Centre wallon de Recherches agronomiques

Spatial patterns in winter wheat growth related to soil properties and historical management practices. A case study from central Belgium.

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Abstract (new version)

Intra-field heterogeneity of soil properties is function of complex interactions between biological, physical factors and historic agricultural management. Quantifying the influence of soil properties such as soil organic carbon (SOC), nitrogen (N), phosphorous, exchangeable cations, pH or soil texture on crop growth throughout the growing season contributes to an optimization of fertilizer application and crop yield. The field of 17ha consists of four fields that have been merged in early 2017 and cropped with winter wheat in 2018. Historical management data were collected. The top soil characteristics were analysed by a grid based sampling and kriged to create maps. We tested the capacity of a multispectral MicaSense® RedEdge-M™ camera mounted on a UAV to map the growth of winter wheat. Relating several Vegetation Index (VI) to the Plant Area Index (PAI) measured in the field highlighted the Red-Edge NDVI (RENDVI) as the most suitable to follow the crop growth throughout the cultural season. The geo-referenced final grain yield of the winter wheat was measured by a combine harvester. The spatial patterns in RENDVI at three phenological stages were mapped and analysed together with the yield map. For each of these images a conditional inference forest (CI-forest) algorithm was used to identify the soil properties significantly influencing these spatial patterns. Former fields historical management induces significant heterogeneity in soil properties and crop growth. The spatial patterns of RENDVI maps are rather constant over time and their spearman rank correlation with yield is similar along the growing season (r≈0.7). Differences in historical management Soil properties explain between 87 % (mid-march) to 78 % (mid-may) of the variance in RENDVI throughout the growing season as well as 66 % of the variance in yield. pH and exchangeable K are the most significant factors explaining from 15 to 26 % of the variance in crop growth. The methodology proposed in this paper to quantify the importance of soil parameters based on CI-forest algorithm can contribute to a better management of fertilizer inputs by stressing the most important parameters to take into consideration in site specific management.

Study site

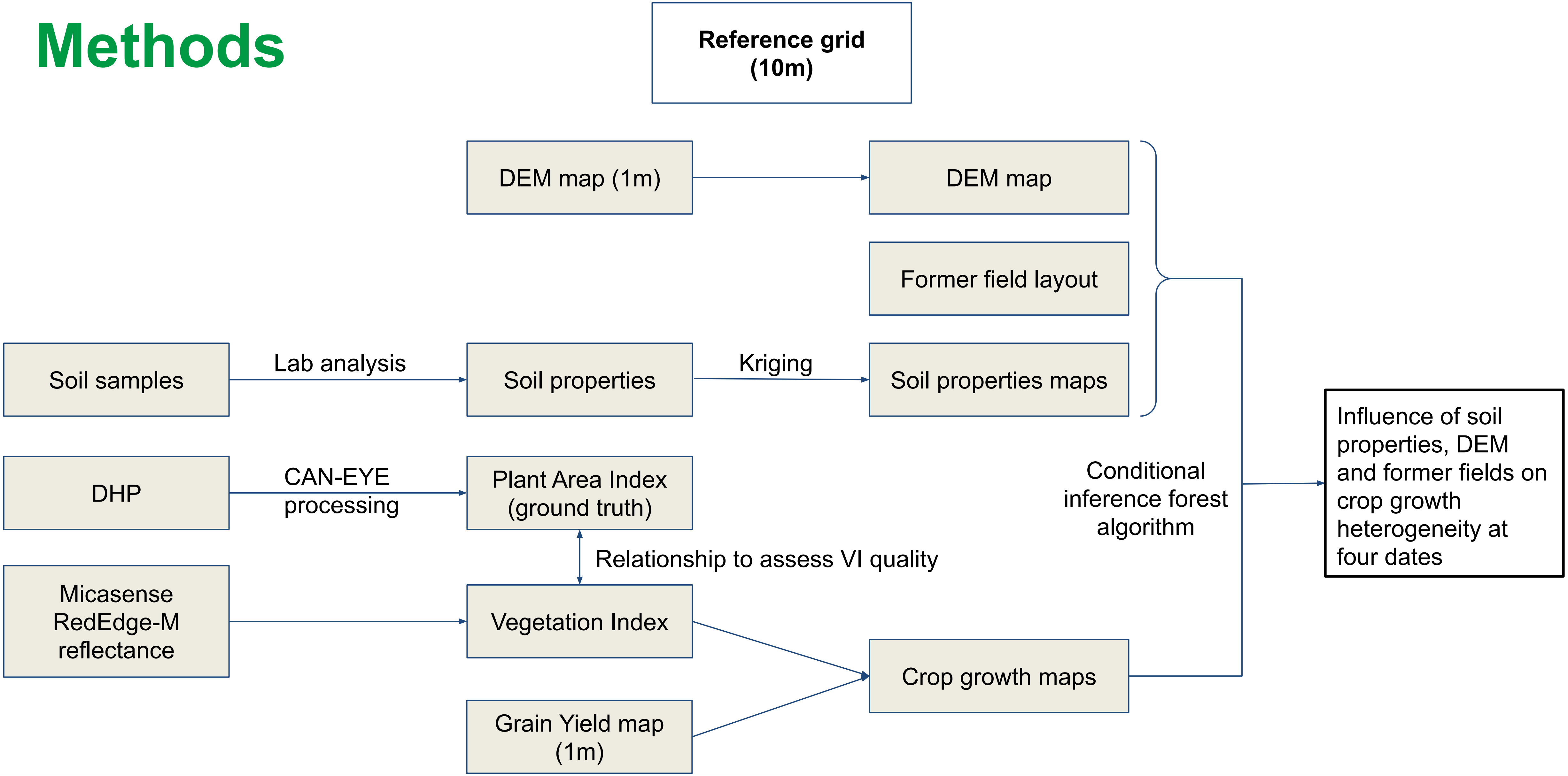
- 17 ha field
- Conventional farming
- 4 fields before 2017
- Data collection in 2018 (winter wheat)

