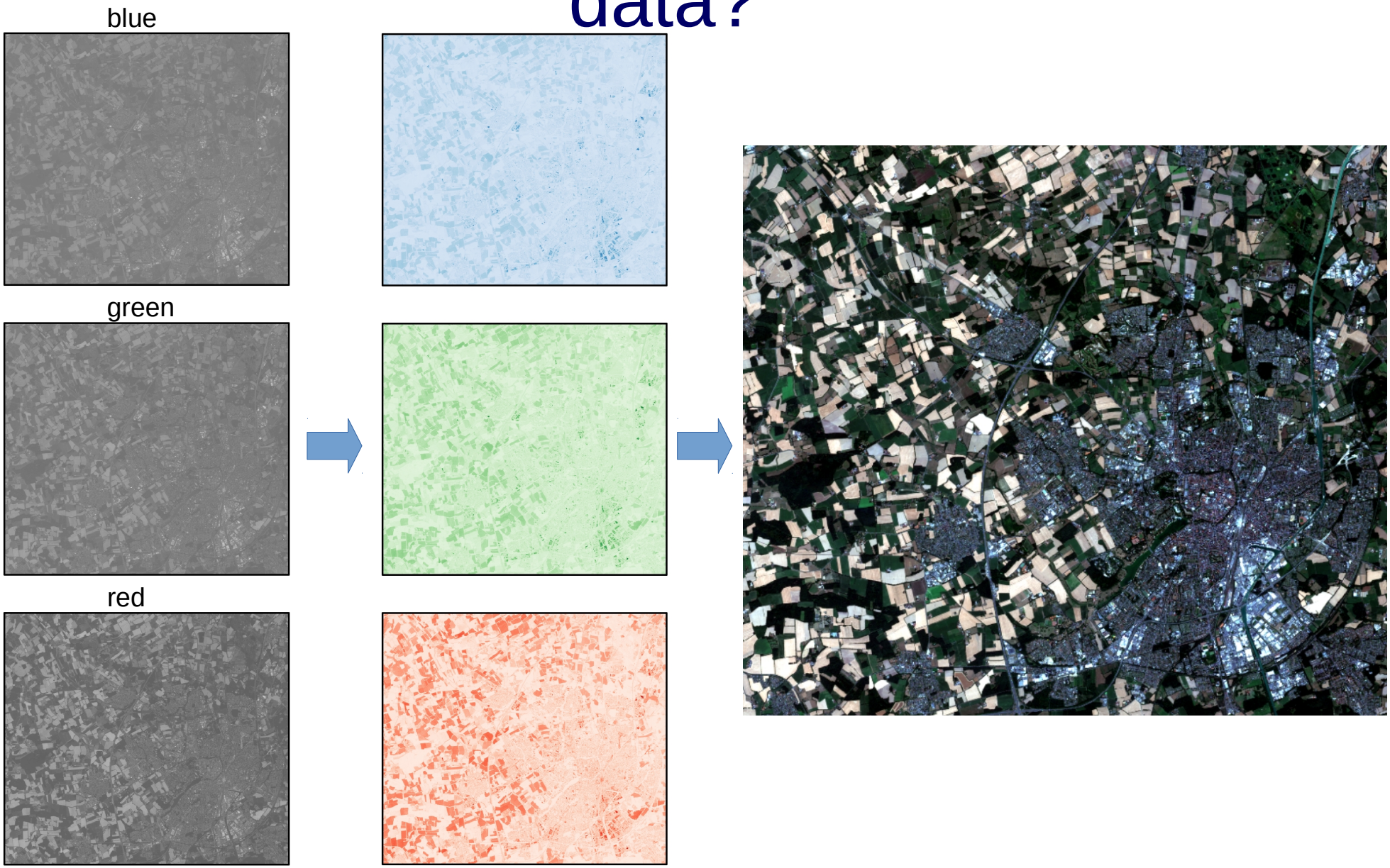
- Our eyes have three “sensors”: Blue, Green, Red
- Different colors through color mixing
- Combine visible channels to create a “true color composite”



How to do a color composite in R

```
sen <- stack("blue.tif","green.tif",
             "red.tif","NIR.tif")
plotRGB(sen,r=3,g=2,b=1,stretch="lin")
```

How do we get the “color” in the satellite data?

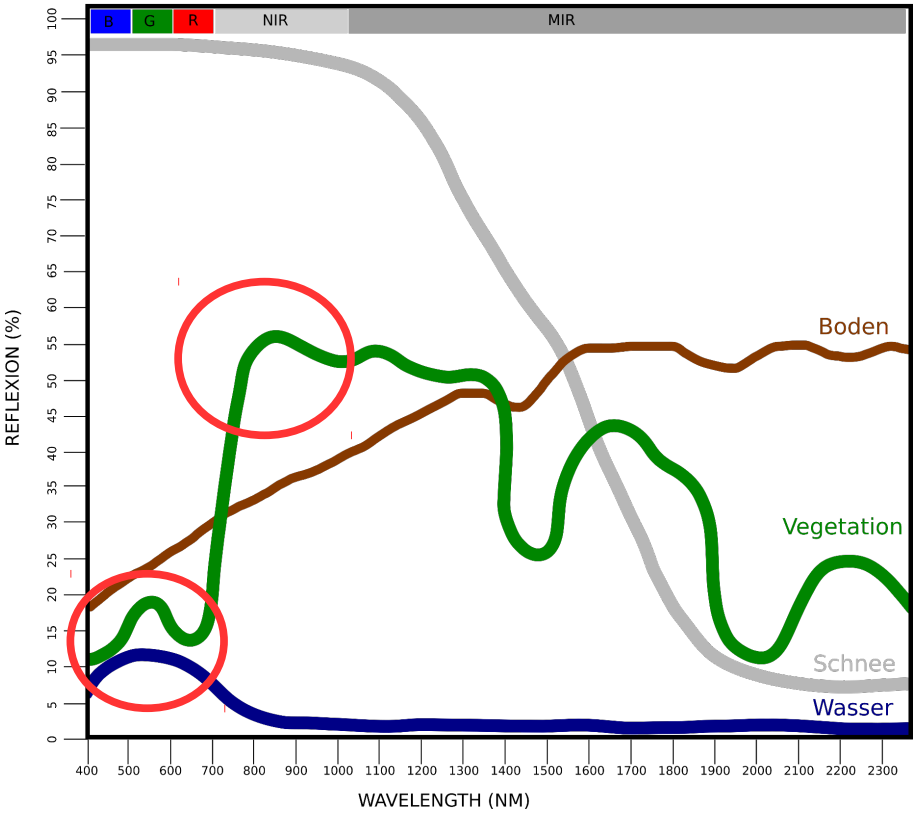


But satellite data contain more than what we can see...

Marburg Uni-Stadion

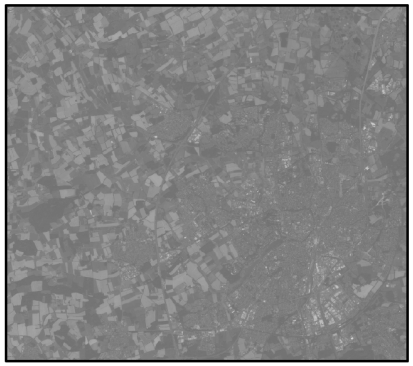
Is this real grass or artificial???

