Identification of vulnerable zones for nitrogen leaching in arable land using airborne hyperspectral and space borne multispectral data

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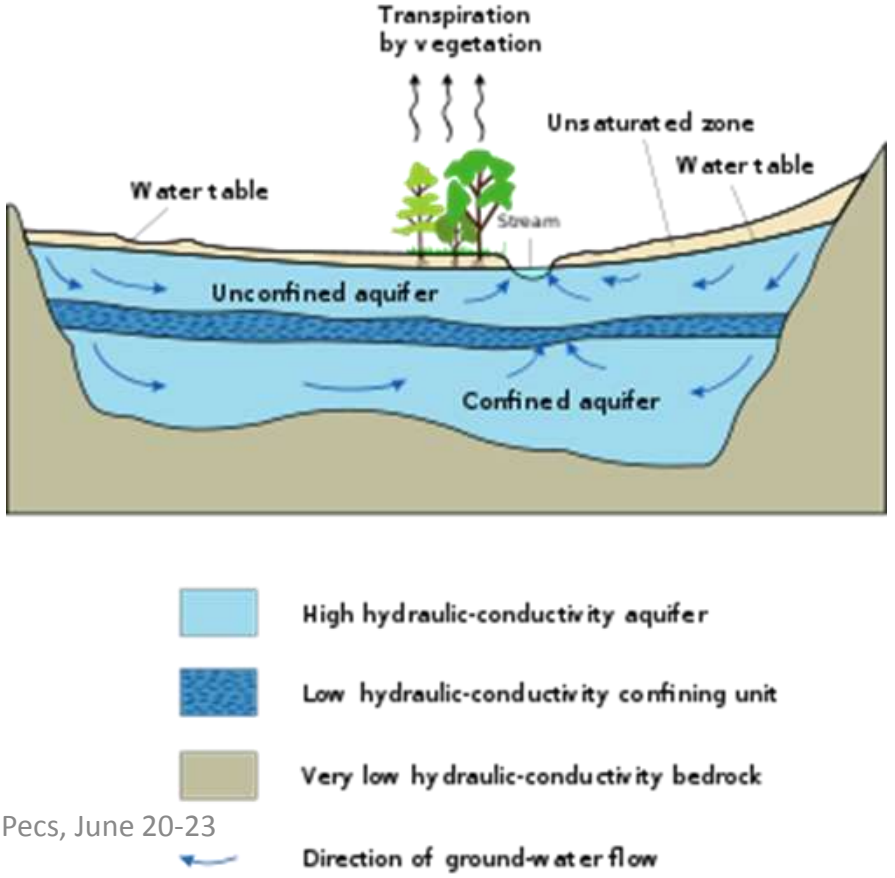
Motivation

Protection of ground water for drinking from pollution caused by i**ntensive agriculture practices on arable land** in the areas feeding aquifers - **leaching of pesticides and fertilizers** (**nitrogen**)



Objectives

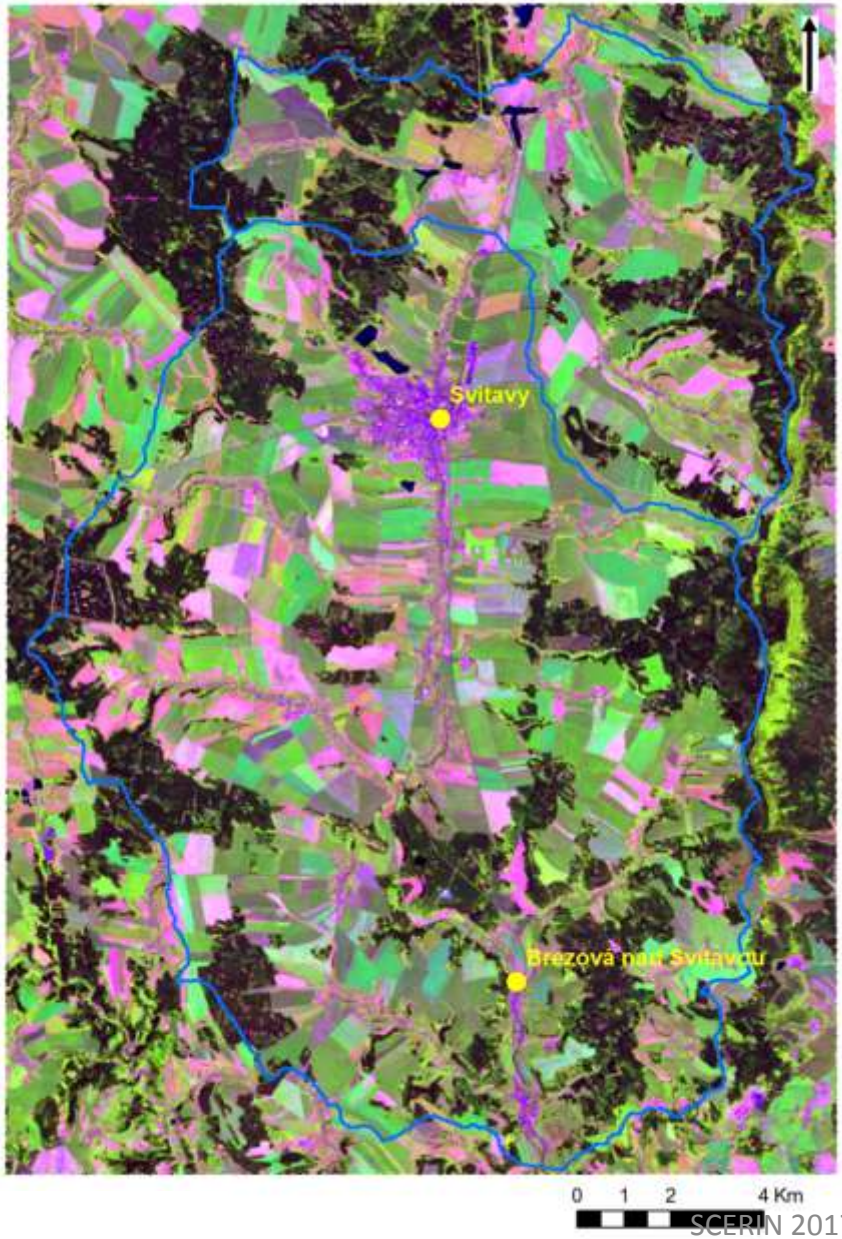
To identify the **areas with high risk of N leaching** to underground water in arable land - cca 200 km^2

Hypothesis

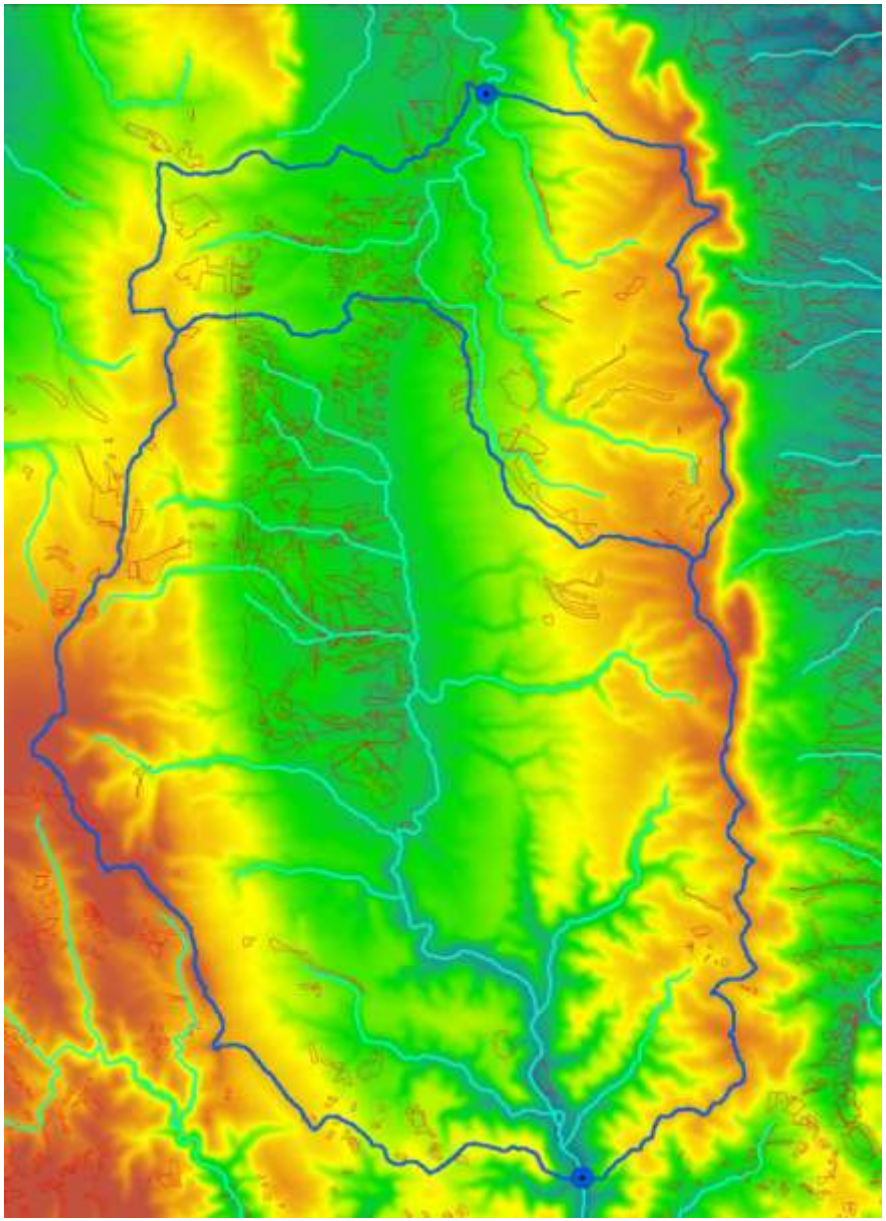
Potential sites where nitrogen can leach to underground water identified **from geological and soil properties** are related with **spectral features of wheat canopy derived from airborne hyperspectral and/or Sentinel-2 data**

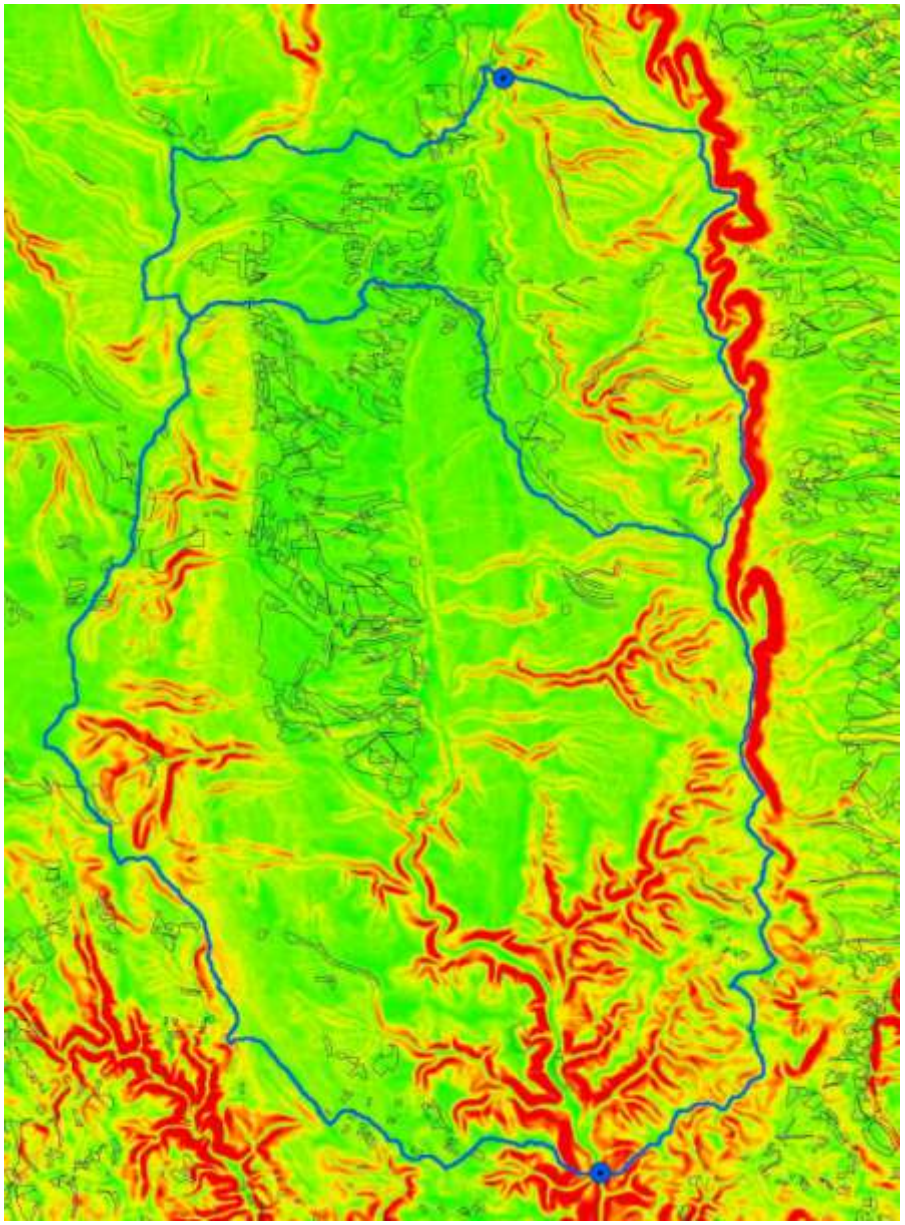

Poland
Czech Republic
Germany
Slovakia
Austria

Landsat TM5 1986



Sentinel-2 2016





Elevation [m]