Materials

- Soil samples (grey points) in August
- Digital Hemispherical Pictures (DHP, triangle)
- Micasense Rededge-M on UAV
- Grain yield map (impulsion plate sensor)
- Historical management data (1990-2018)
- Digital Elevation Model

March, April, May

Methods


Reference grid (10m)
DEM map (1m)
DEM map
Former field layout
Soil samples
Lab analysis
Soil properties
Kriging
Soil properties maps
DHP
CAN-EYE processing
Plant Area Index (ground truth)
Relationship to assess VI quality
Micasense RedEdge-M reflectance
Vegetation Index
Crop growth maps
Grain Yield map (1m)
Conditional inference forest algorithm
Influence of soil properties, DEM and former fields on crop growth heterogeneity at four dates

Historical management analysis

- **Main conclusion** : distinction between management of former parcels A - C and B - D.
- More organic amendments on B and D former parcels, higher frequency of residues restitution on D ⇒ more SOC expected
- Balance between import and export of P, K, Mg and Ca :
  - Higher on B and D
  - Higher pH expected on B and D

Soil properties

Significance from one factor ANOVA (former field layout)

Variable	Unit	Min	Max	Mean	SD	CV (%)	p-V SC
Clay	%	12.39	22.25	17.98	2.37	13	.
Ca	mg/100g	223.73	803.02	339.34	84.70	25	*
Fe	mg/kg	241.70	593.02	346.65	83.42	24	
K	mg/100g	13.85	34.67	21.71	3.63	17	*
Mg	mg/100g	4.98	14.68	9.15	1.78	19	
Mn	mg/kg	187.66	317.56	231.19	32.95	14	
Na	mg/100g	0.38	4.21	1.94	0.81	42	.
Ntot	%	0.08	0.11	0.09	0.01	7	.
P	mg/100g	7.16	25.47	12.33	3.83	31	*
pH	/	6.90	7.93	7.57	0.26	3	***
Sand	%	5.38	11.35	6.65	0.83	12	
Silt	%	71.15	79.98	75.36	2.02	3	.
SOC	g/kg	8.30	15.02	10.31	1.30	13	***