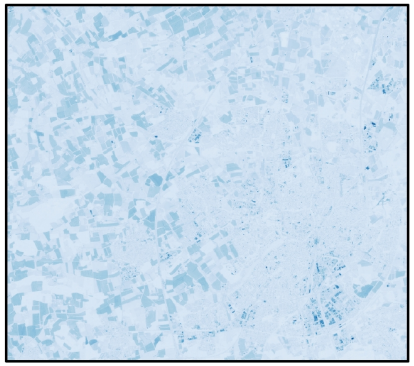
Marburg Gaßmann-Stadion



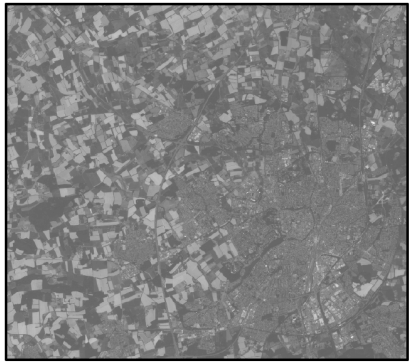
False color composite

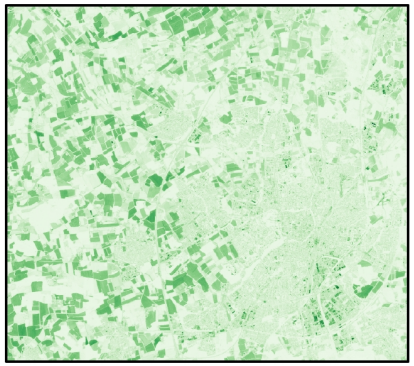
green



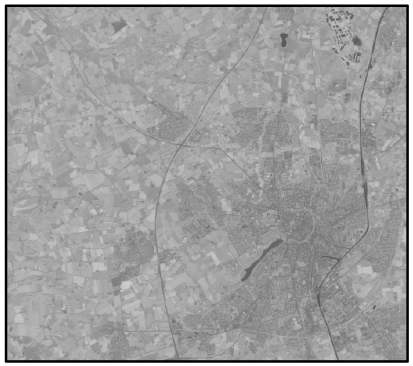


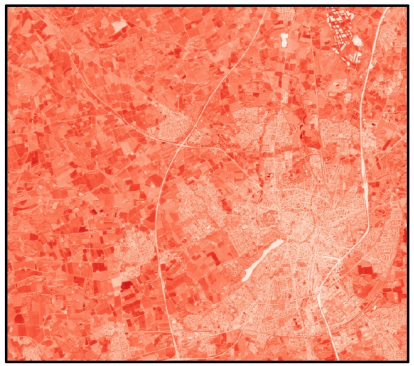
red

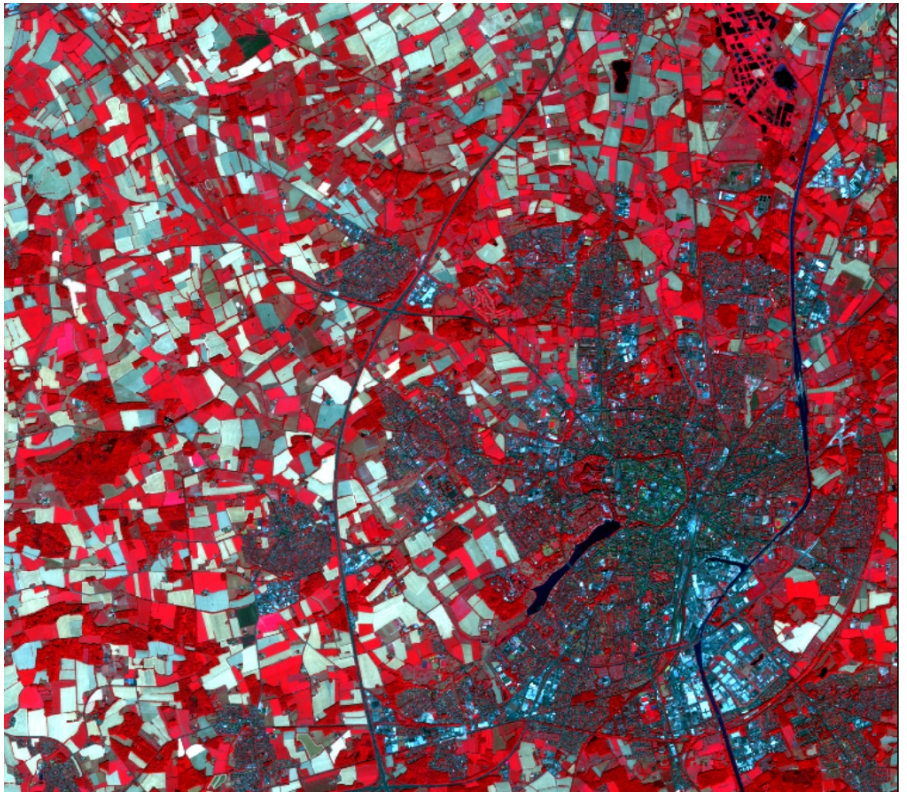




Near Infrared







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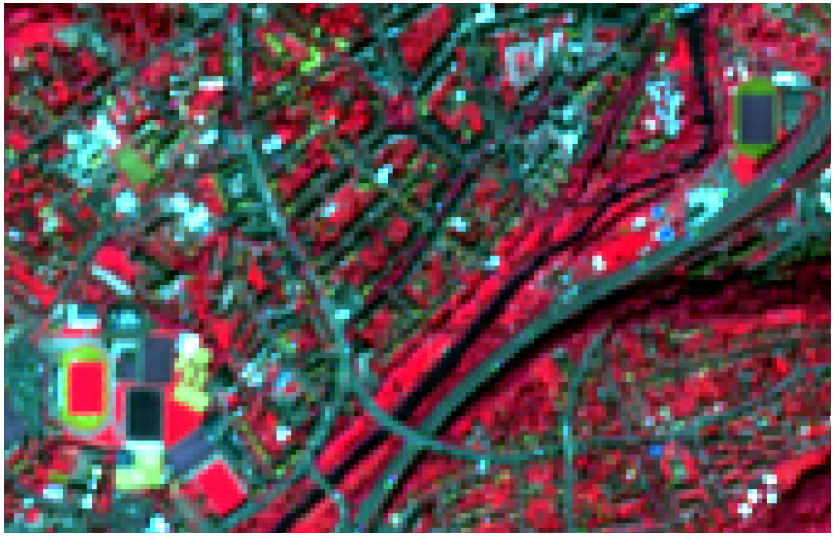
```

False color composite

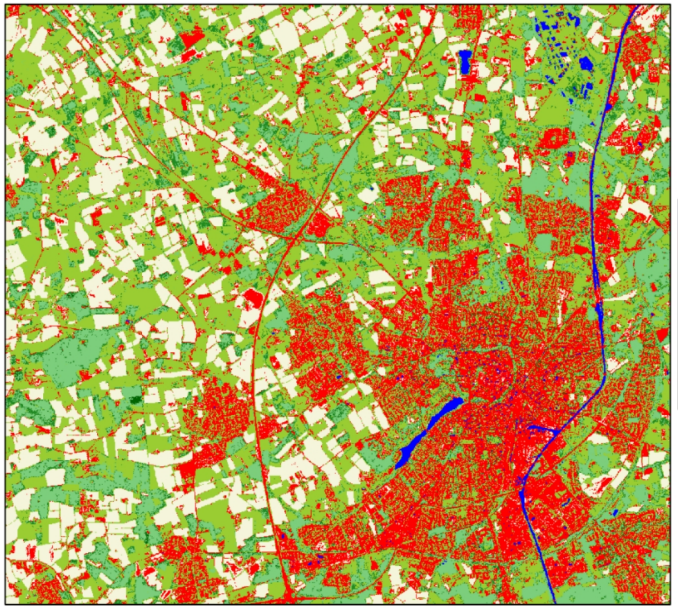
Marburg Uni-
Stadion



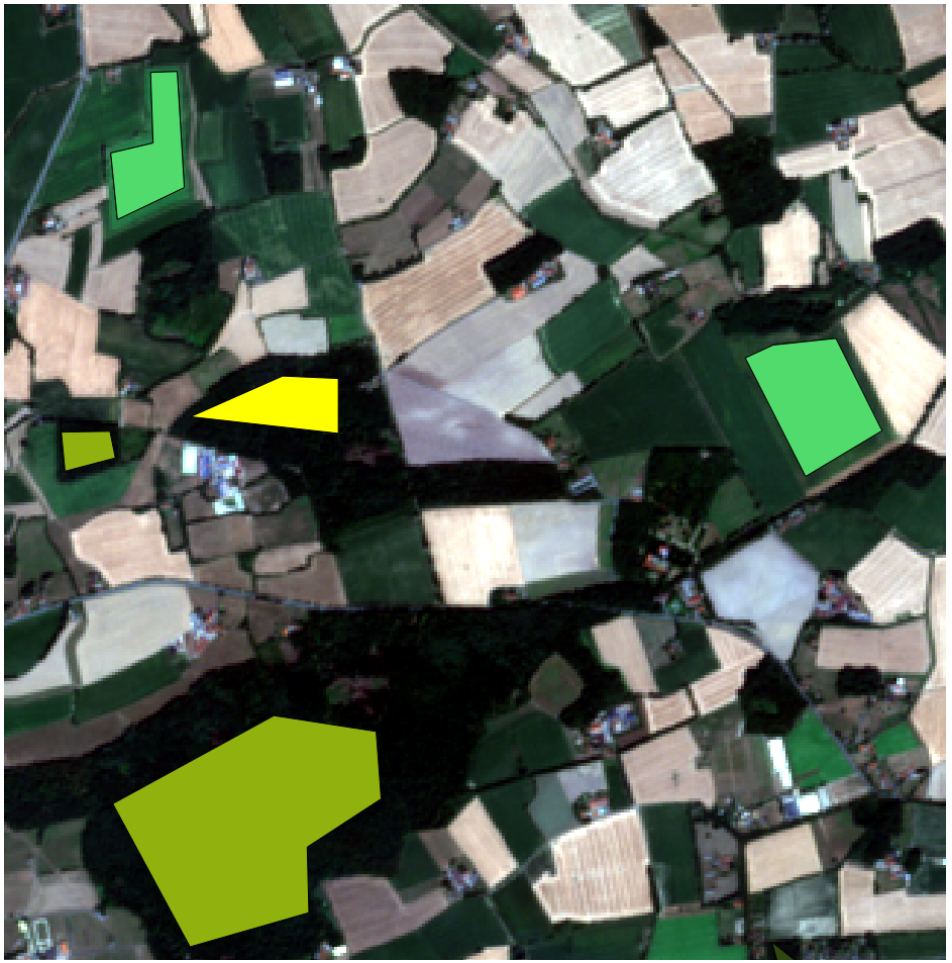
Marburg Gaßmann-
Stadion

How to relate the spectral properties to land cover classes?

Classification algorithm



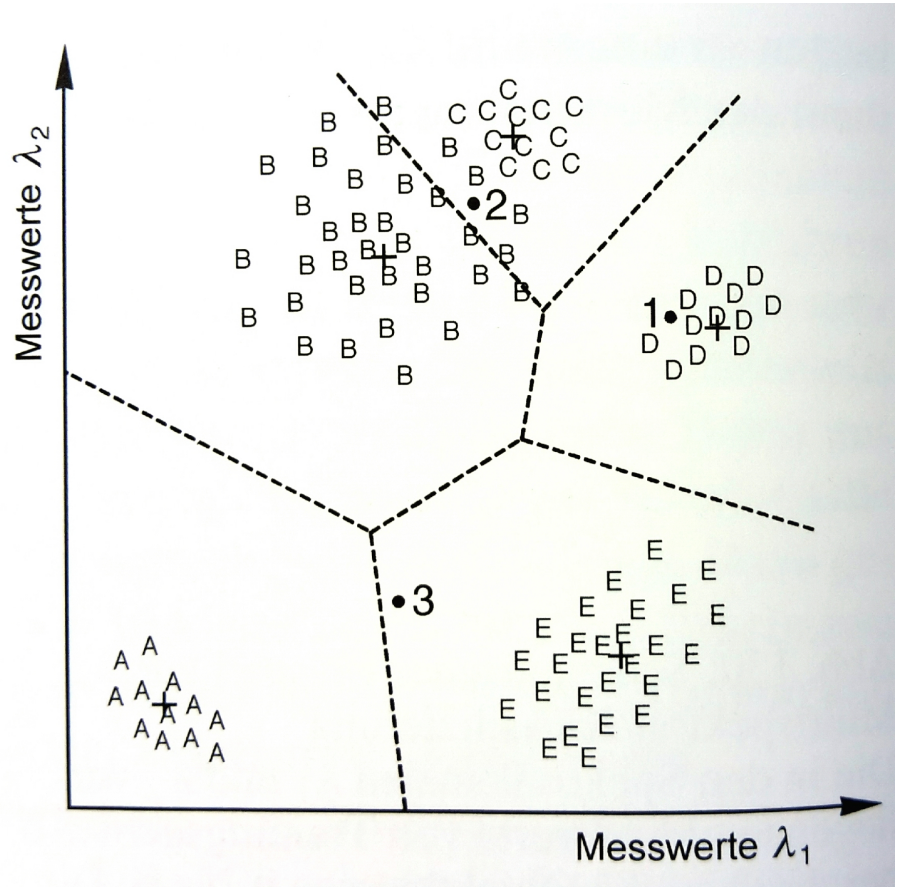
Reference data



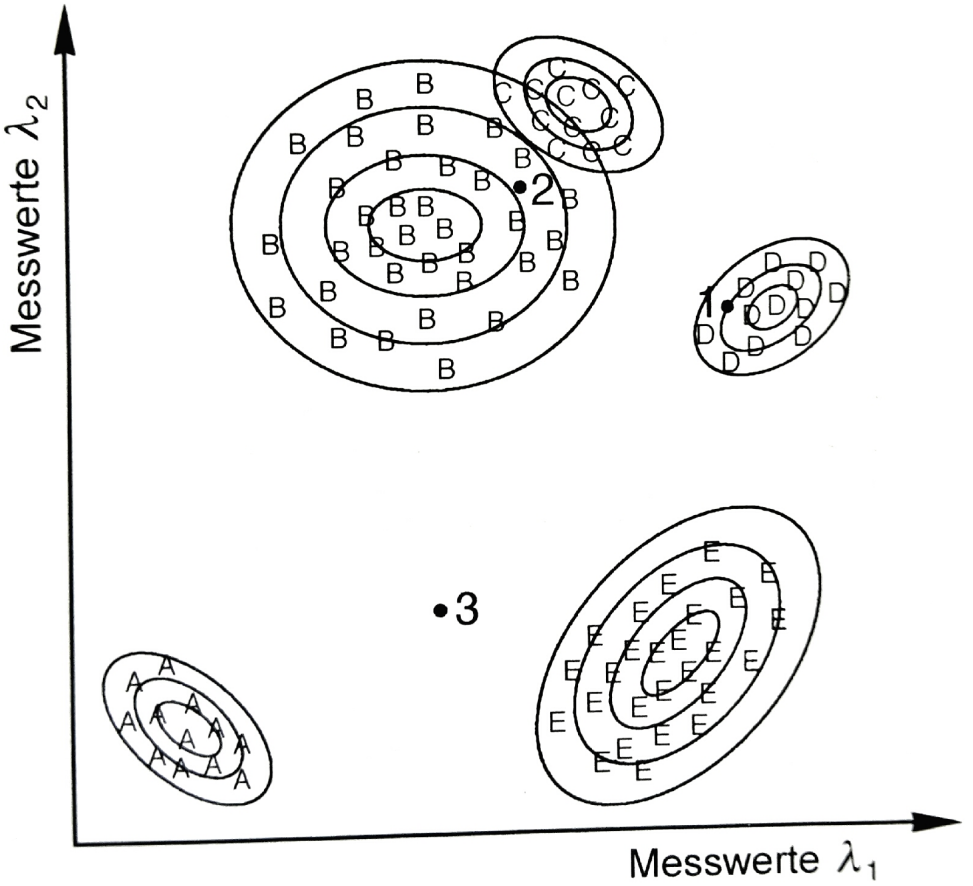