771,204

314,449

Slope [°]

40,6

0

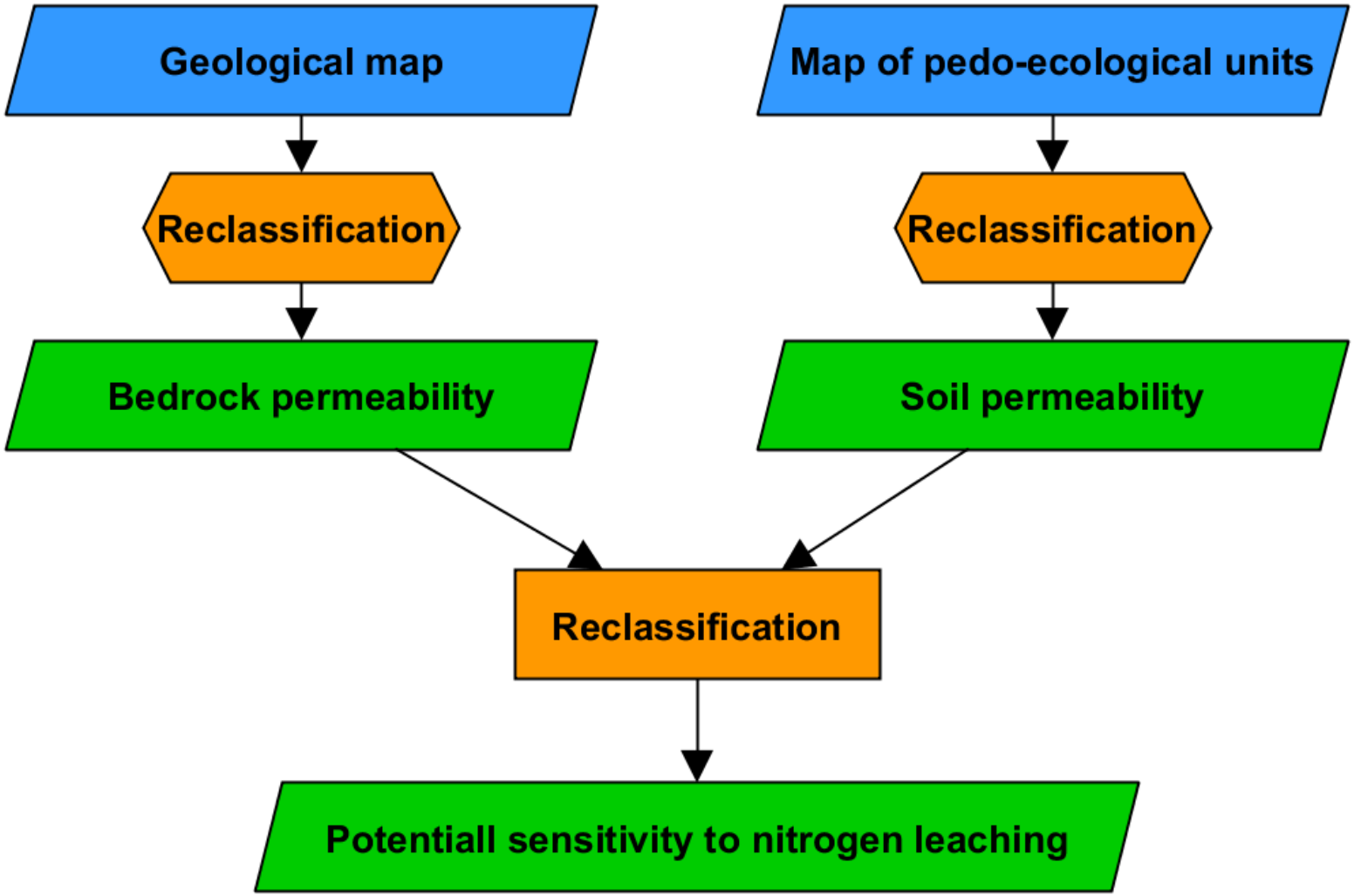
Land use of the watershed

1986

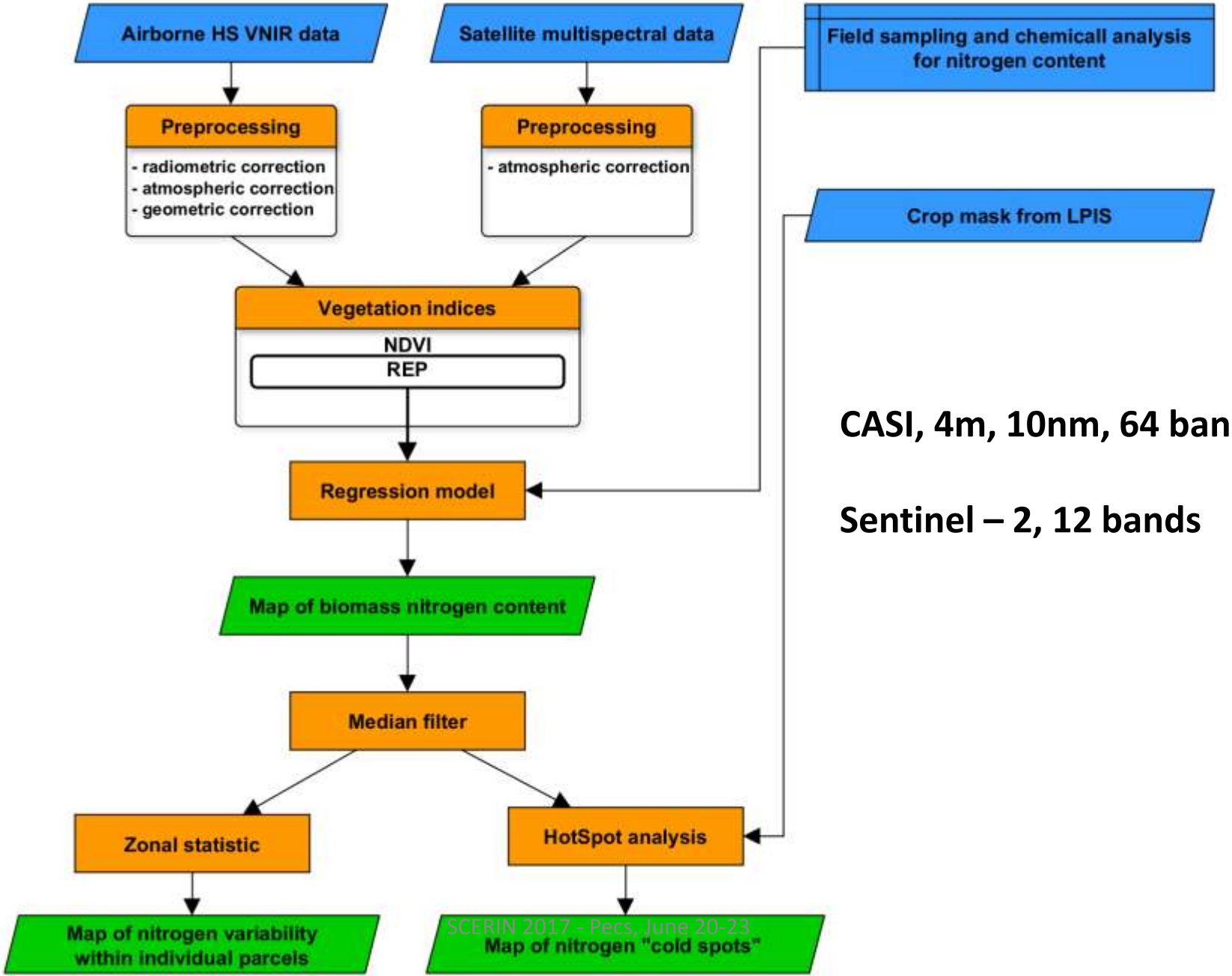
2002

2013

Methods - “conservative” features



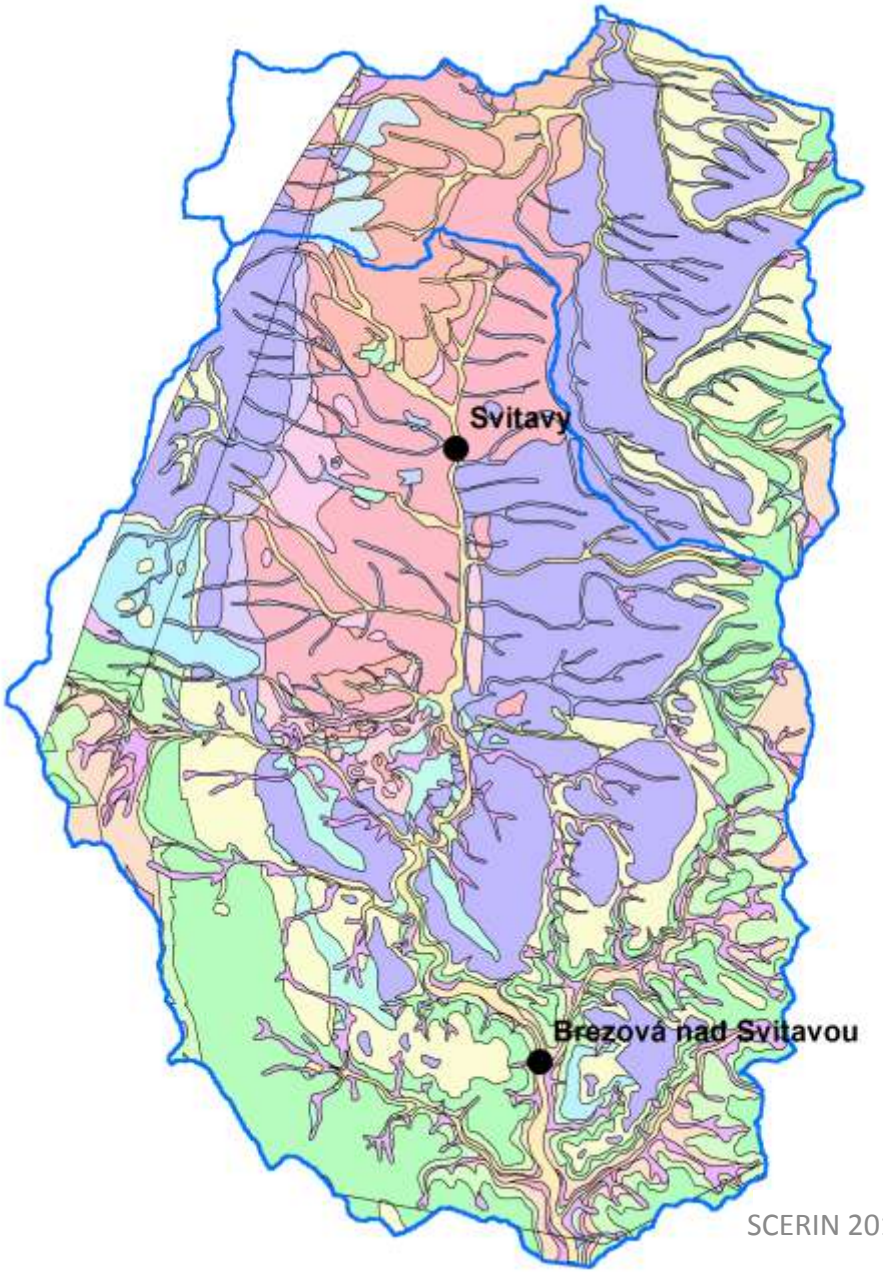
Methods – “dynamic” features



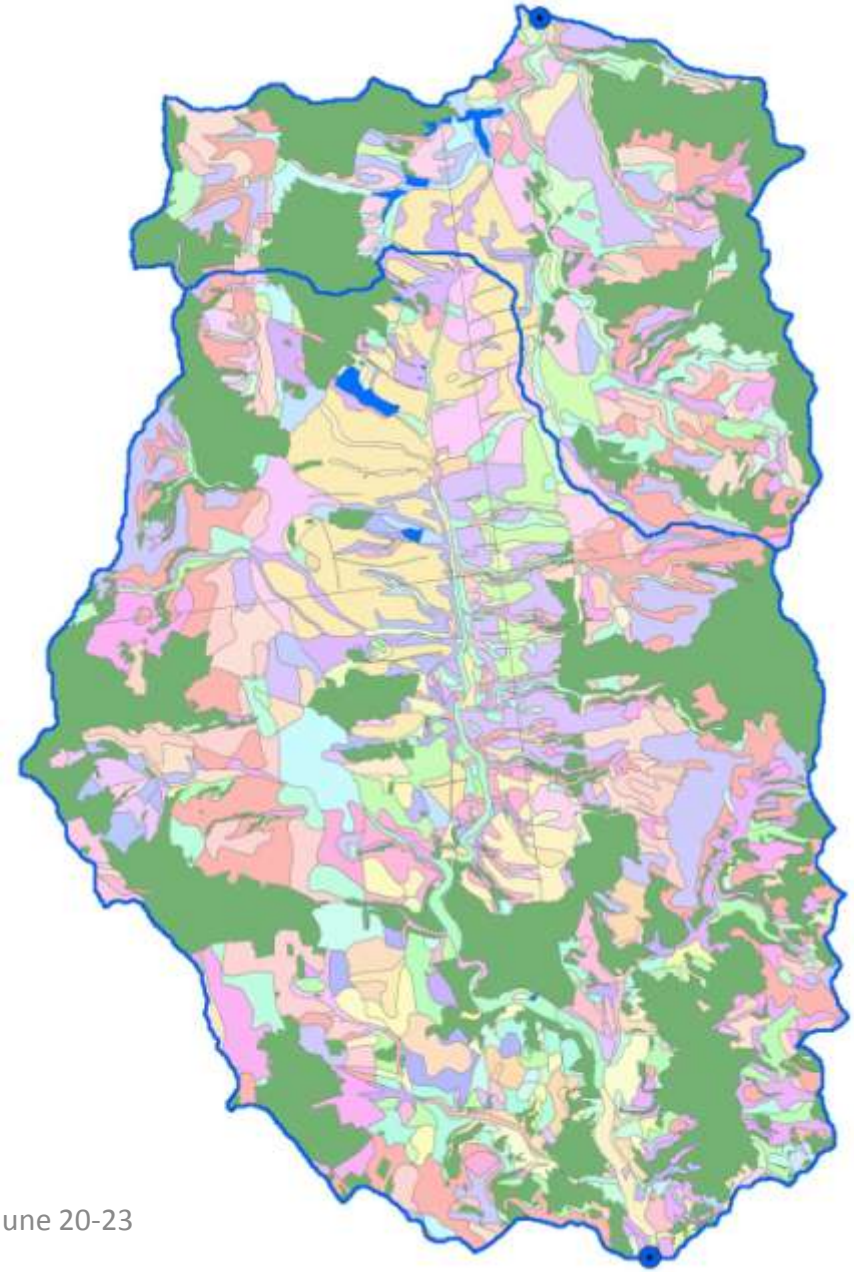
CASI, 4m, 10nm, 64 bands

Sentinel – 2, 12 bands

Map of the bedrock

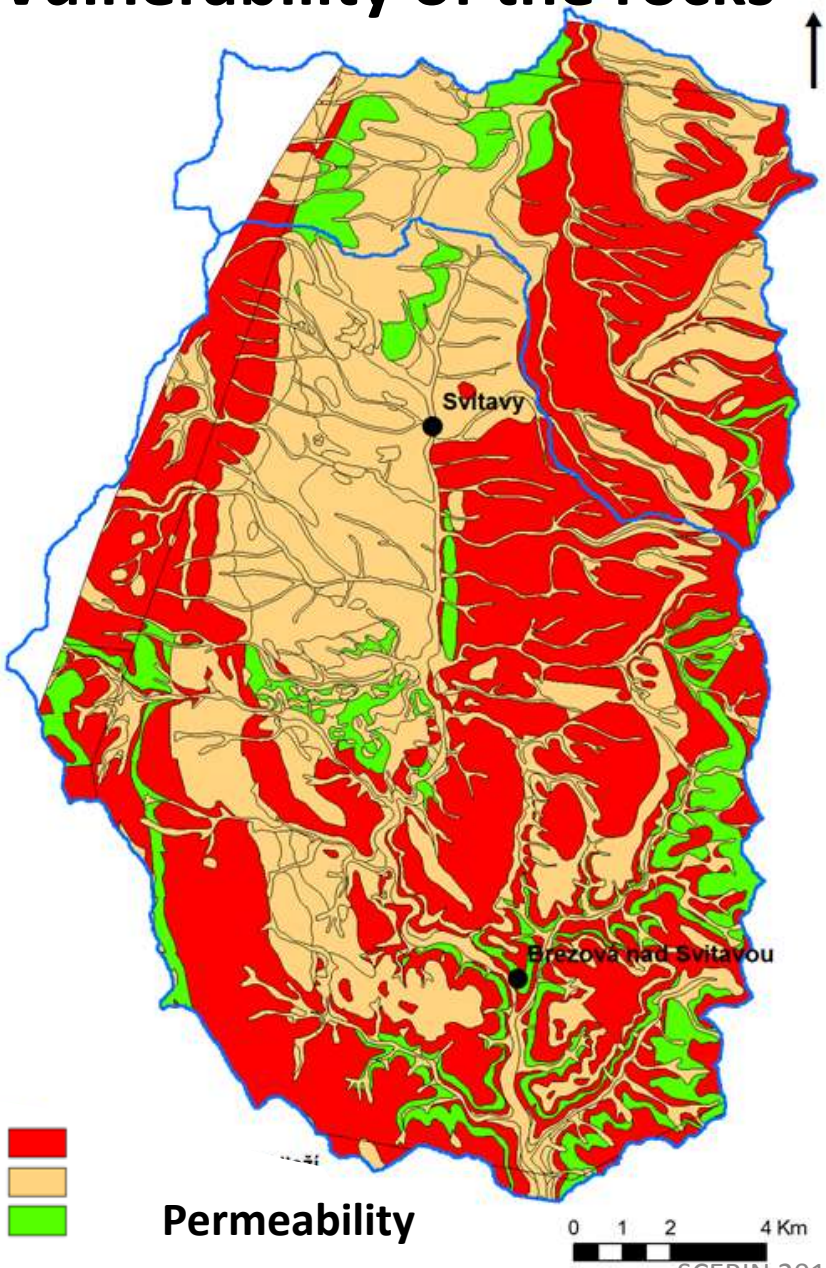


Soil types and forest cover