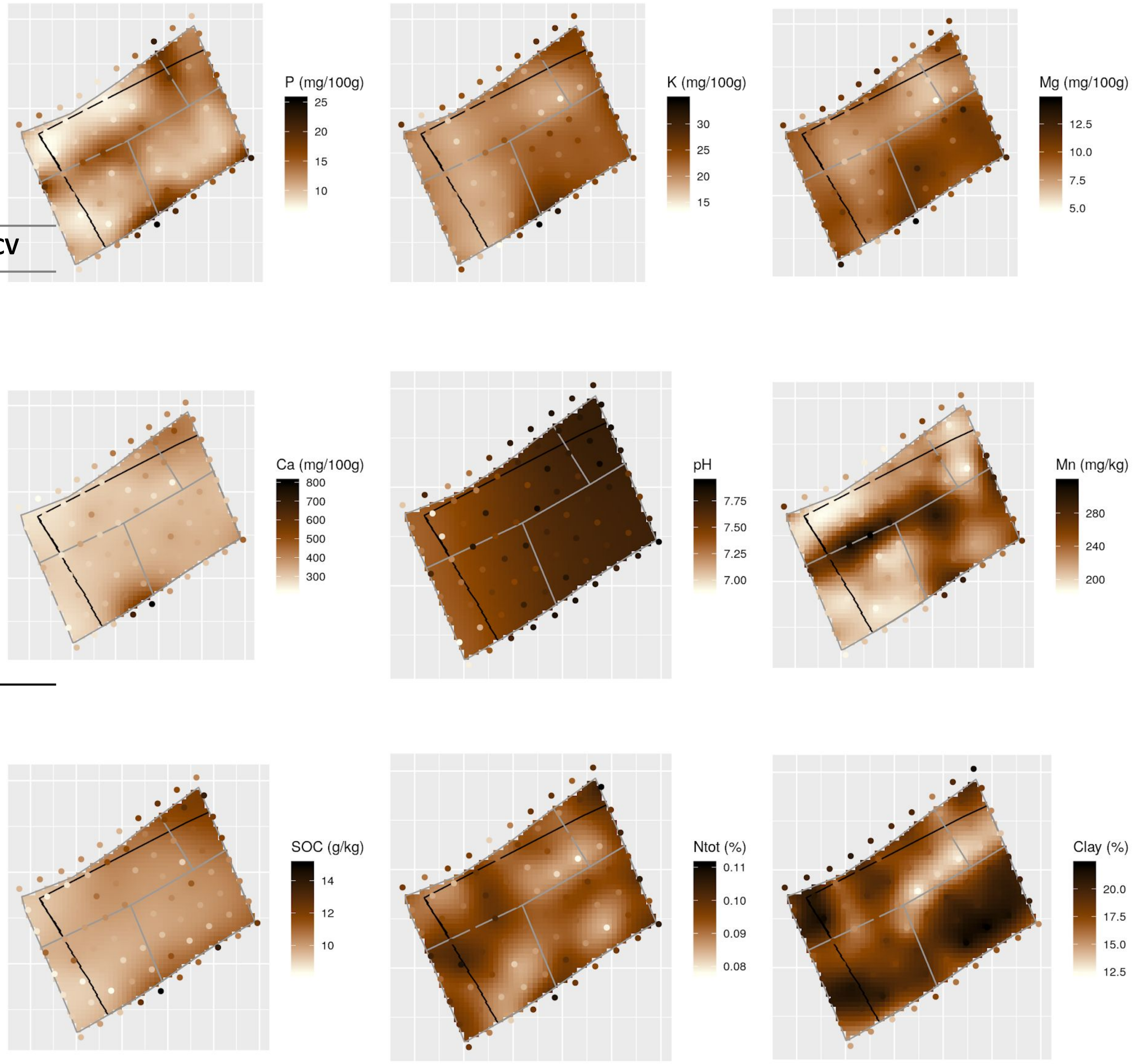
- Highly significantly different between former fields
- Significantly different
- High correlation with other parameters and then not used for the following CI-forest analysis

Main conclusion of analysis of the distribution by former parcels : higher SOC, K, P, Ca and pH on B and D former parcels

= main conclusion of historical management analysis (except for Mg)