Training data from field work, expert knowledge,…
either polygons taken with GPS or digitized e.g. using QGIS

Traditional Supervised Classifiers

Minimum distance classifier

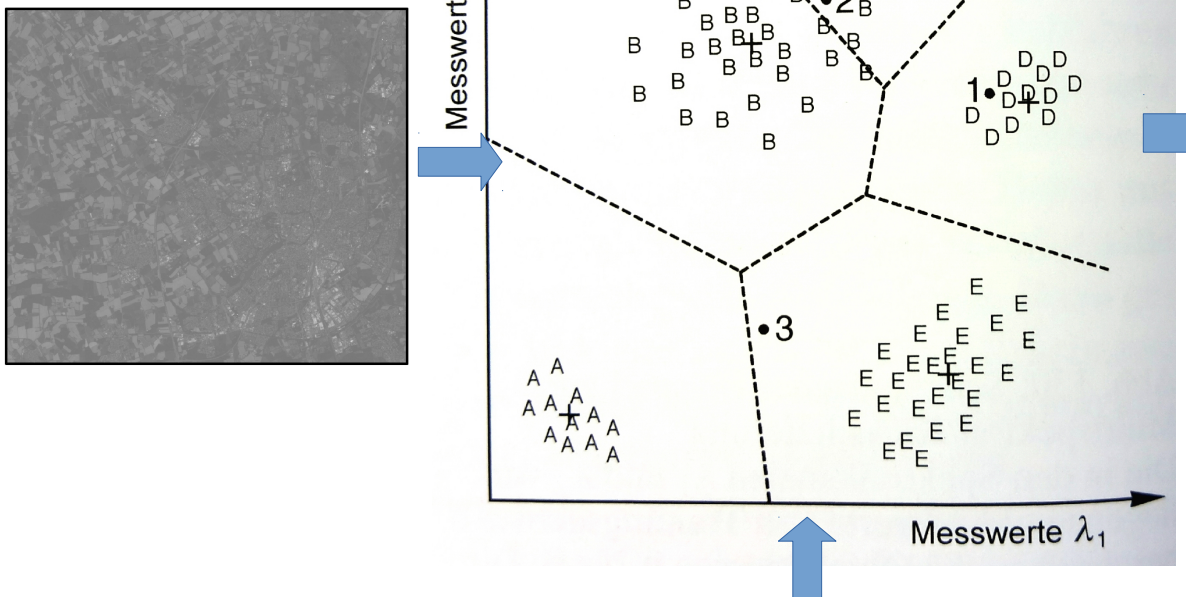


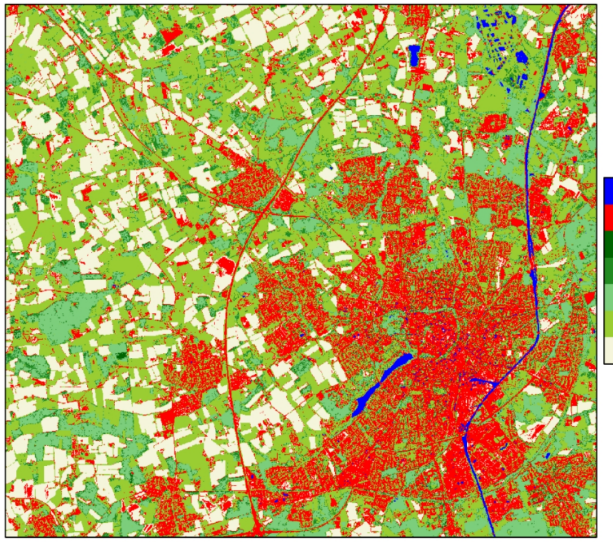
Maximum likelihood classifier

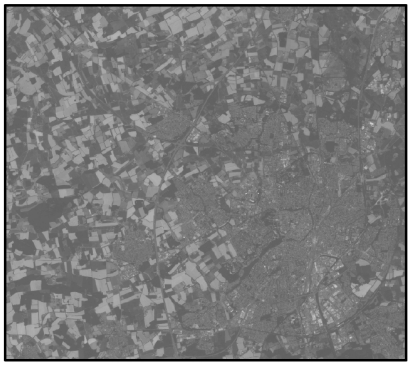


Albertz (2009): Einführung in die Fernerkundung. WBG, Darmstadt

Image Classification







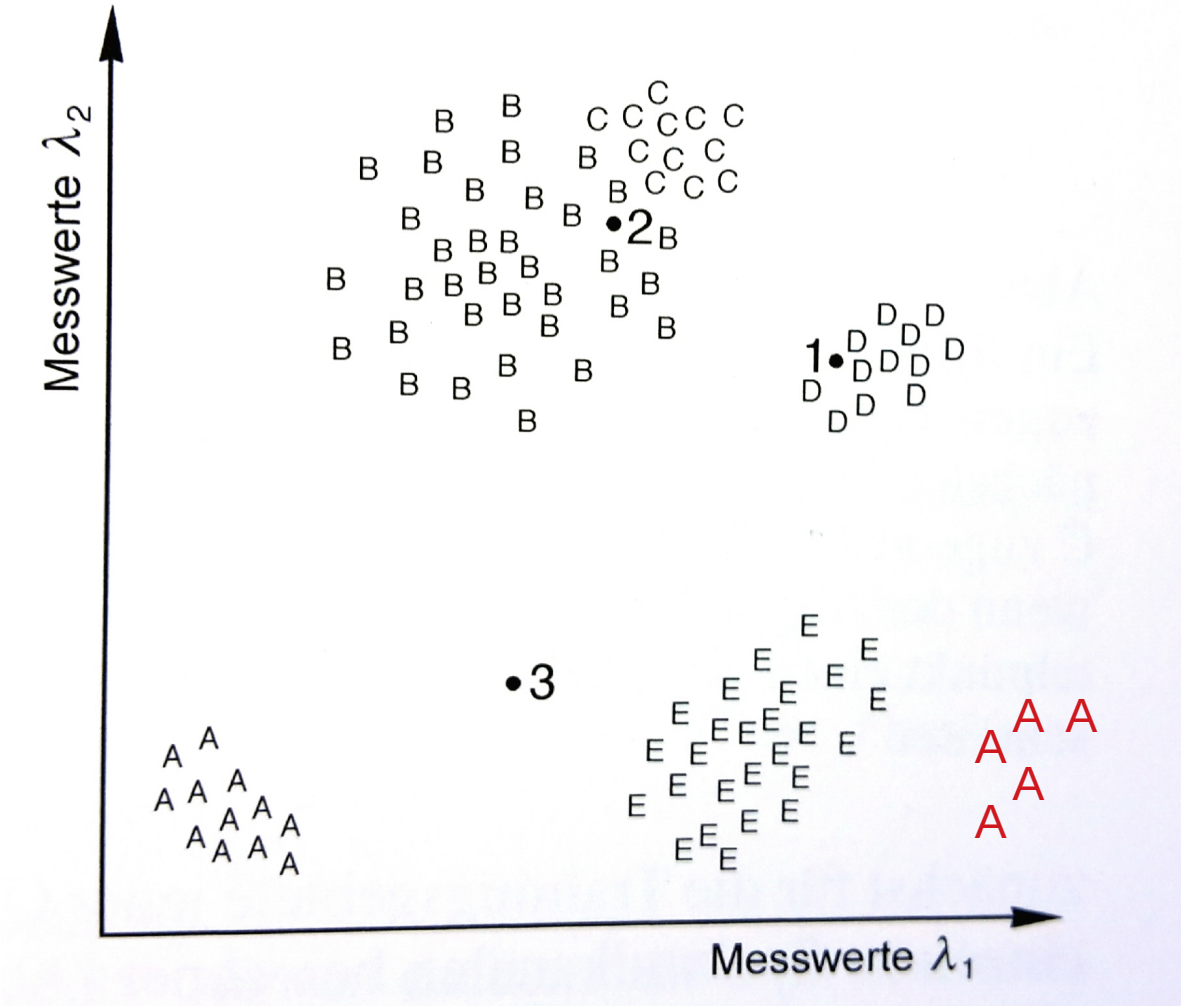
Classification of each Pixel (1-3,…)
according to its location in the feature space

Traditional Classifiers

Complex patterns cannot be accounted for by these algorithms!

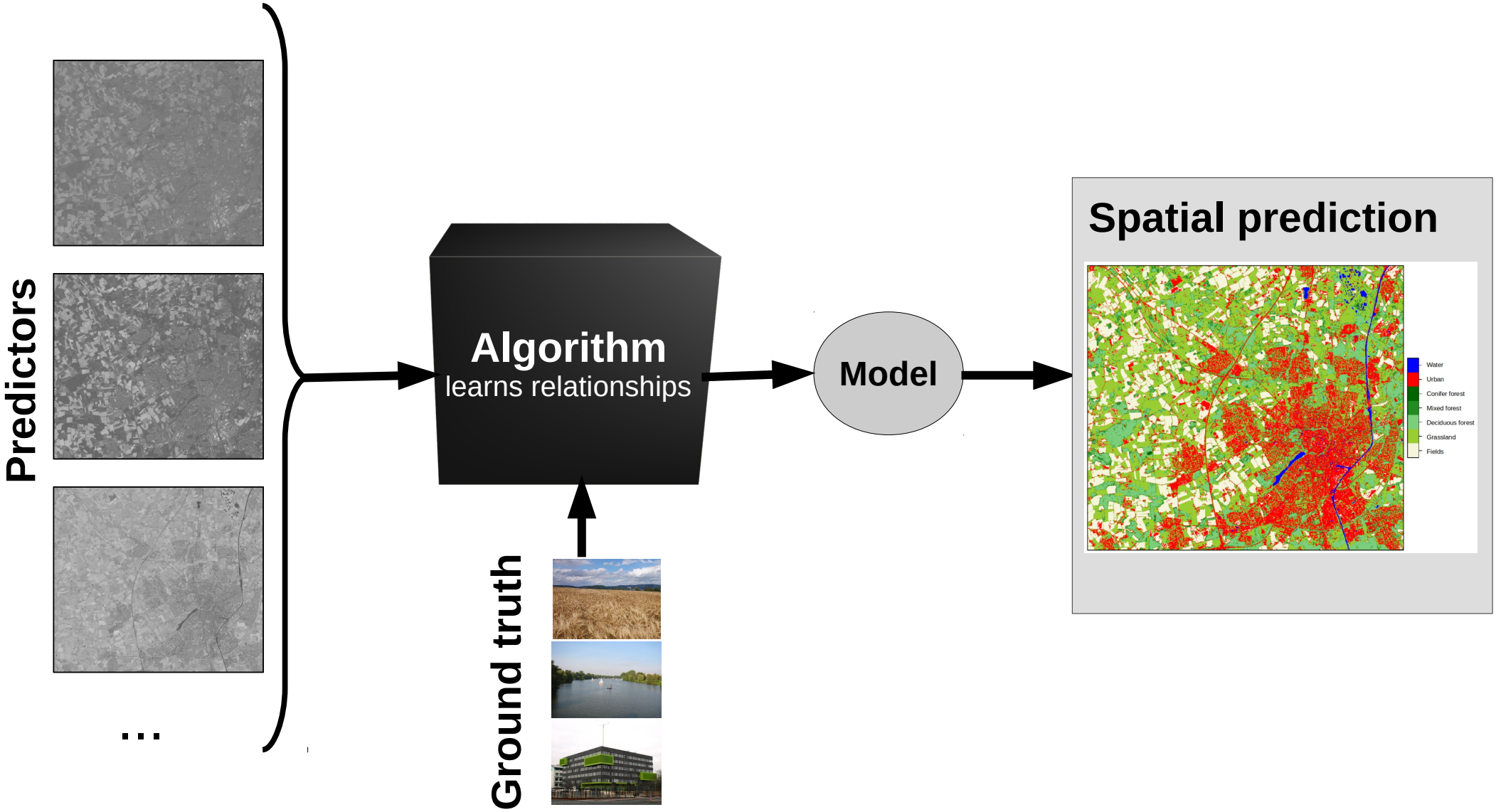
E.g. variations in the spectral characteristics depending on