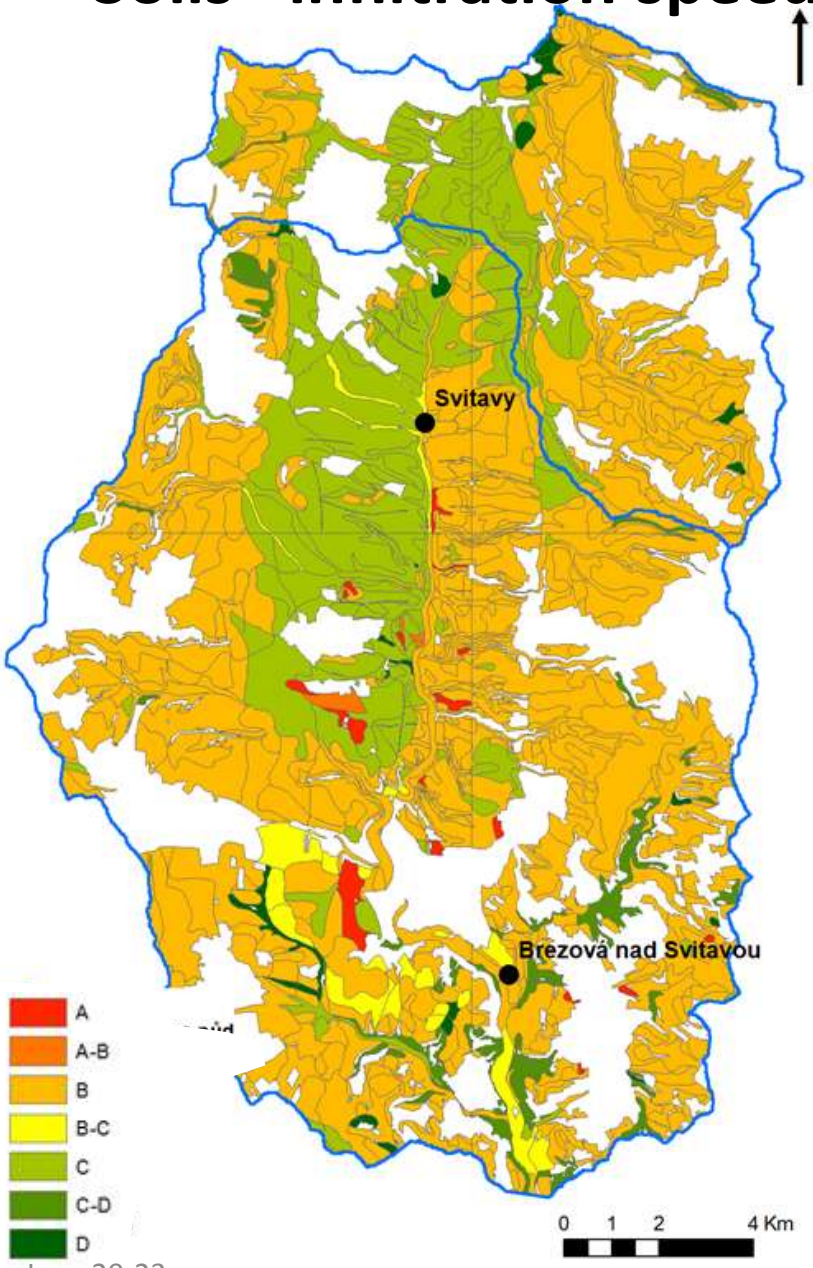


Hydraulic properties of soils	Class
High infiltration (> 0,12 mm.min^{-1}) – deep sand and gravel	A
Medium infiltration (0,06 - 0,12 mm.min^{-1}) - deep and medium deep soils, well drained, loamy and sandy soil	B
Low infiltration(0,02 - 0,06 mm.min^{-1}) - silt and silty-clay soil	C
Very low infiltration (< 0,02 mm.min^{-1}) - clay soils and shallow soils above unpermeable bedrock	D

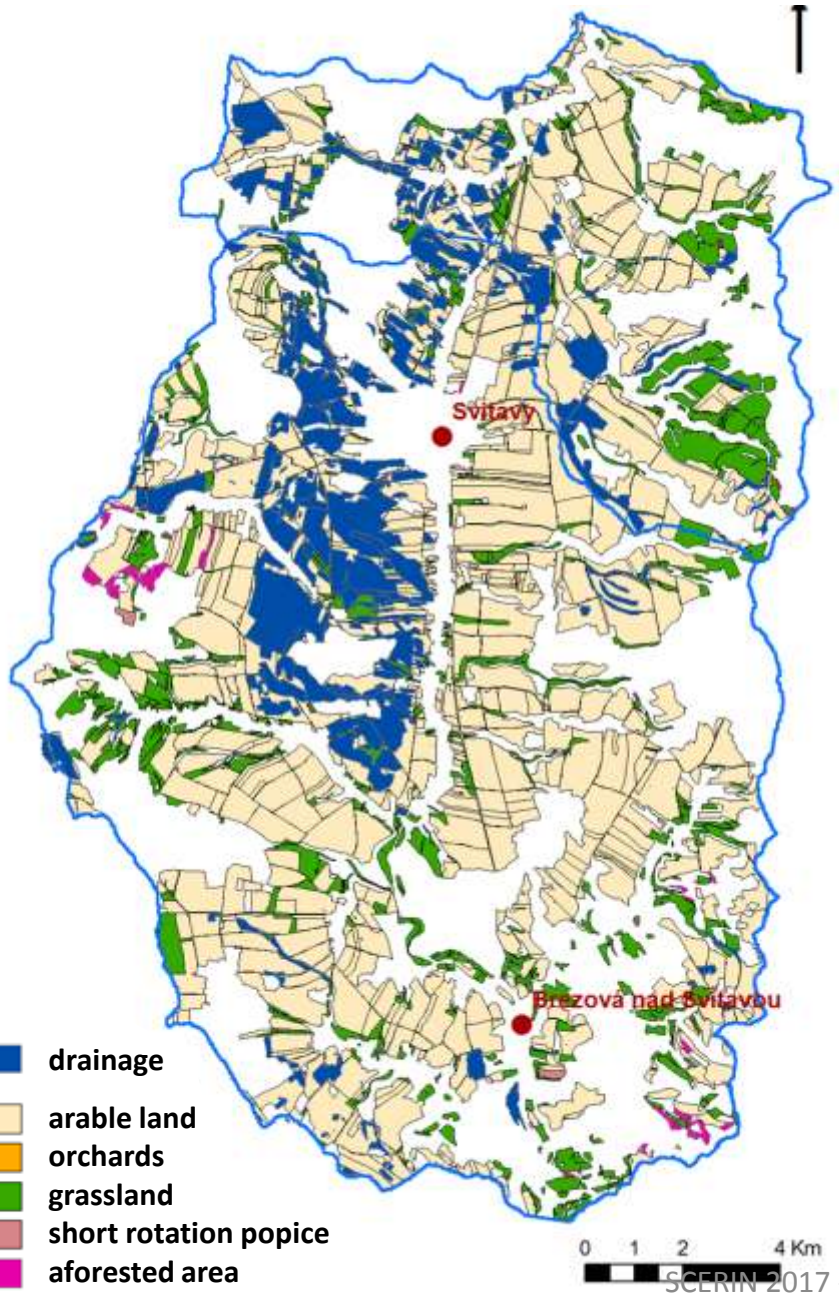
Vulnerability of the rocks



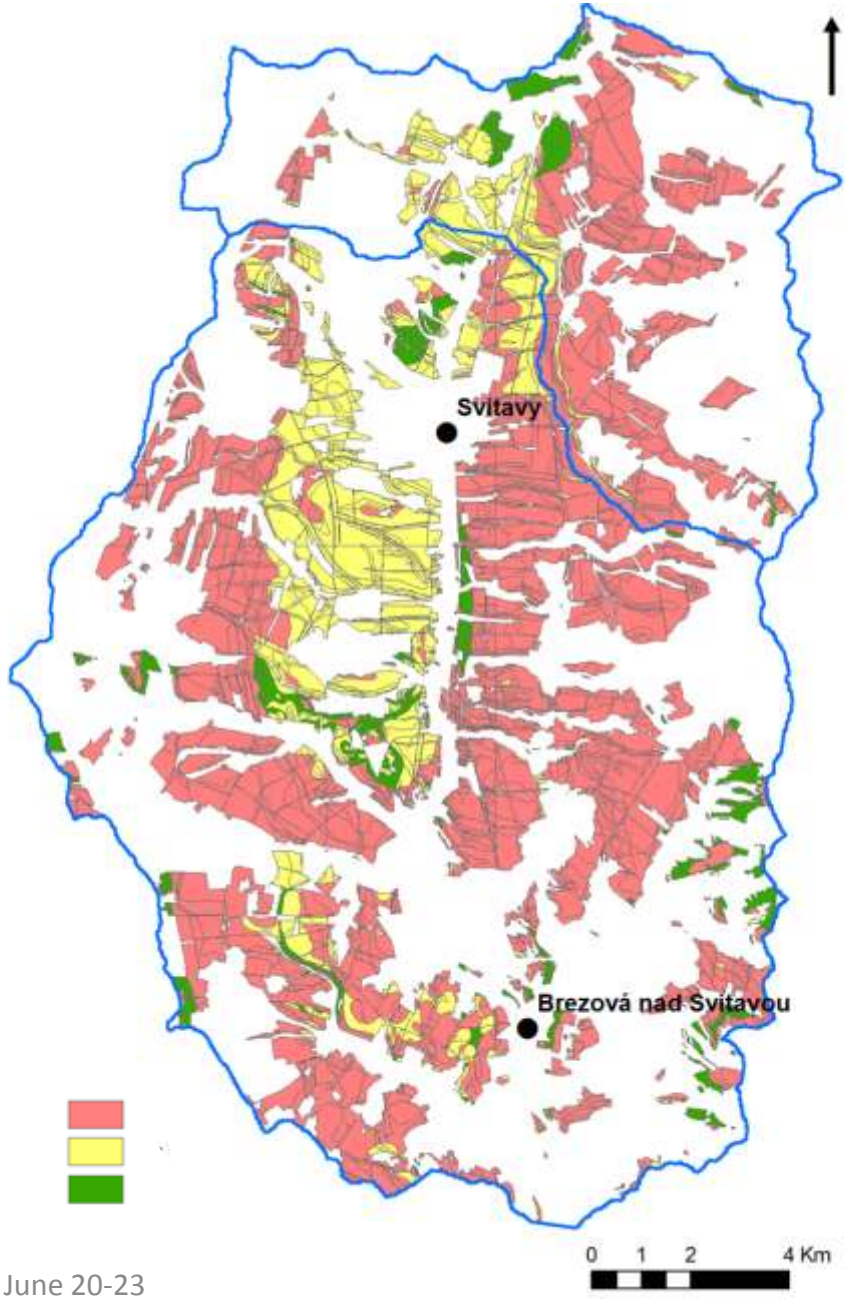
Soils– infiltration speed



Categories of land use and drainage



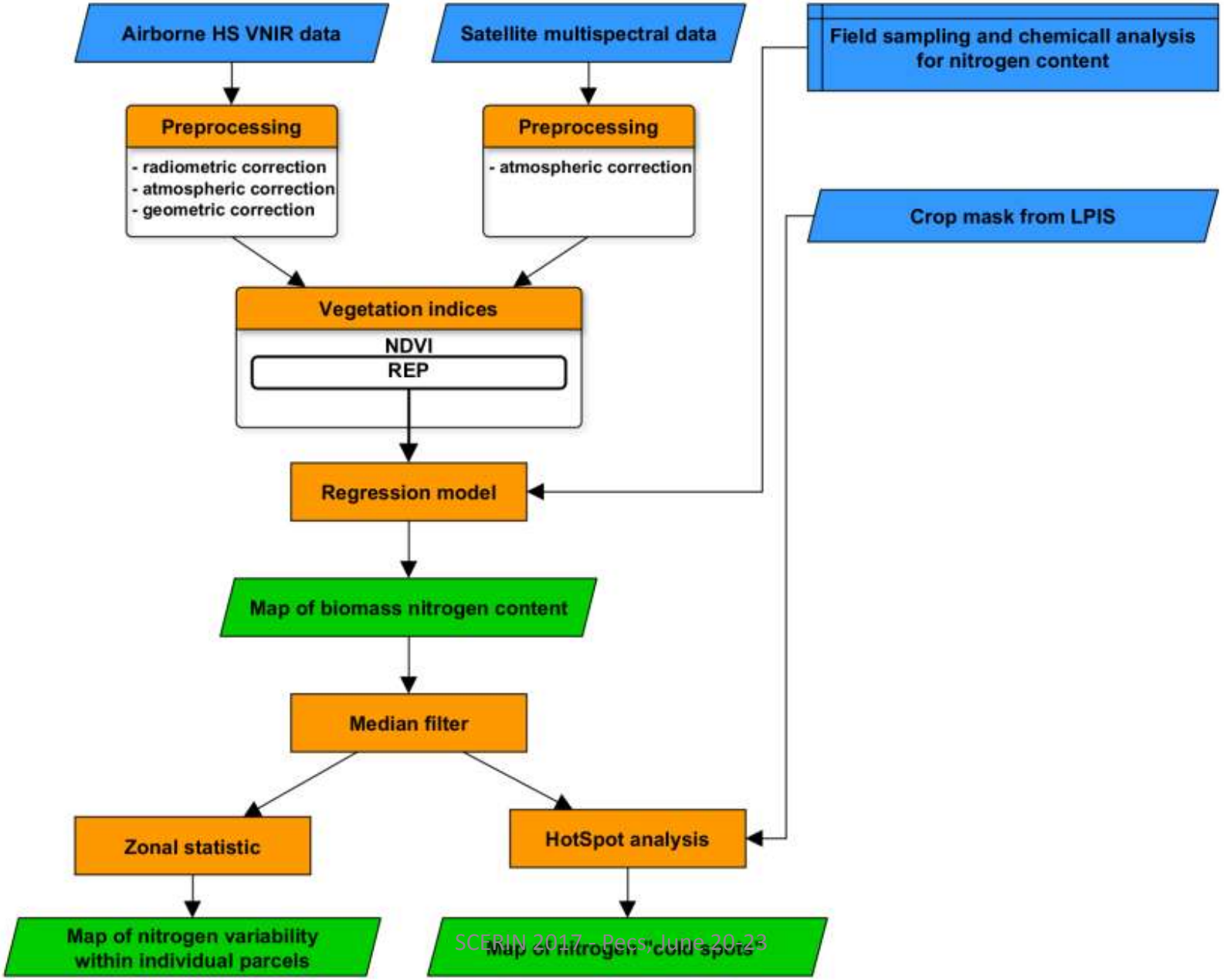
Vulnerable zone areas



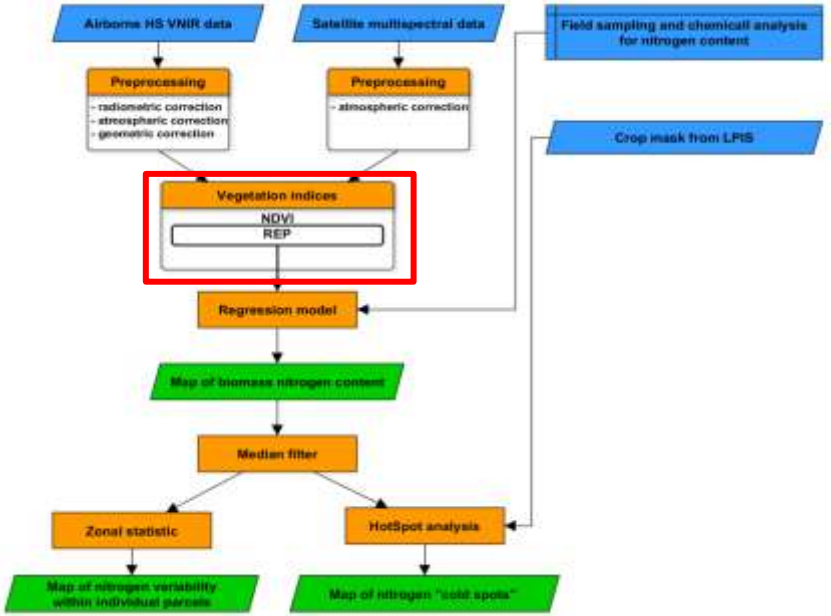
Extent of vulnerable area in arable land

Vulnerability of rocks	Vulnerability of soil	Degree of vulnerability	Arable land [%]	Drained soils [%]
1	A, B, A-B	high	**71,53**	21,28
2	B-C, C	medium	**21,81**	41,23
3	C-D, D	low	6,67	6,85