- Forest on slopes with different aspect
- Crops that are irrigated/non irrigated
- Water in streams/lakes
- ...

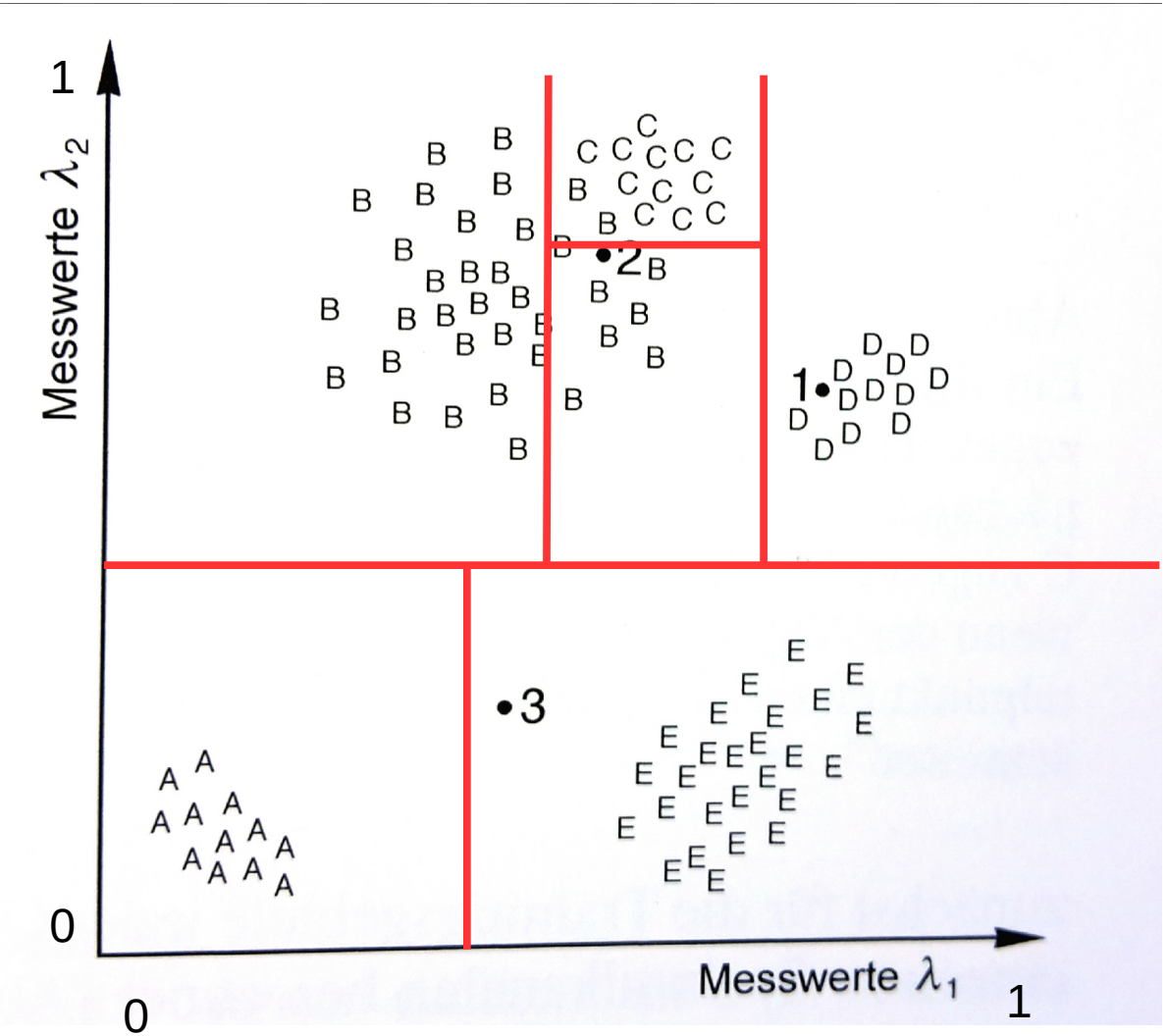


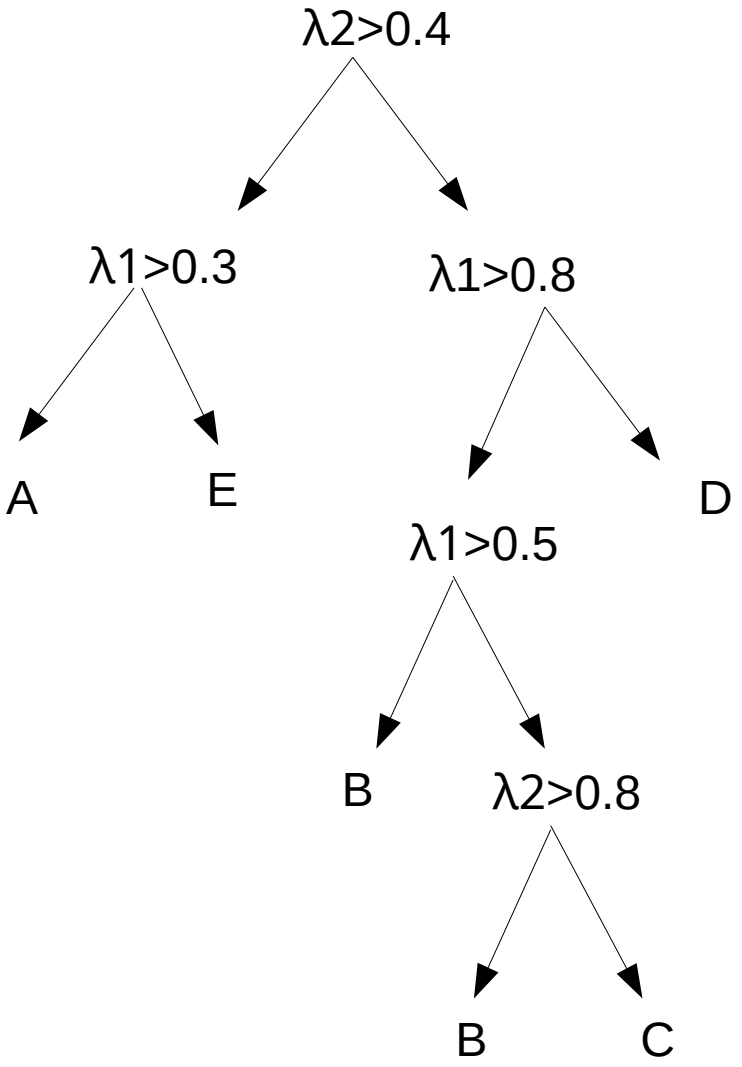
→ we need more complex models

Classification with machine learning

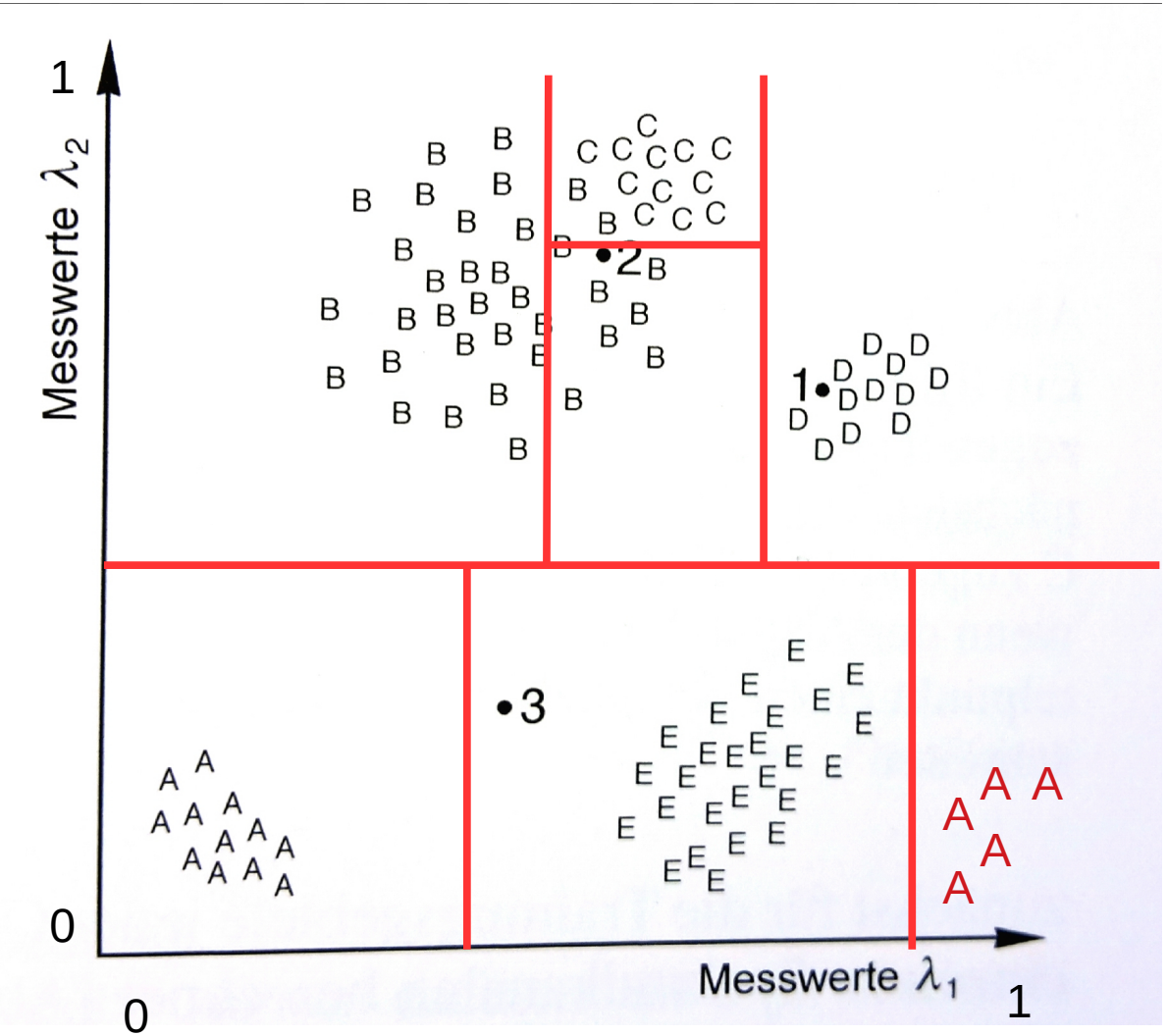


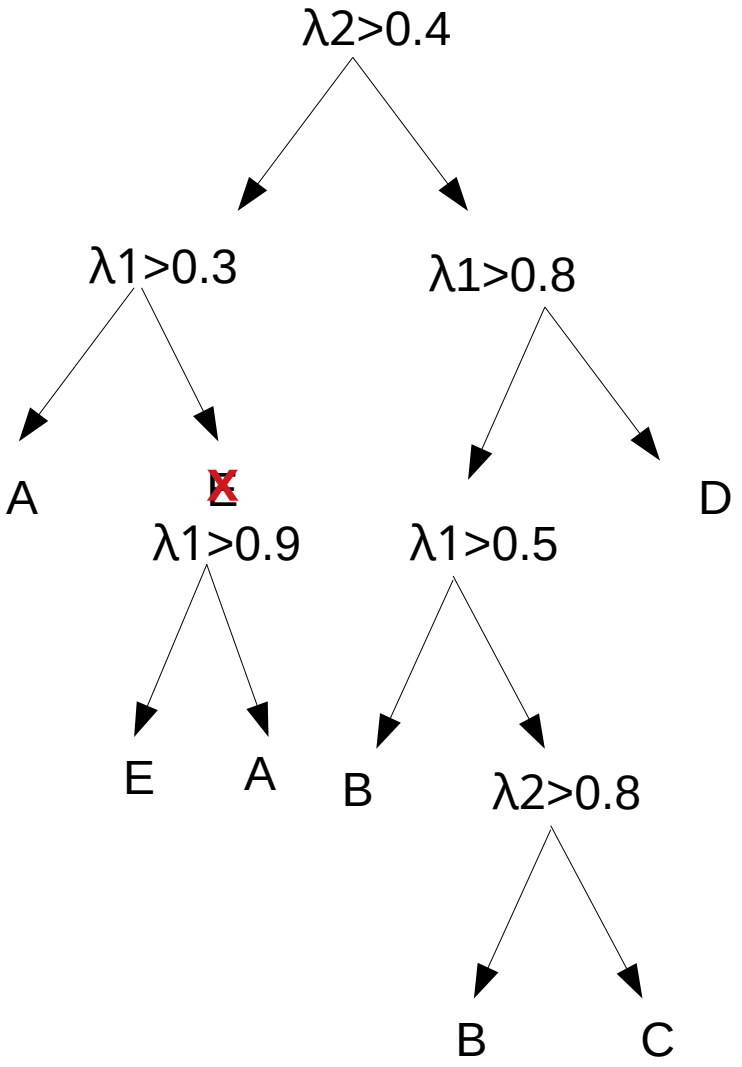
Random Forest basics: Classification trees



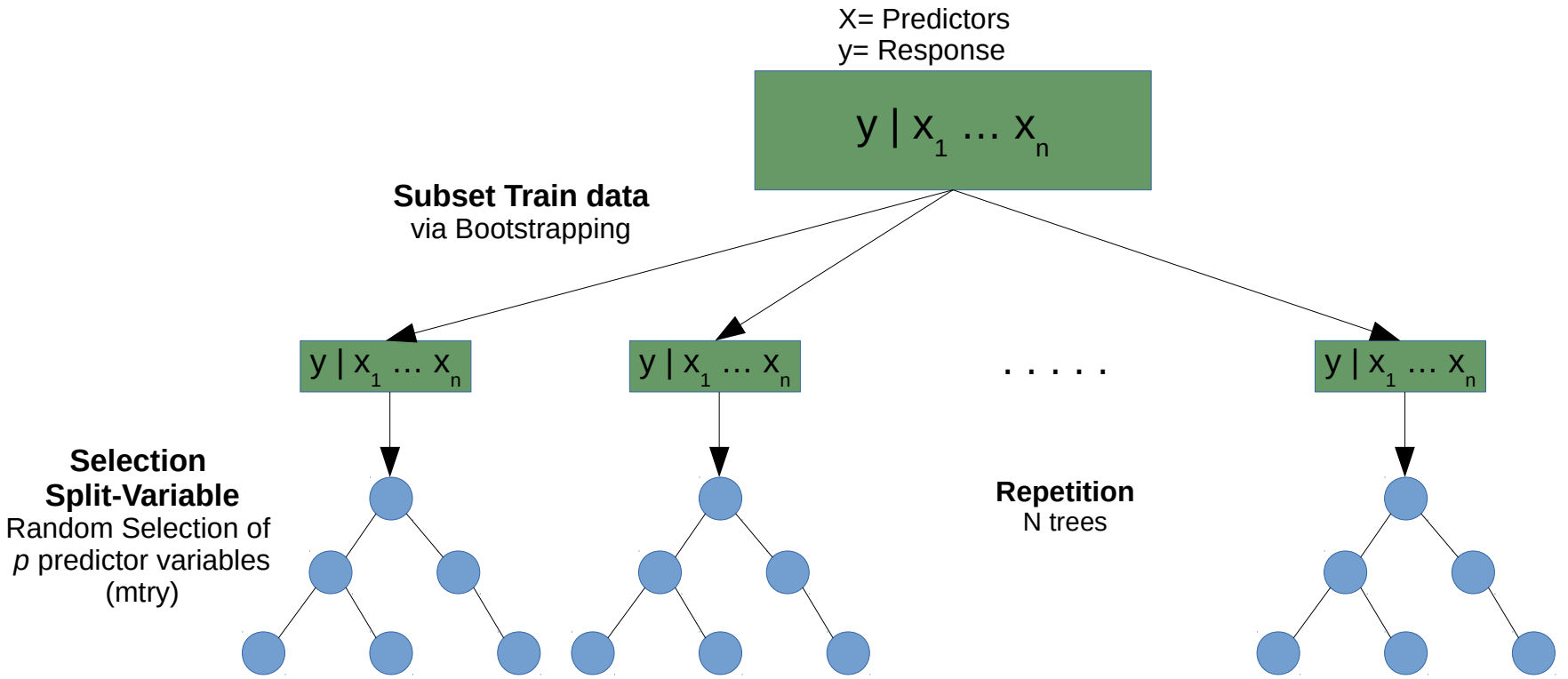


Random Forest basics: Classification trees

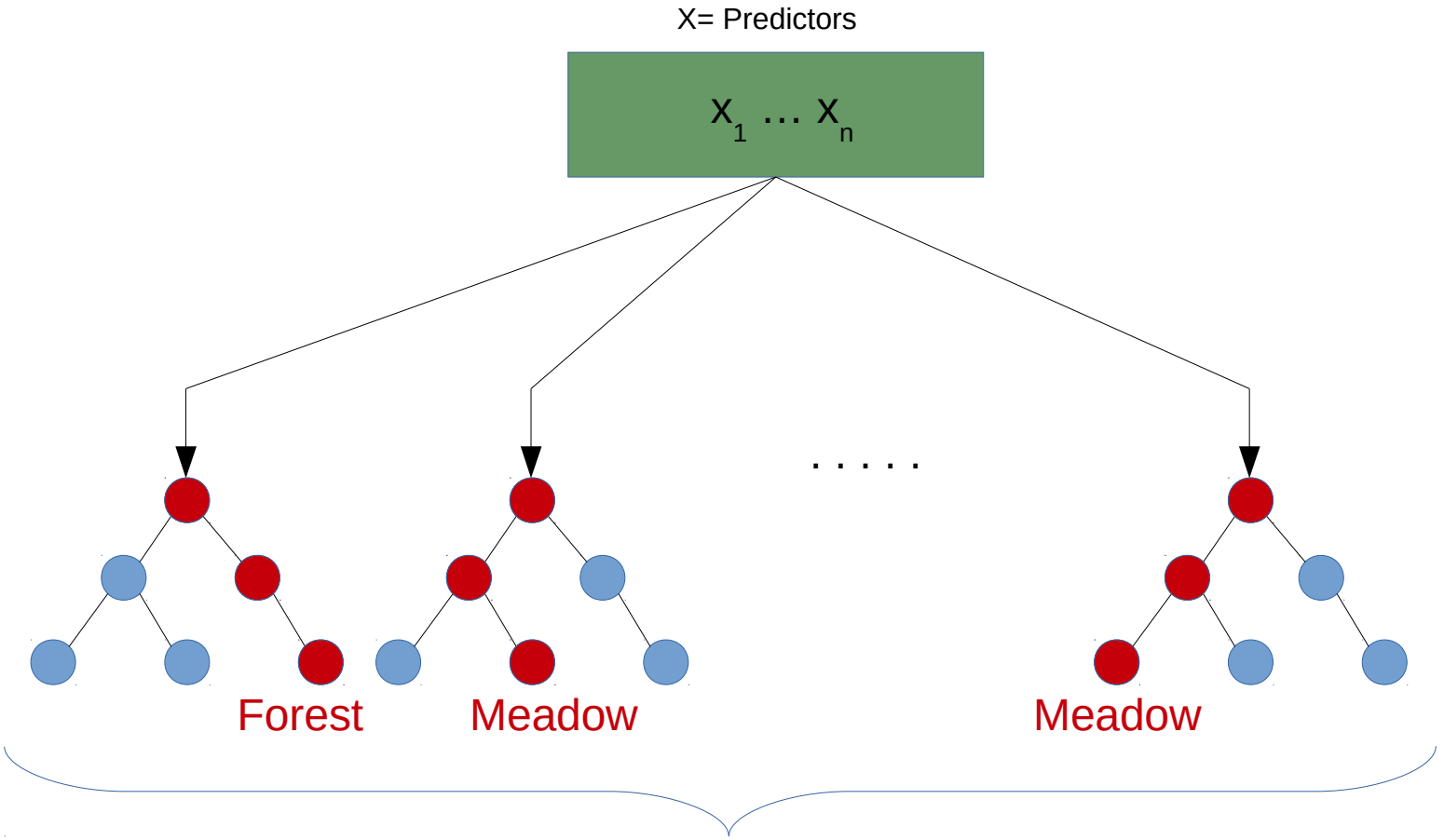




Random Forest: Model training



Random Forest: Prediction



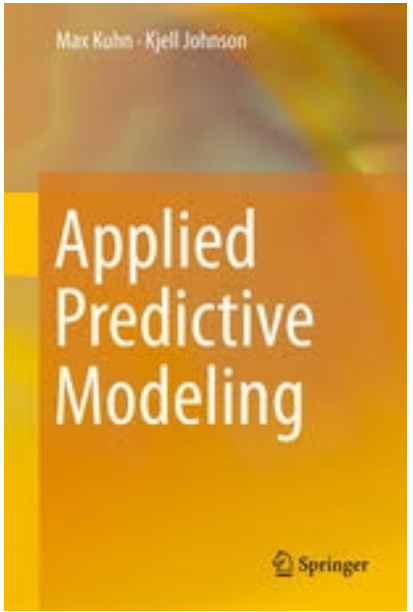
Decision made by combining the individual trees

(Classification: Majority; Regression: Mean)

Machine learning in R

- Many packages for different ML algorithms (e.g. Random Forests, Neural Networks, Support Vector Machines, ...)
- For classification and regression problems
- Wrapper packages
  - allowing access to many algorithms via a unified syntax
  - Supporting functionality for cross-validation etc.
  - Caret (Classification And REgression Training)
  - Mlr (Machine Learning in R)
  - Tidymodels

For today's session



Step 1: Model training in R

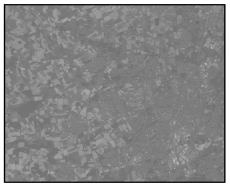
Predictors | Response

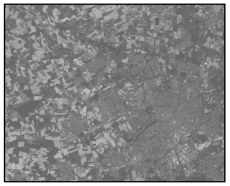
	B02	B03	B04	B08	...	Class
1	857	632	387	308		Water
2	848	633	389	312		Water
3	843	624	357	343		Water
4	854	630	360	333		Water
5	854	628	376	302		Water
6	859	615	364	350		Water

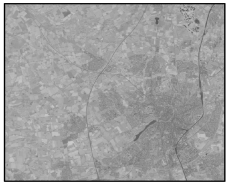
How to do it in R