Heterogeneity in blocks - N content in AGB

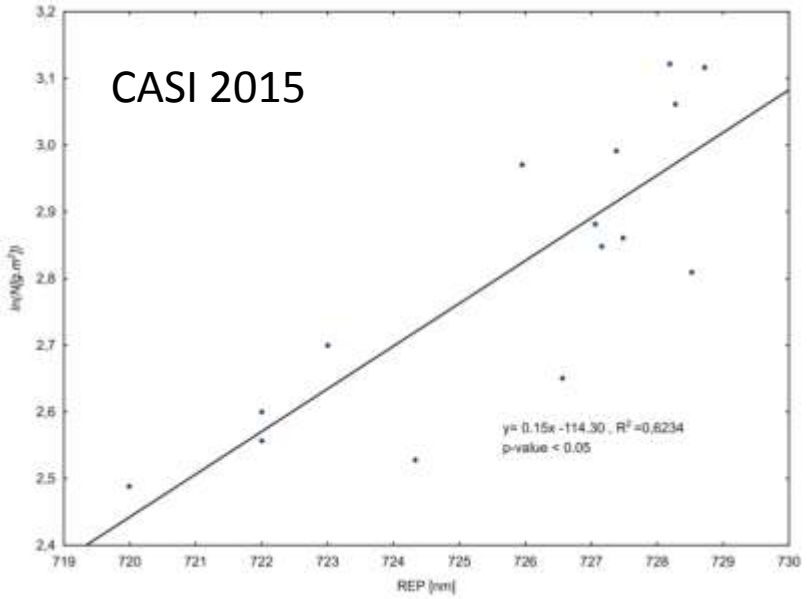


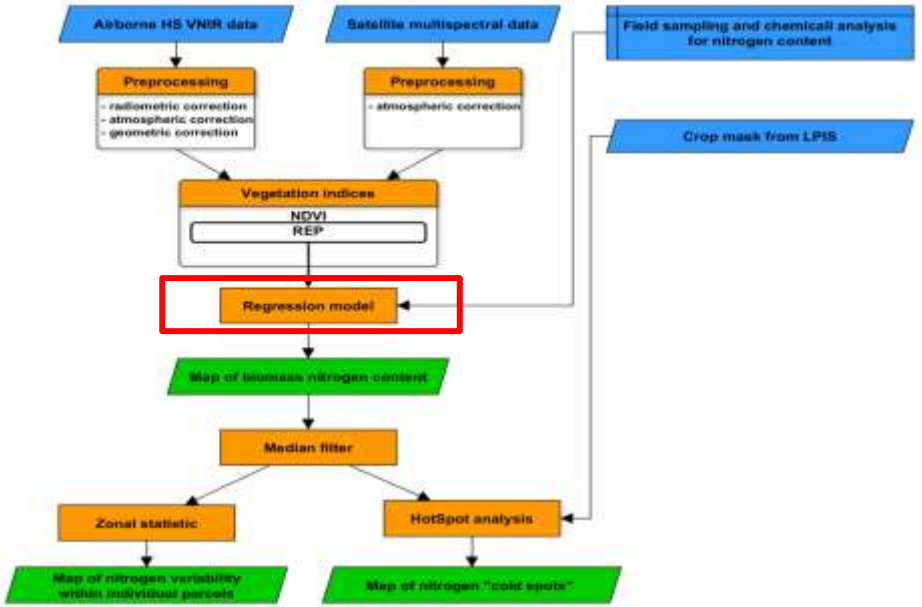
Regression models: N vegetation indices x chemical analyses



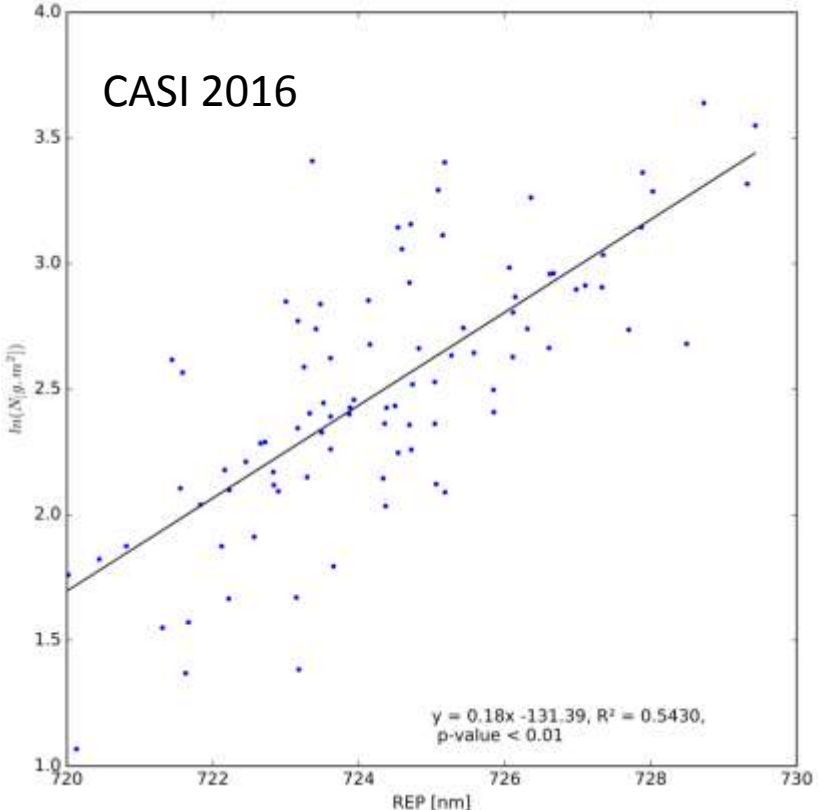
$NDVI = \frac{R_{B8} - R_{B4}}{R_{B8} + R_{B4}}$	(Rouse et al. 1973)
$REP = 700 + 40\left(\frac{\left(\frac{R_{670} + R_{780}}{2}\right) - R_{700}}{R_{740} - R_{700}}\right)$	(Guyot a Baret 1988)
$REP_{Sen} = 705 + 35\left(\frac{\left(\frac{R_{665} + R_{783}}{2}\right) - R_{705}}{R_{740} - R_{705}}\right)$	(Herrmann et al. 2011)

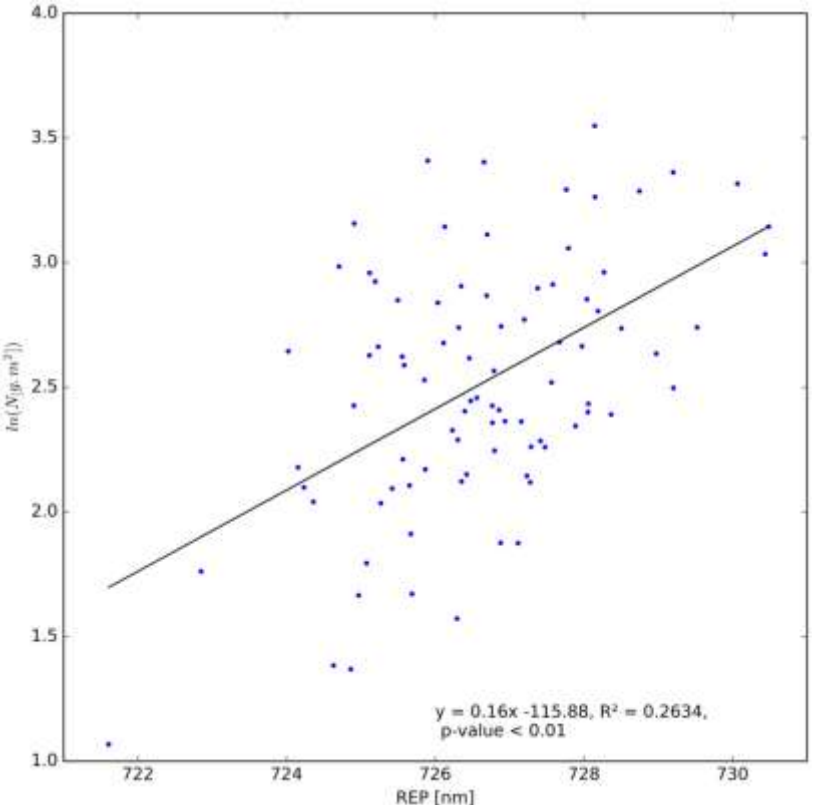
CASI 2015

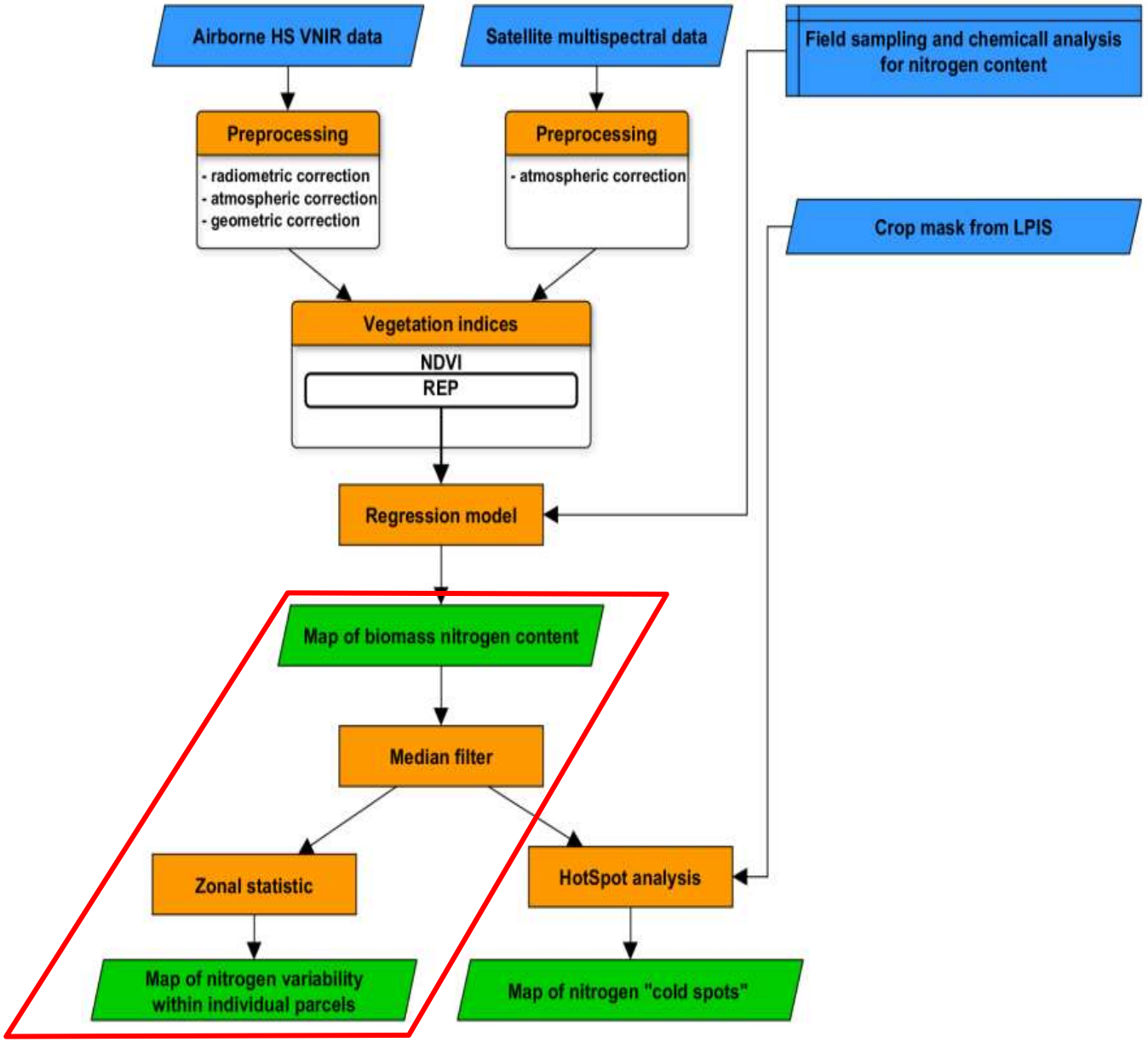




CASI 2016

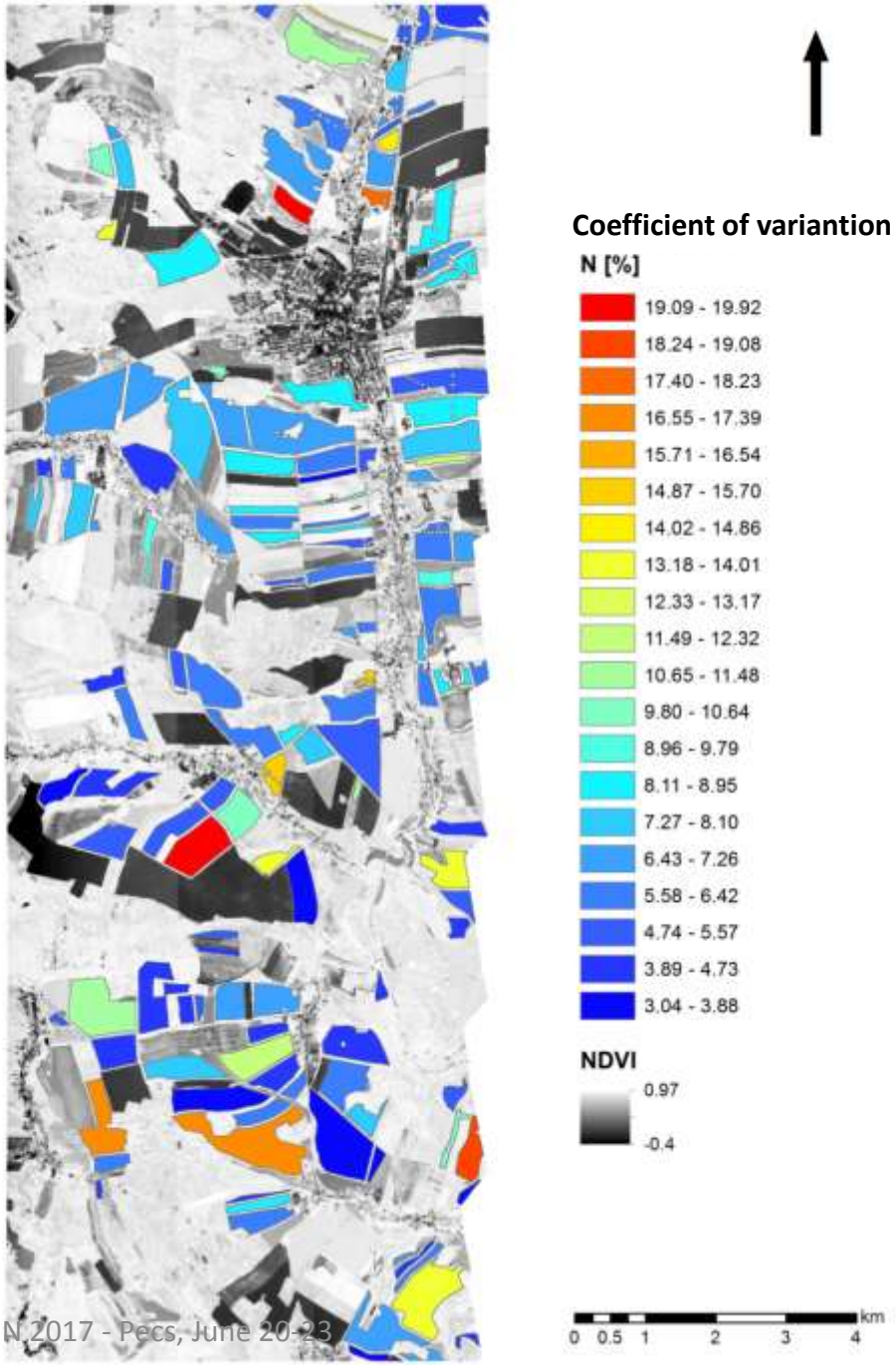





Airborne HS VNIR data
Satellite multispectral data
Field sampling and chemicall analysis for nitrogen content
Preprocessing
- radiometric correction
- atmospheric correction
- geometric correction
Preprocessing
- atmospheric correction
Crop mask from LPIS
Vegetation indices
NDVI
REP
Regression model
Map of biomass nitrogen content
Median filter
Zonal statistic
HotSpot analysis
Map of nitrogen variability within individual parcels
Map of nitrogen "cold spots"

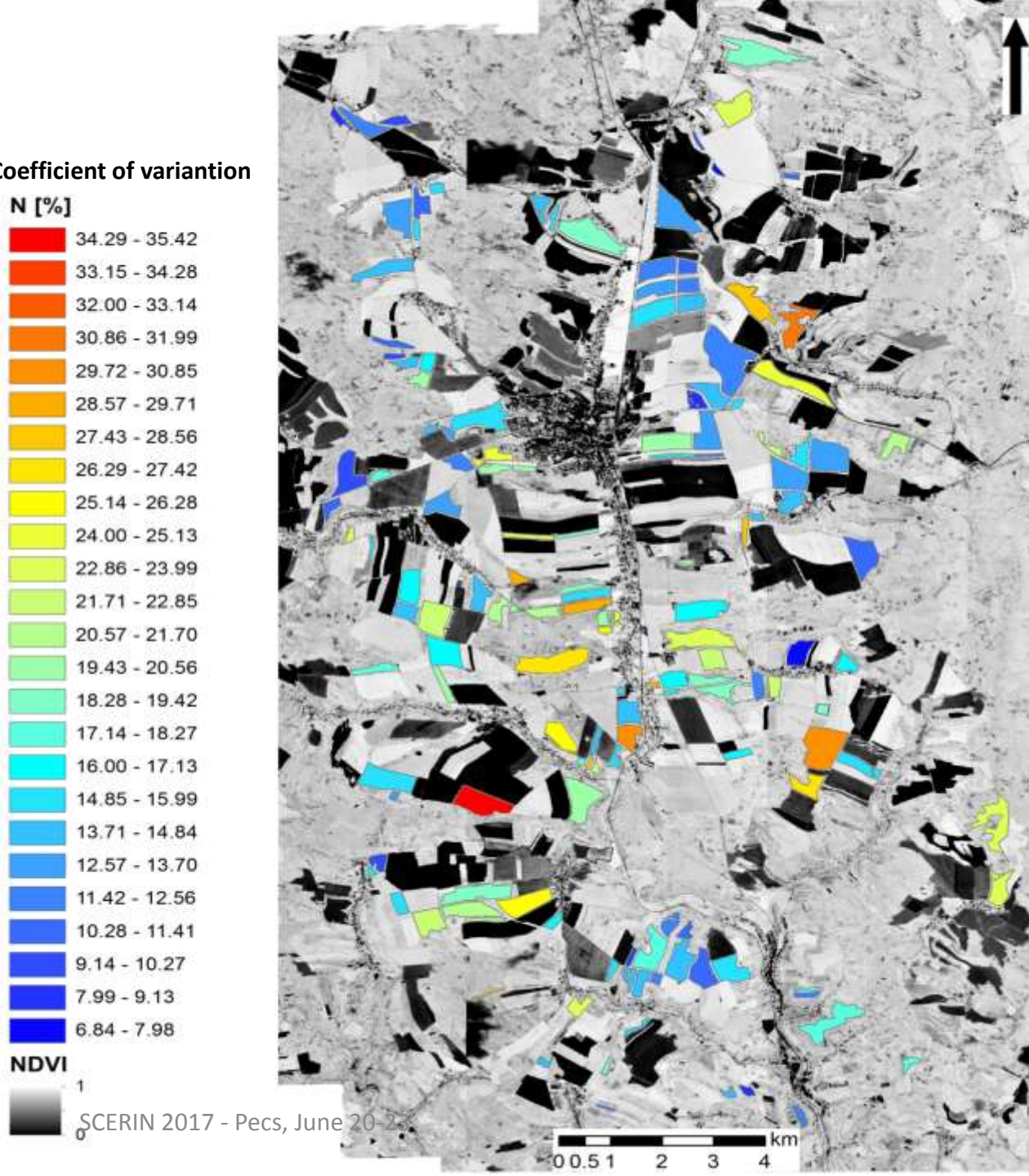
Variability of nitrogen in above ground biomass calculated from regression model, CASI 5. 6. 2015

NDVI – the background

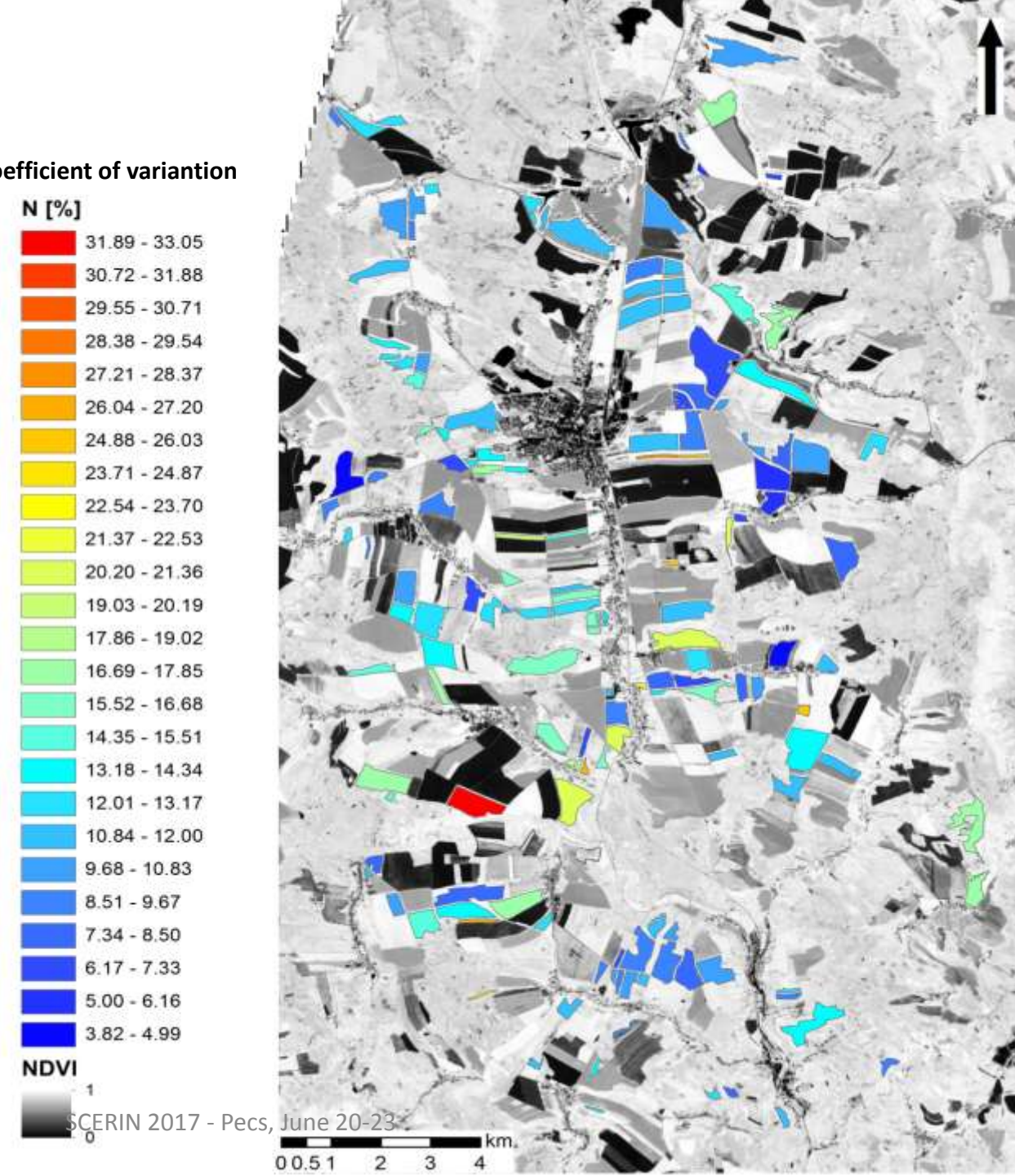


Variability of nitrogen in above ground biomass calculated from regression model CASI 6. 5. 2016