```
library(caret)
model <- train(predictors,
                response,
                method="rf")
```

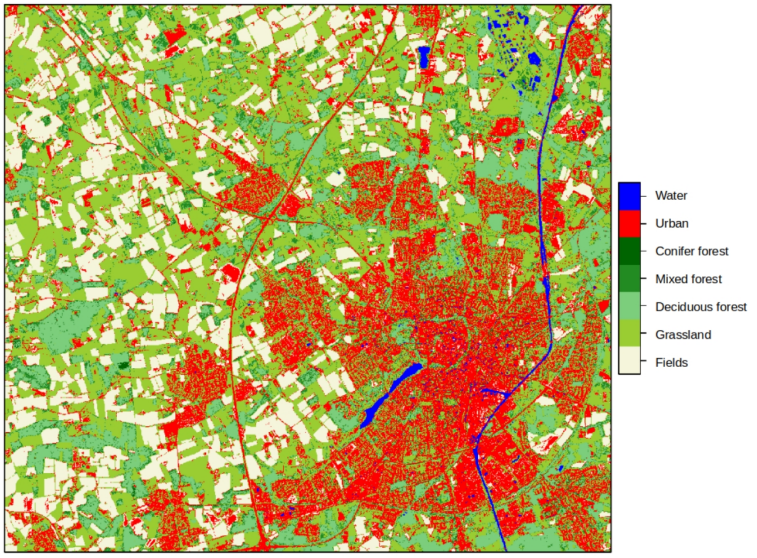
Step 2: Model prediction in R







+ trained model =

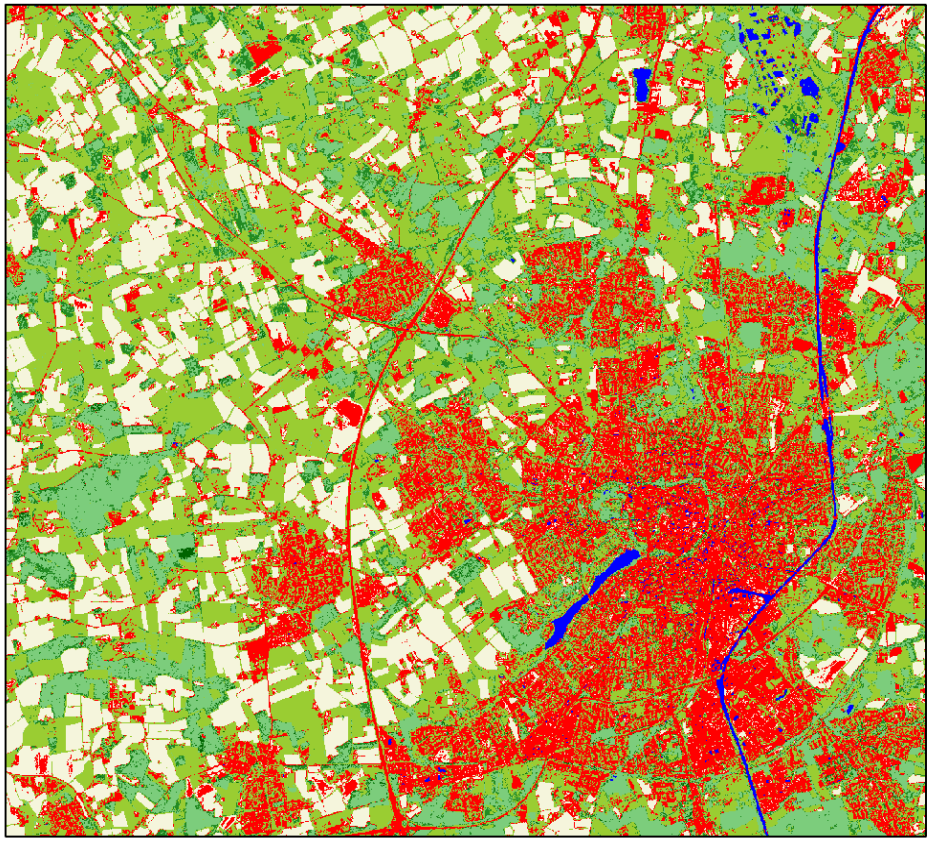


...

How to do it in R

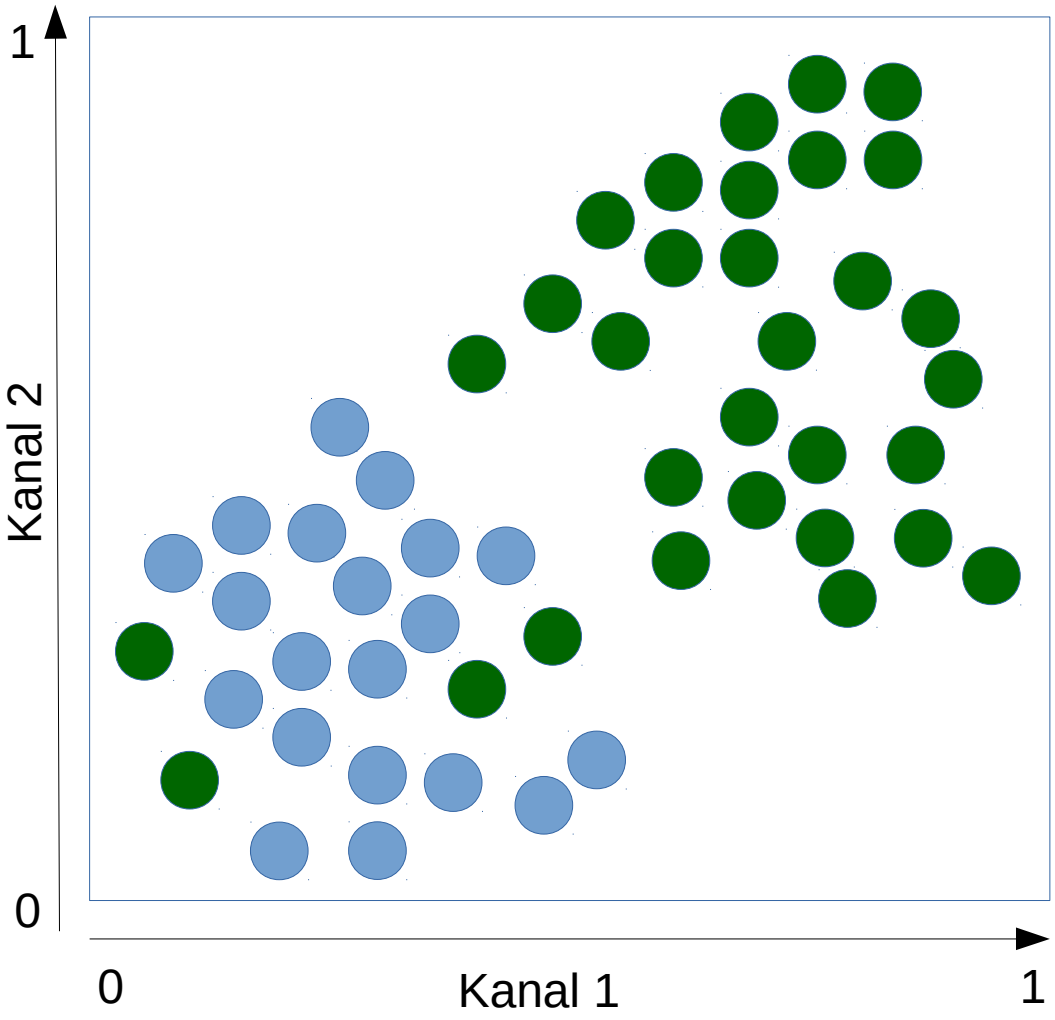
```
library(raster)
pred_sp <- stack(predictors)
prediction <- predict(pred_sp,model)
```

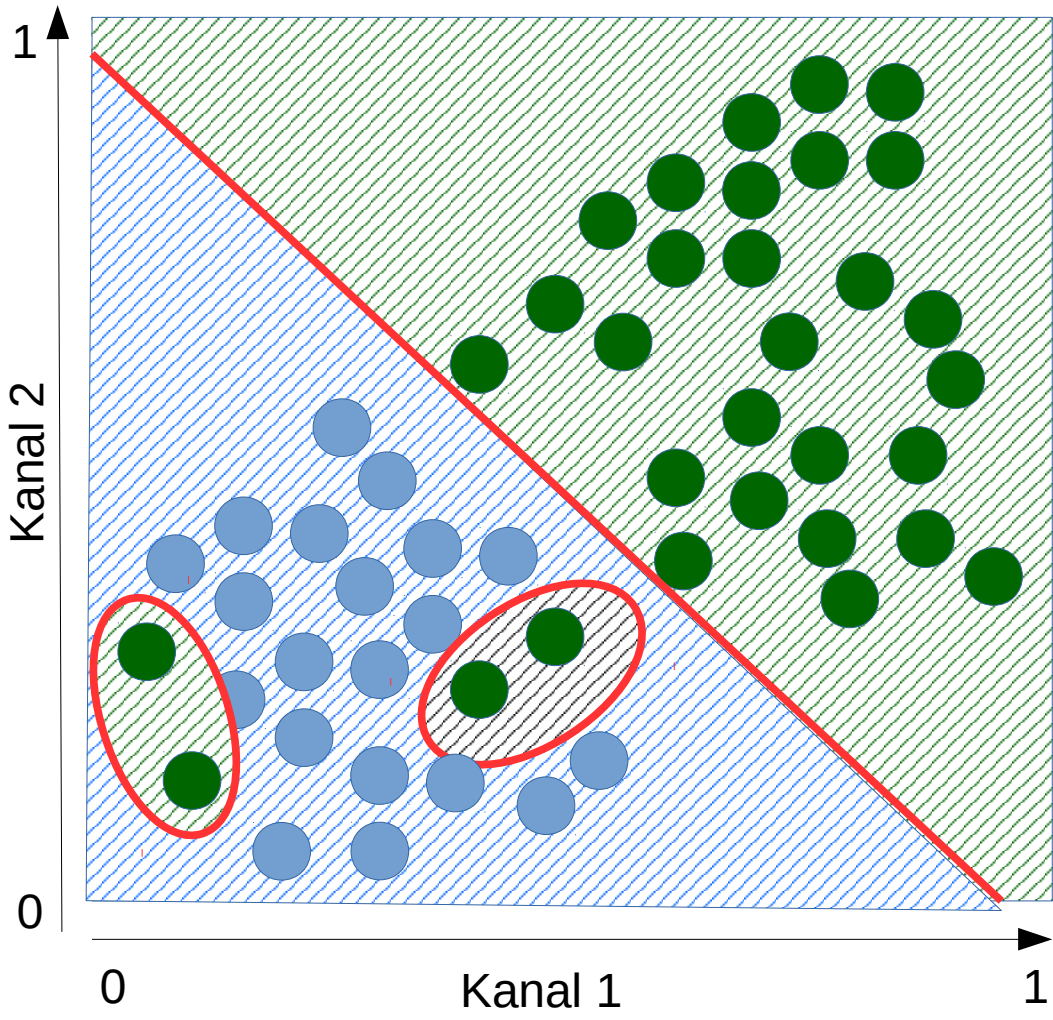
Result



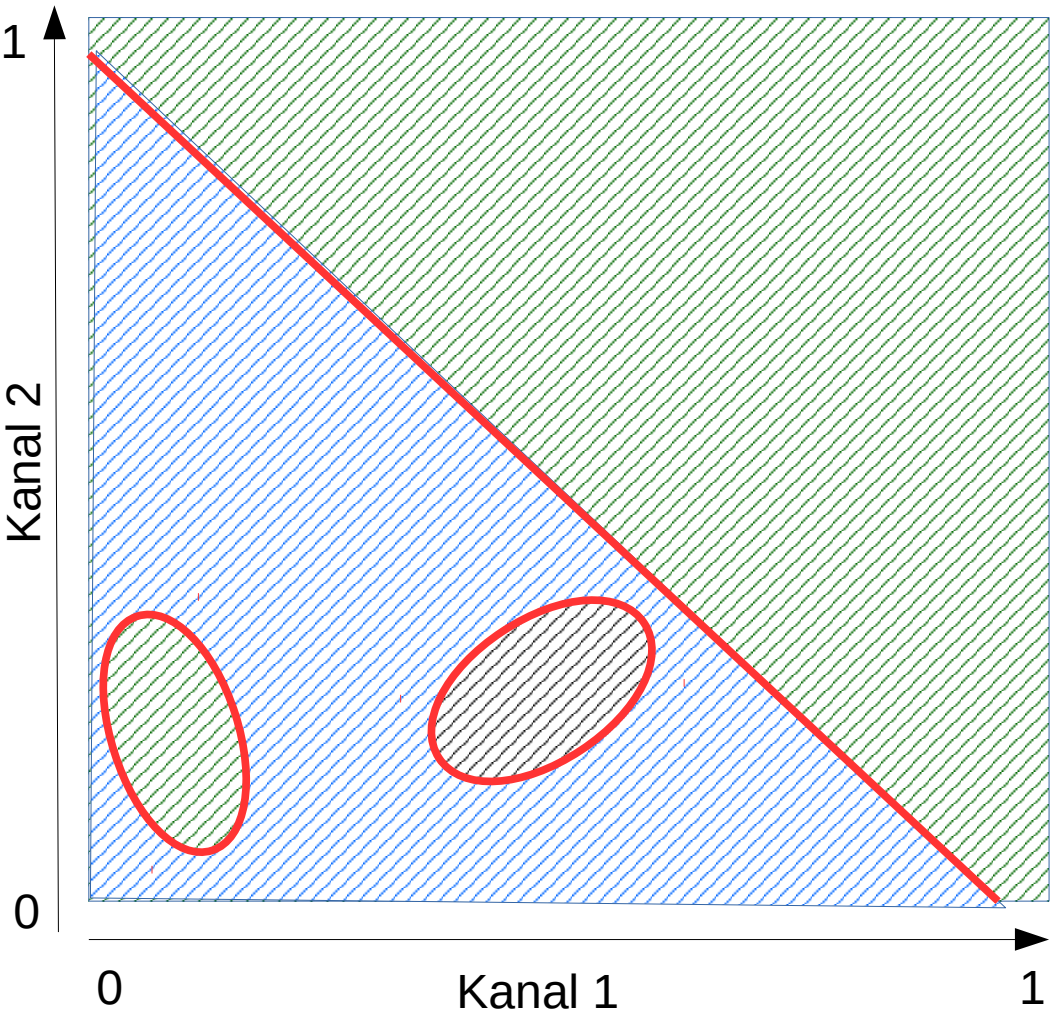
How good is this map?

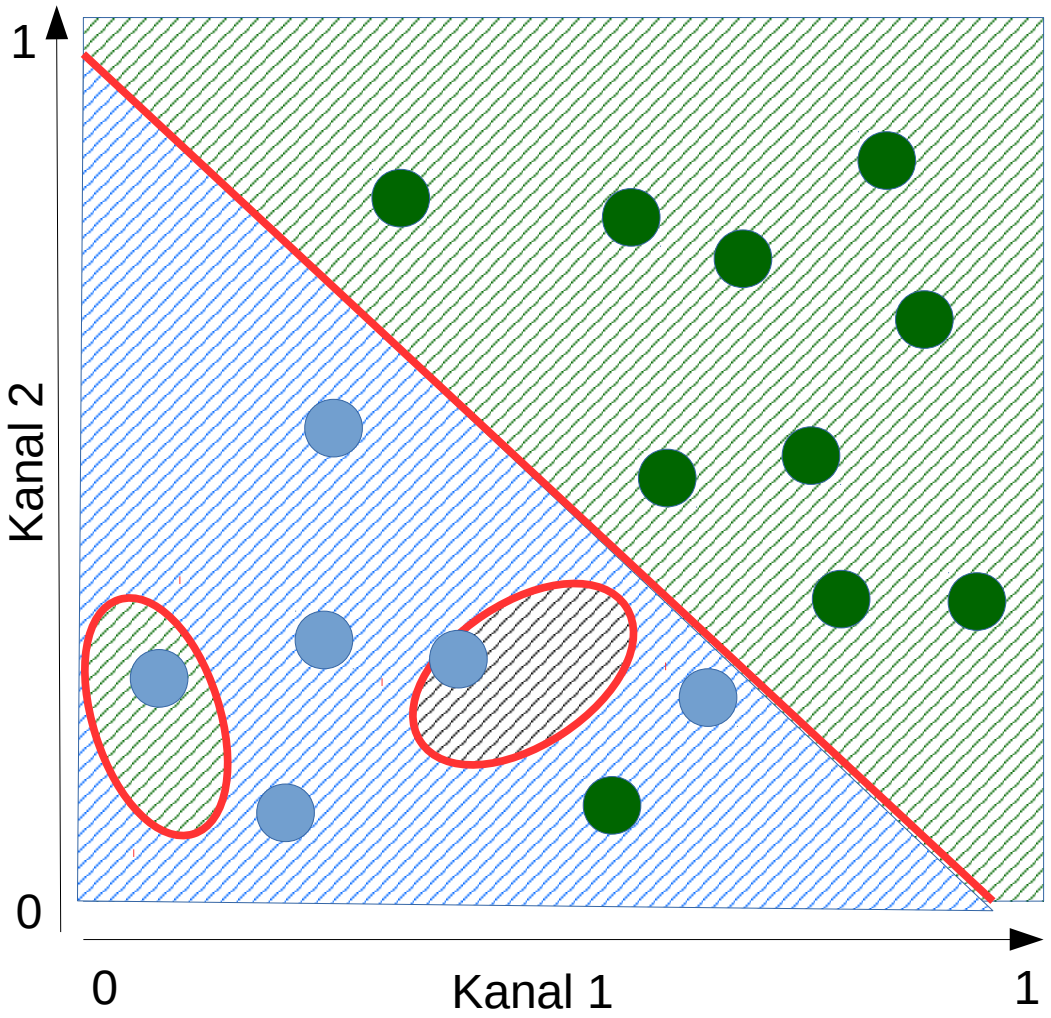
Problem: Overfitting



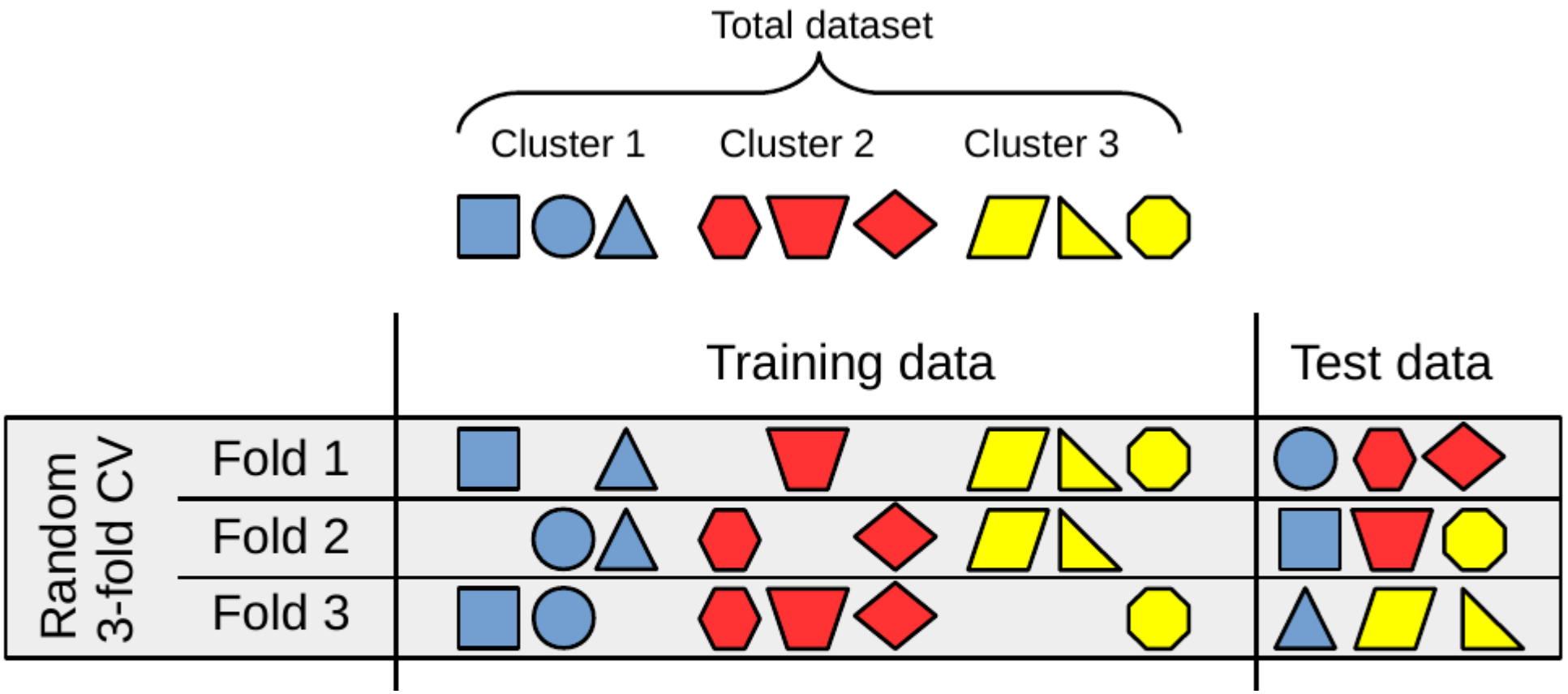


Problem: Overfitting





“Default” random cross-validation



“Default” random cross-validation

How to do it in R