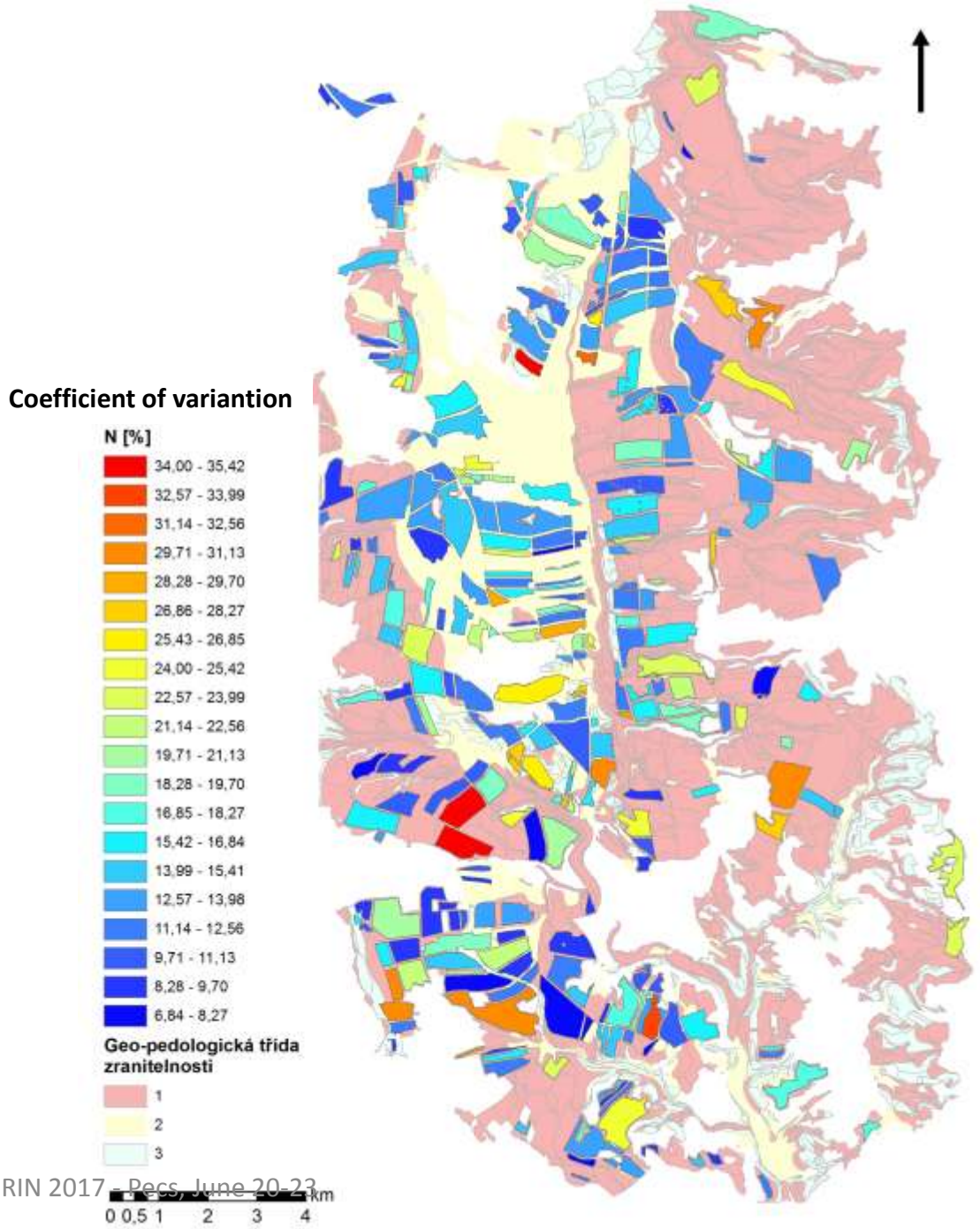
NDVI – the background

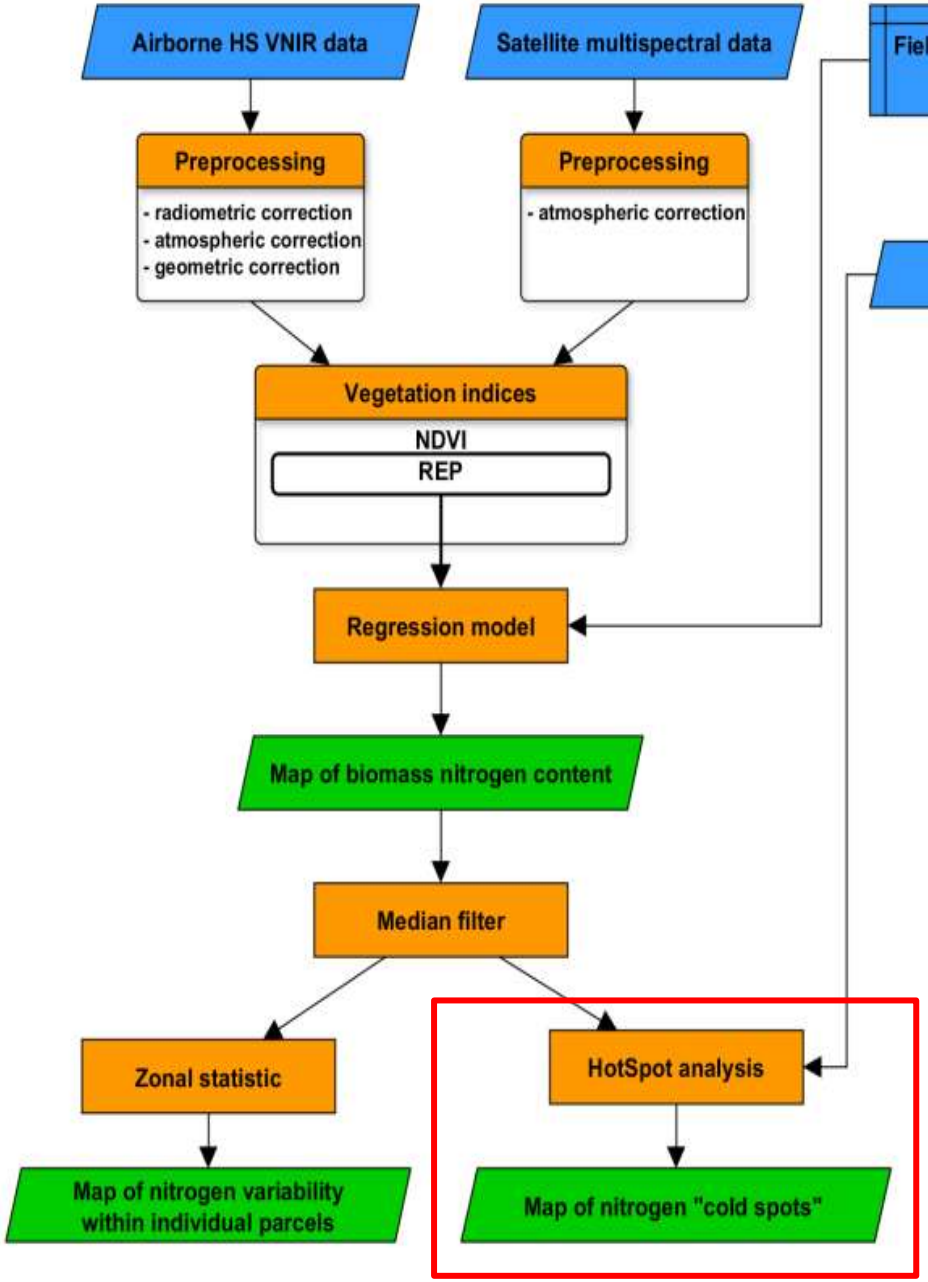


Variability of nitrogen in above ground biomass calculated on regression model Sentinel-2, 23. 5. 2016

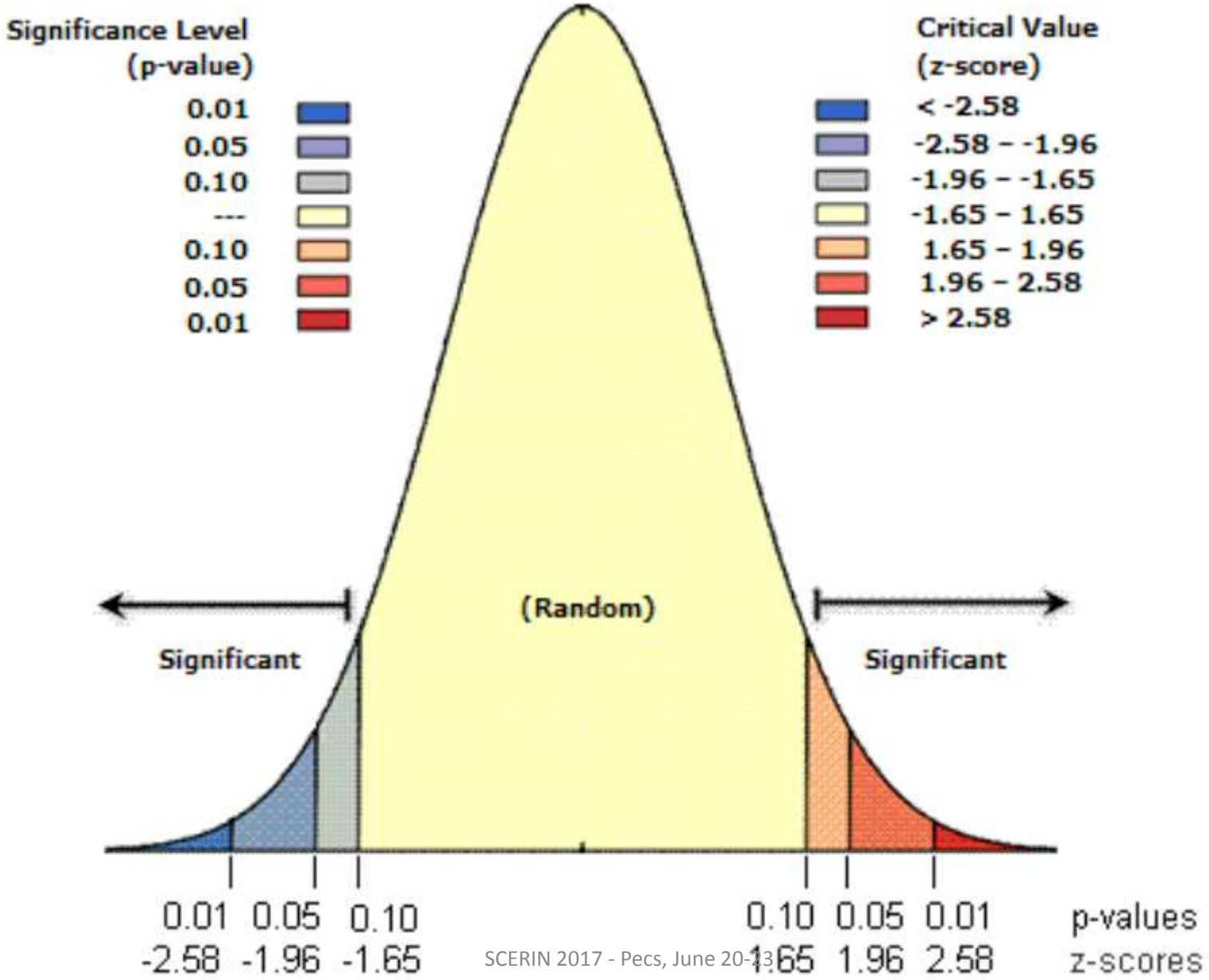


Synthehesis of indicatores for N leaching in arrable land from the rocks and soil propeties, and CASI 2015, 2016 analyses of wheat biomass



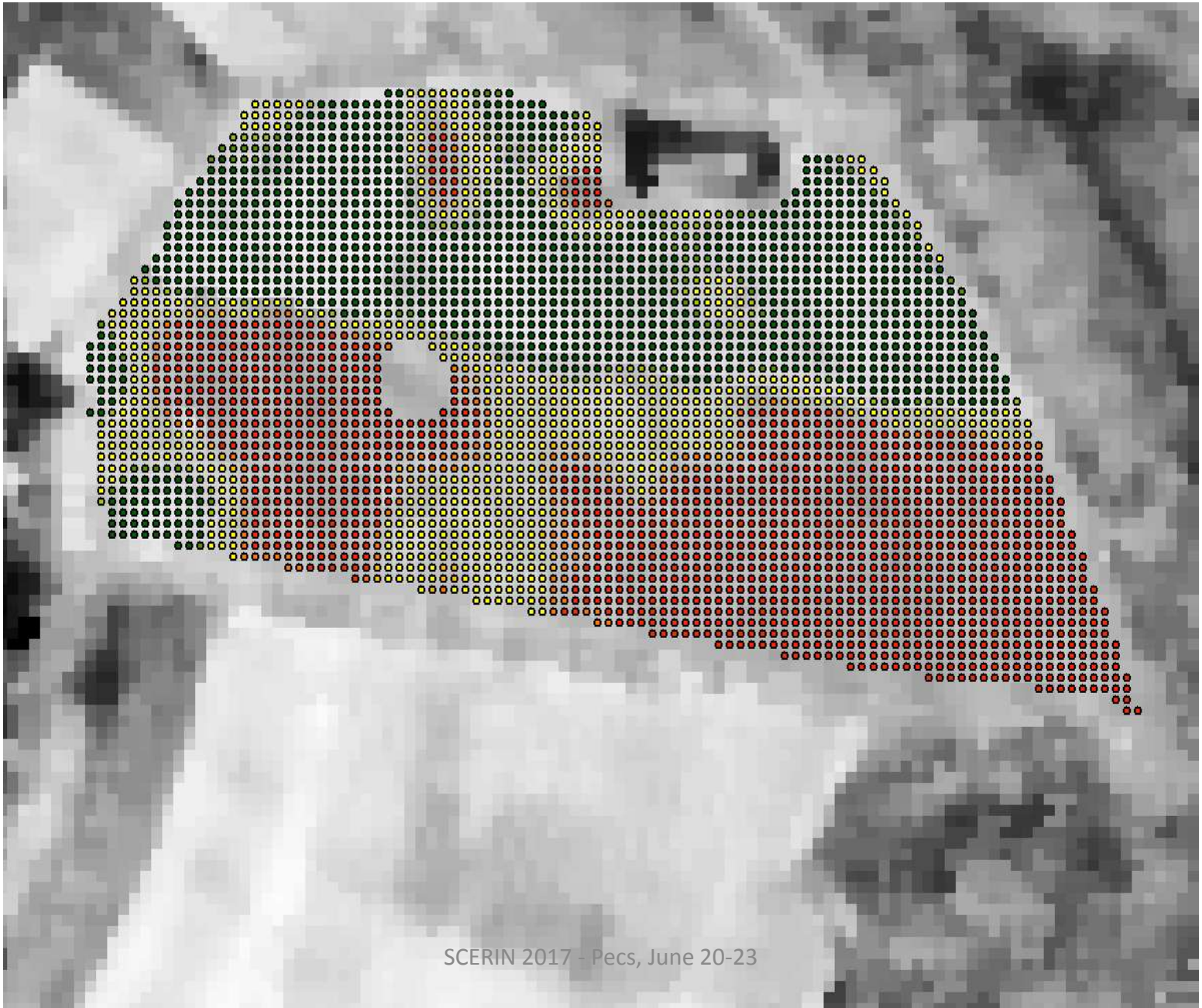


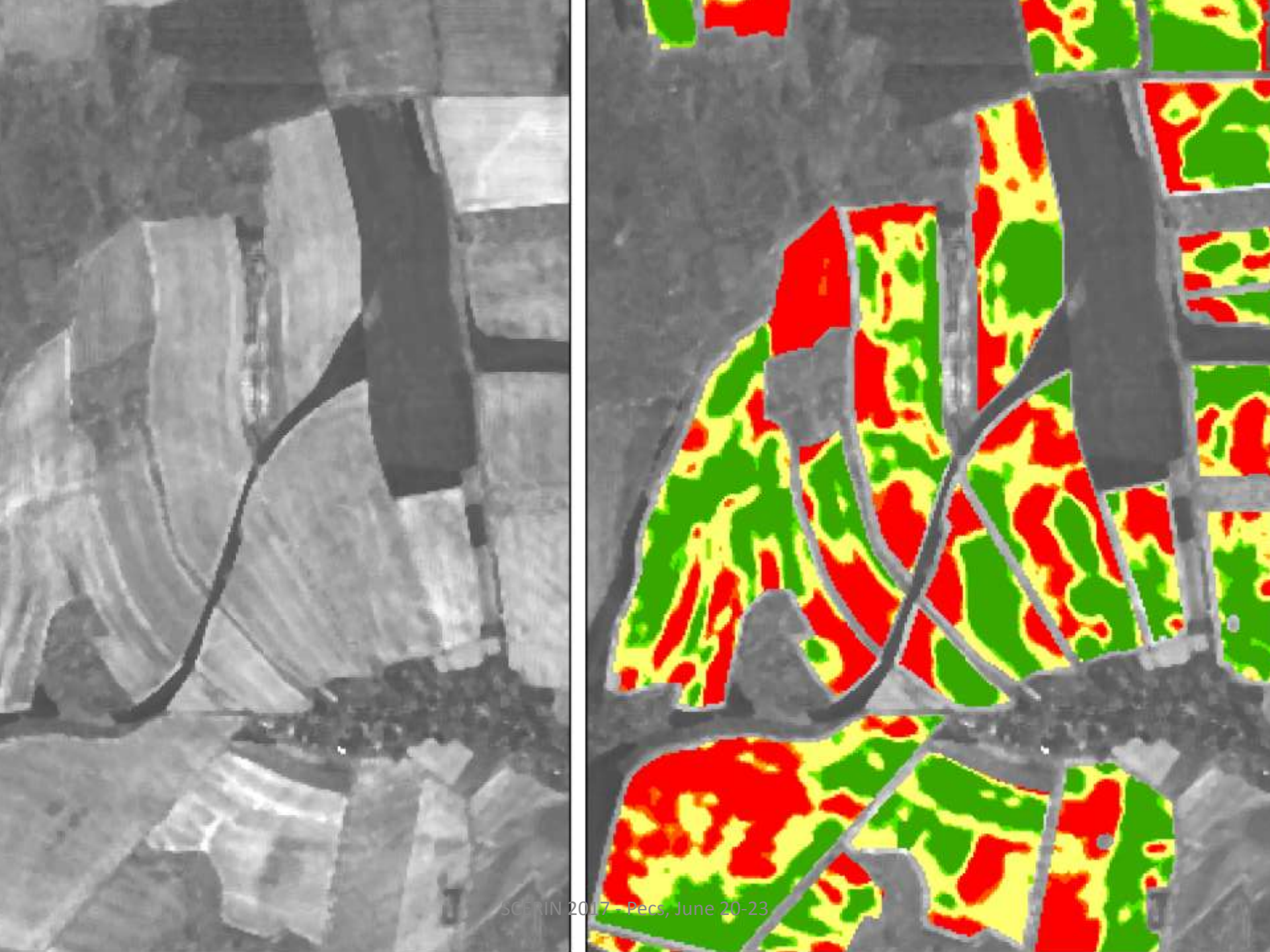
Getis-Ord Gi* statistics

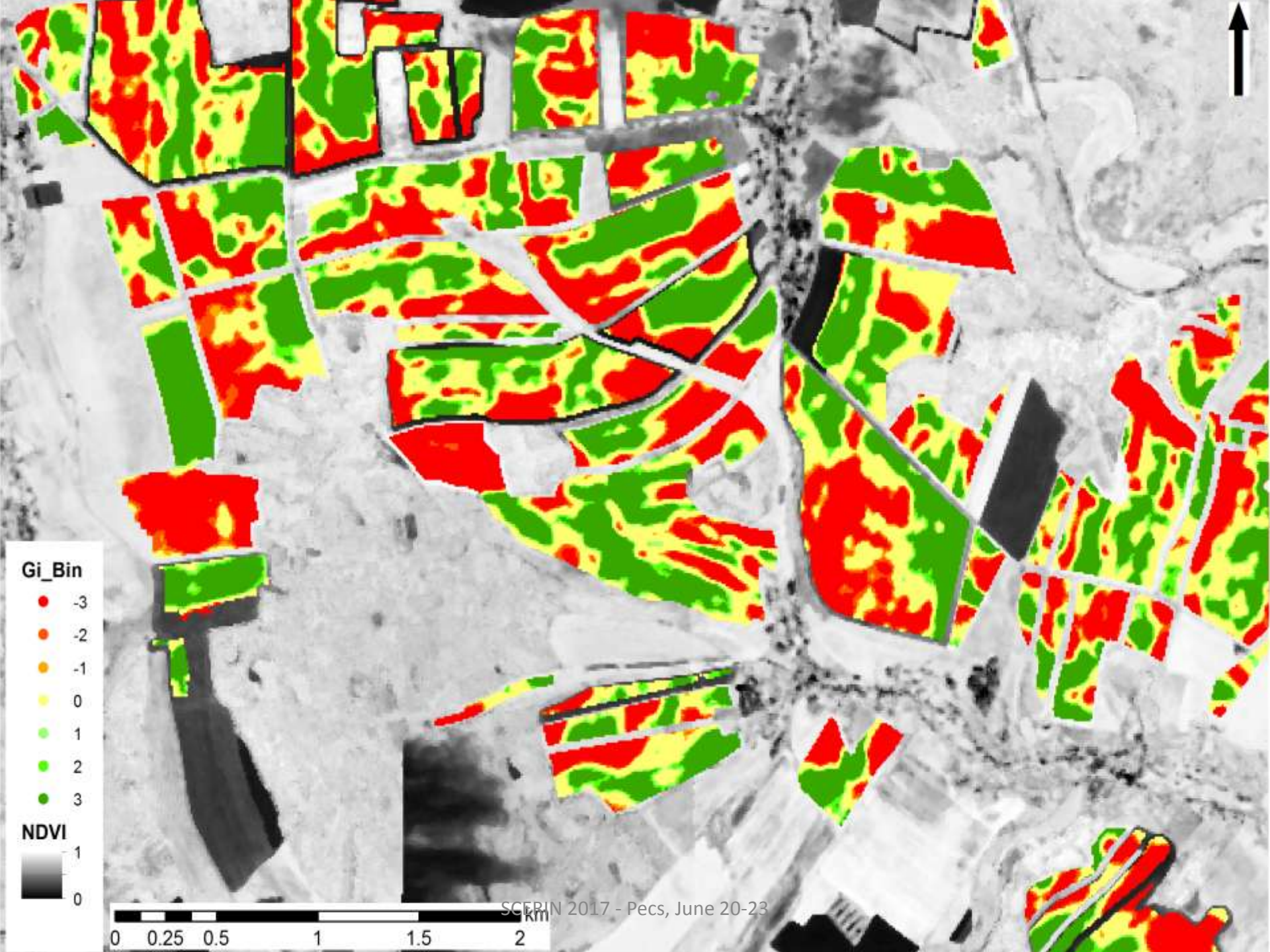

Significance Level
(p-value)
0.01
0.05
0.10

0.10
0.05
0.01
Critical Value
(z-score)
< -2.58
-2.58 – -1.96
-1.96 – -1.65
-1.65 – 1.65
1.65 – 1.96
1.96 – 2.58
> 2.58
(Random)
Significant
Significant
0.01 0.05 0.10
-2.58 -1.96 -1.65
0.10 0.05 0.01
1.65 1.96 2.58
p-values
z-scores

HotSpot analysis of N content






Gi_Bin
-3
-2
-1
0
1
2
3
NDVI
1
0
0 0.25 0.5 1 1.5 2
km

Conclusions

A hotspot analysis of vegetation indices carried out in each wheat field, revealed:

1/ Highest spatial variability of Vis in the most vulnerable class

2/ Spatial context between “hot and cold” places in neighbouring fields no matter what the total concentration of N in biomass was

3/ Results of hot spot analyses of spectral properties derived from multispectral Sentinel-2 data and from airborne hyperspectral CASI display similar spatial patters

Next steps – validation of vulnerable sites from time series and different phenology of crops

This also creates **high potential of application of the Sentinel-2** data in agriculture management, especially **in targeted application of nitrogenous fertilizers** and hence protection of environment

CzechGlobe
Global Change Research Institute CAS

Thank you for your attention

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