```
model <- train(predictors,
               response,
               method="rf",
               trControl=trainControl(method="cv"))
```

```
> model
Random Forest

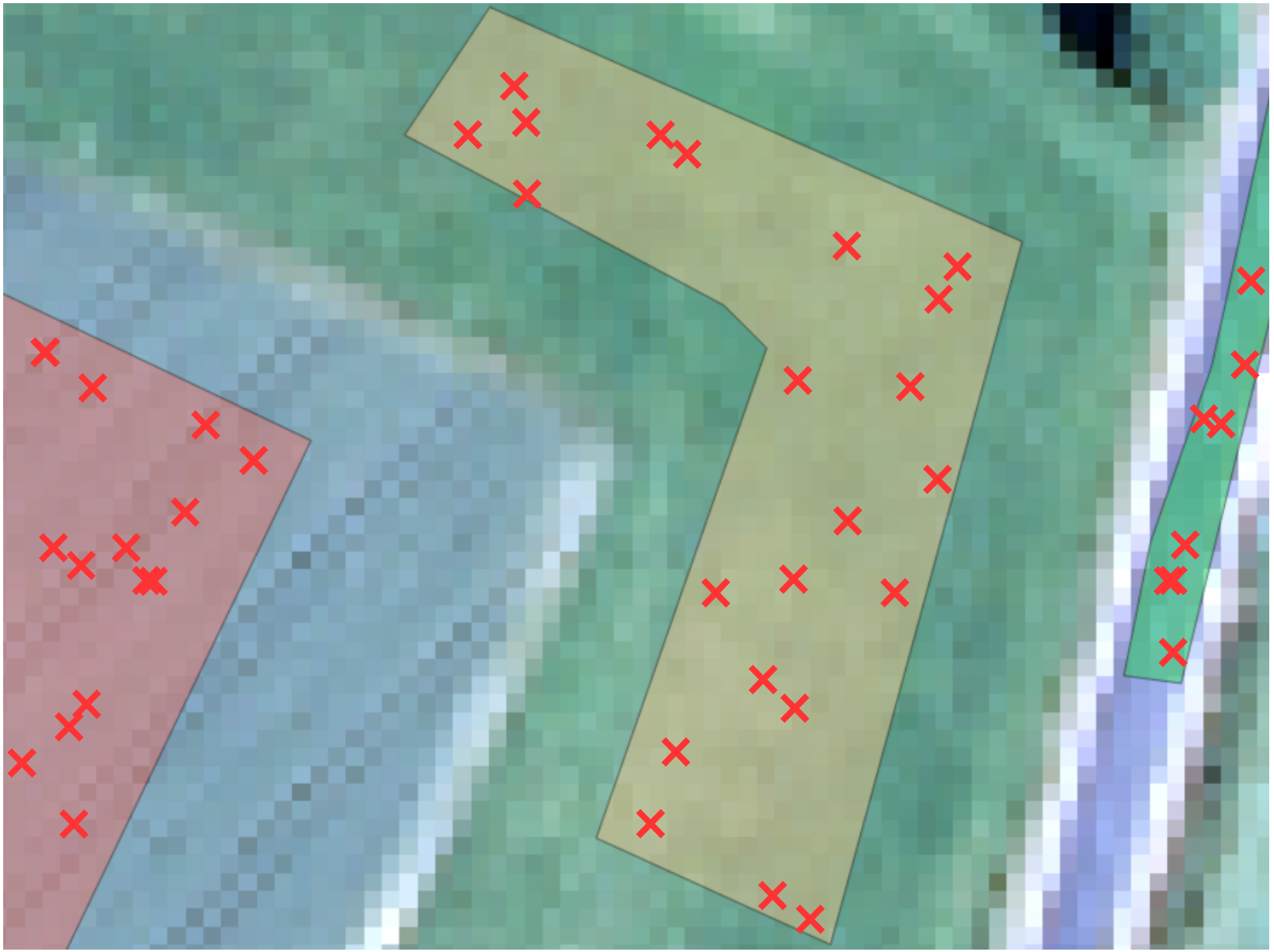
3962 samples
  16 predictor
   9 classes: 'Feld_bepfl', 'Feld_unbepfl', 'Gewaesser', 'Laubwald', 'Mischwald', 'Na
nat_Feuchtw', 'Siedlungsgebiet', 'StrGruenland'

No pre-processing
Resampling: Cross-Validated (10 fold)
Summary of sample sizes: 3566, 3565, 3567, 3565, 3566, 3565, ...
Resampling results across tuning parameters:

  mtry  Accuracy   Kappa
   2    0.9512871  0.9426287
   9    0.9545617  0.9465151
  16    0.9507795  0.9420838

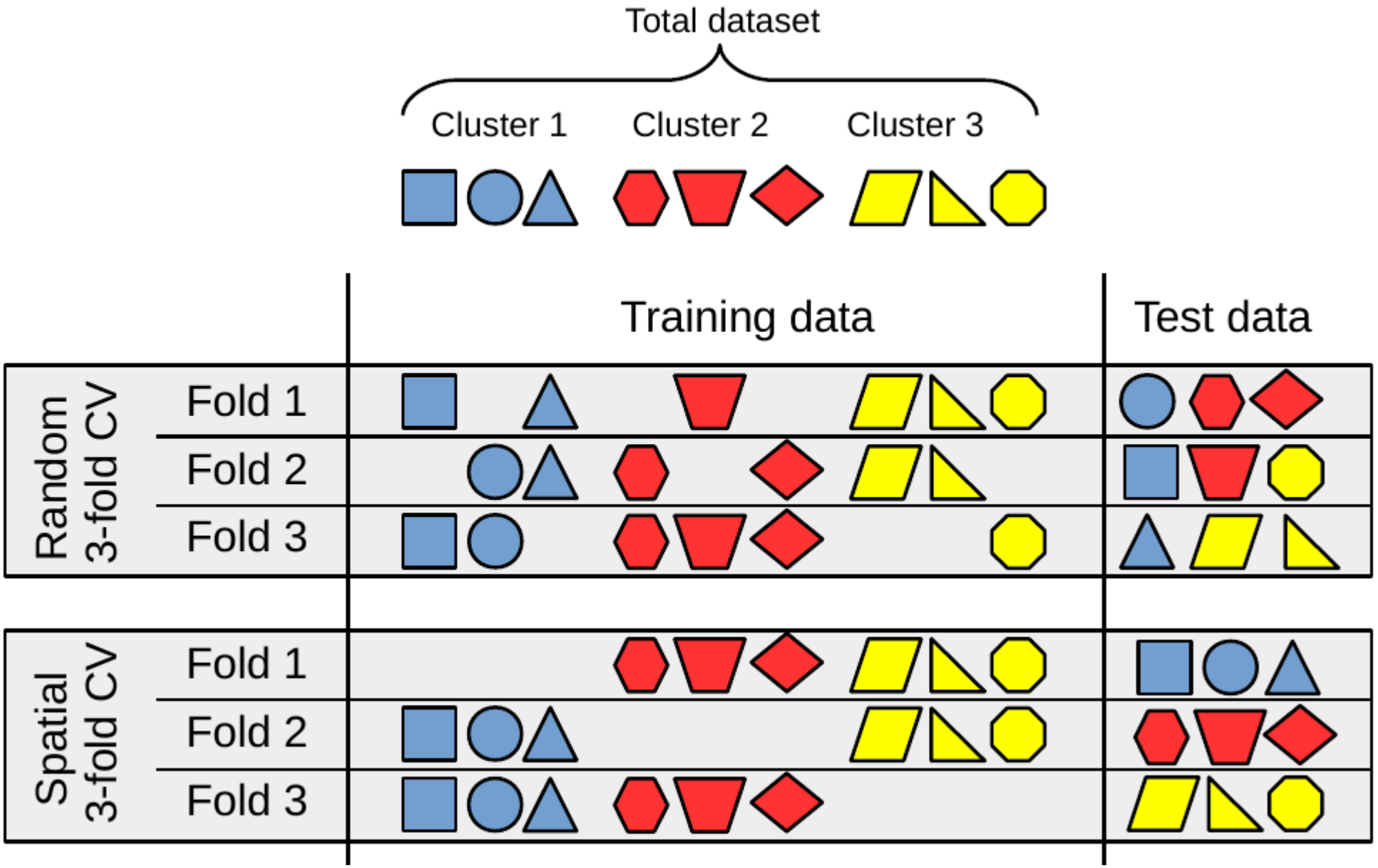
Kappa was used to select the optimal model using the largest value.
The final value used for the model was mtry = 9.
```

“Default” random cross-validation



Model validation

Spatial cross-validation



Spatial cross-validation

How to do it in R

```
library(CAST)
indices <- CreateSpacetimeFolds(trainingData,
                                spacevar="Station")
model <- train(predictors,
               response,
               method="rf",
               trControl=trainControl(method="cv",
                                      index = indices$index))
```

PolygonID/
Spatial block/...

```
> model
Random Forest

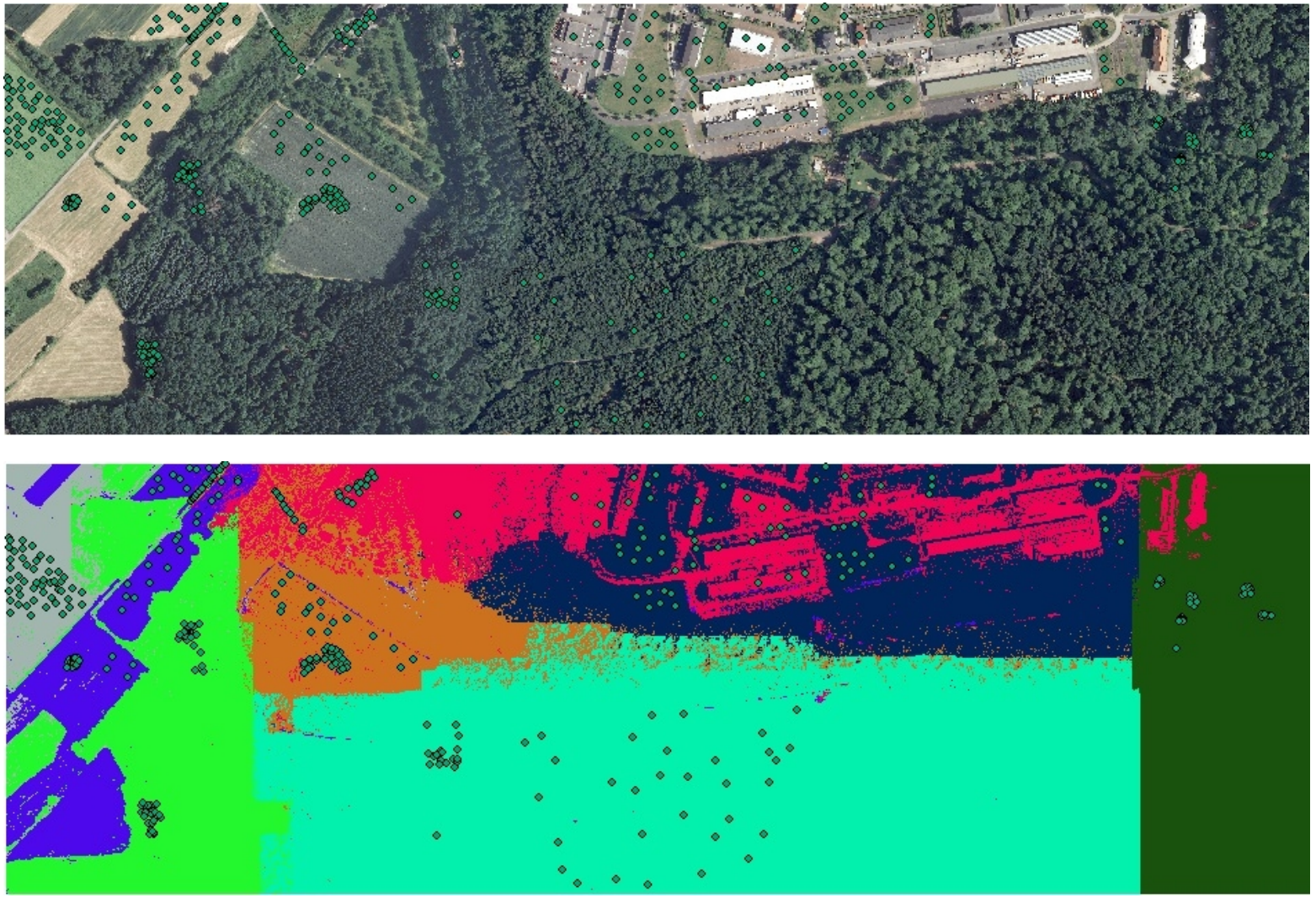
3962 samples
  16 predictor
   9 classes: 'Feld_bepfl', 'Feld_unbepfl', 'Gewaesser', 'Laubwald', 'Mischwald', 'Nadelwald', 'Re
nat_Feuchtw', 'Siedlungsgebiet', 'StrGruenland'

No pre-processing
Resampling: Cross-Validated (10 fold)
Summary of sample sizes: 3650, 3626, 3483, 3785, 3768, 3791, ...
Resampling results across tuning parameters:

  mtry  Accuracy   Kappa
   2    0.6110833  0.4846005
   9    0.6590675  0.5467704
  16    0.6568454  0.5481304

Kappa was used to select the optimal model using the largest value.
The final value used for the model was mtry = 16.
```

Overfitting due to “unsuitable predictors”



https://gis.stackexchange.com/questions/111932/classified-images-of-randomforest-classification-look-clustered

Spatial variable selection

How to do it in R

```
library(CAST)
indices <- CreateSpacetimeFolds(trainingData,
                                spacevar="Station")
model <- ffs(predictors,
             response,
             method="rf",
             trControl=trainControl(method="cv",
                                    index = indices$index))
```

```
> model
Random Forest

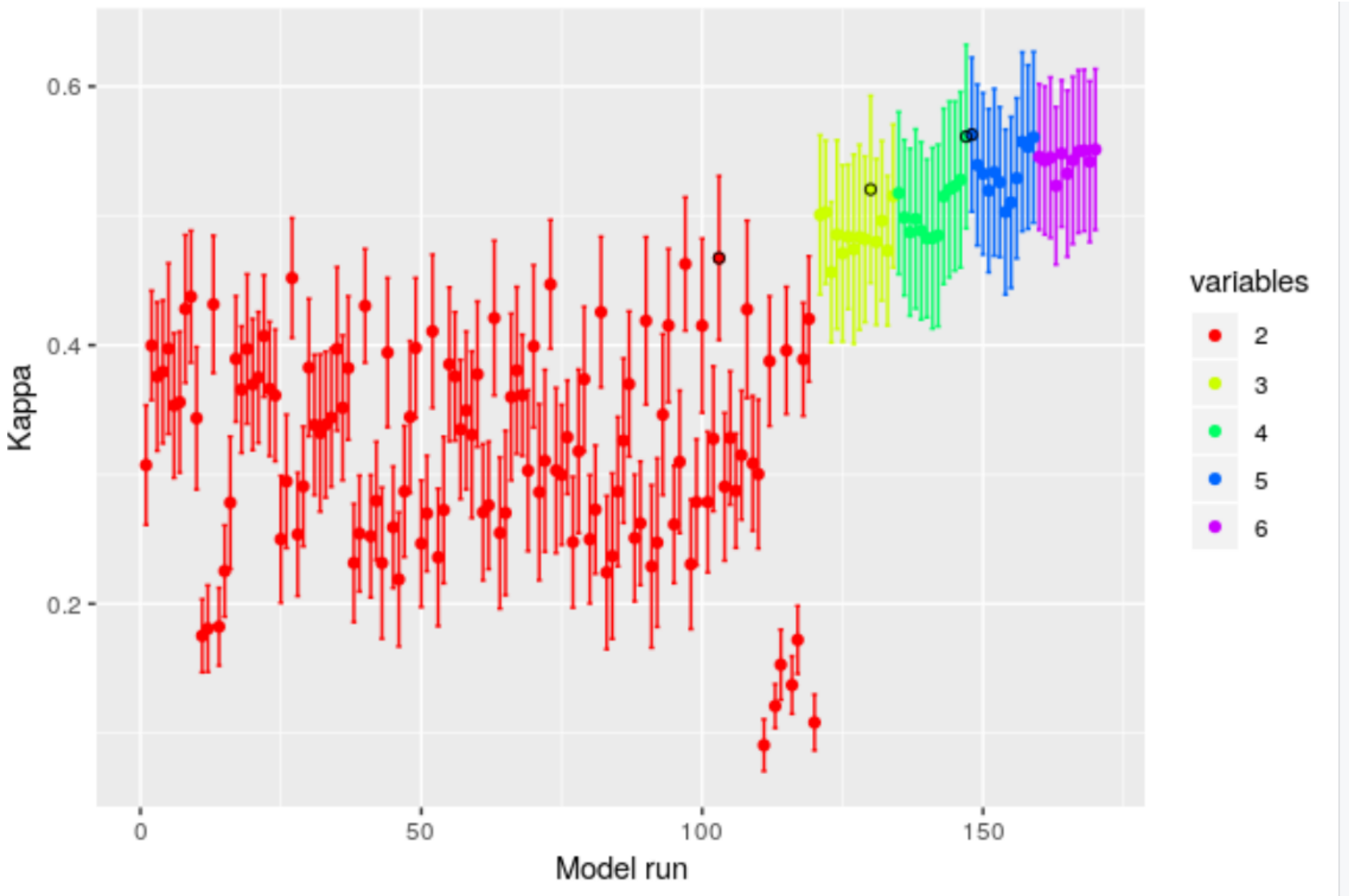
3962 samples
   5 predictor
   9 classes: 'Feld_bepfl', 'Feld_unbepfl', 'Gewaesser', 'Laubwald', 'Mischwald',
nat_Feuchtw', 'Siedlungsgebiet', 'StrGruenland'

No pre-processing
Resampling: Cross-Validated (10 fold)
Summary of sample sizes: 3650, 3626, 3483, 3785, 3768, 3791, ...
Resampling results:

  Accuracy   Kappa
  0.6702505  0.5626794

Tuning parameter 'mtry' was held constant at a value of 1
```

Spatial variable selection



Summary

That's what we need to avoid!

https://xkcd.com/1838/

From the theory to practice...

Practice

- Basic model training for land cover classification
- Spatial cross-validation
- Spatial variable selection

→ Slides and material: https://github.com/HannaMeyer/OpenGeoHub_2019