Soil property maps

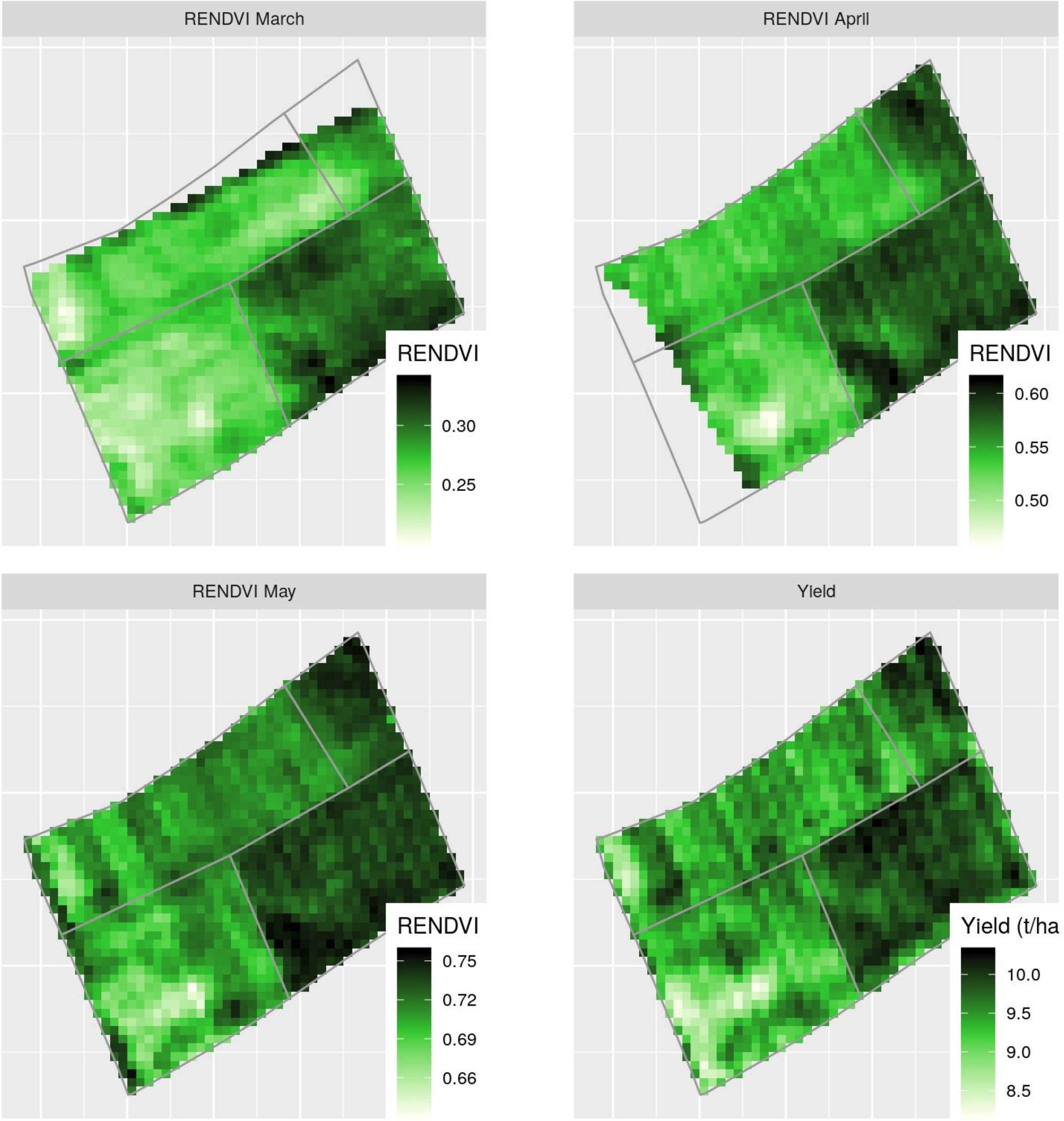
Variable	Nugget	Sill	Range (m)	Nugget/Sill	RMSECV	rRMSECV
P	0.99	13.38	134.77	0.07	2.95	0.24
K	3.99	9.89	237.24	0.40	2.84	0.13
Mg	1.10	2.27	160.19	0.48	1.52	0.17
Ca	2161.69	6816.59	367.59	0.32	65.40	0.19
pH	0.40	0.57	4531.11	0.70	0.19	0.02
Mn	0.00	1191.92	124.91	0.00	25.00	0.11
SOC	0.77	18.61	7525.21	0.04	1.06	0.10
Ntot	0.00	0.00	92.99	0.51	0.01	0.07
clay	0.00	5.99	121.89	0.00	1.85	0.10



Crop maps

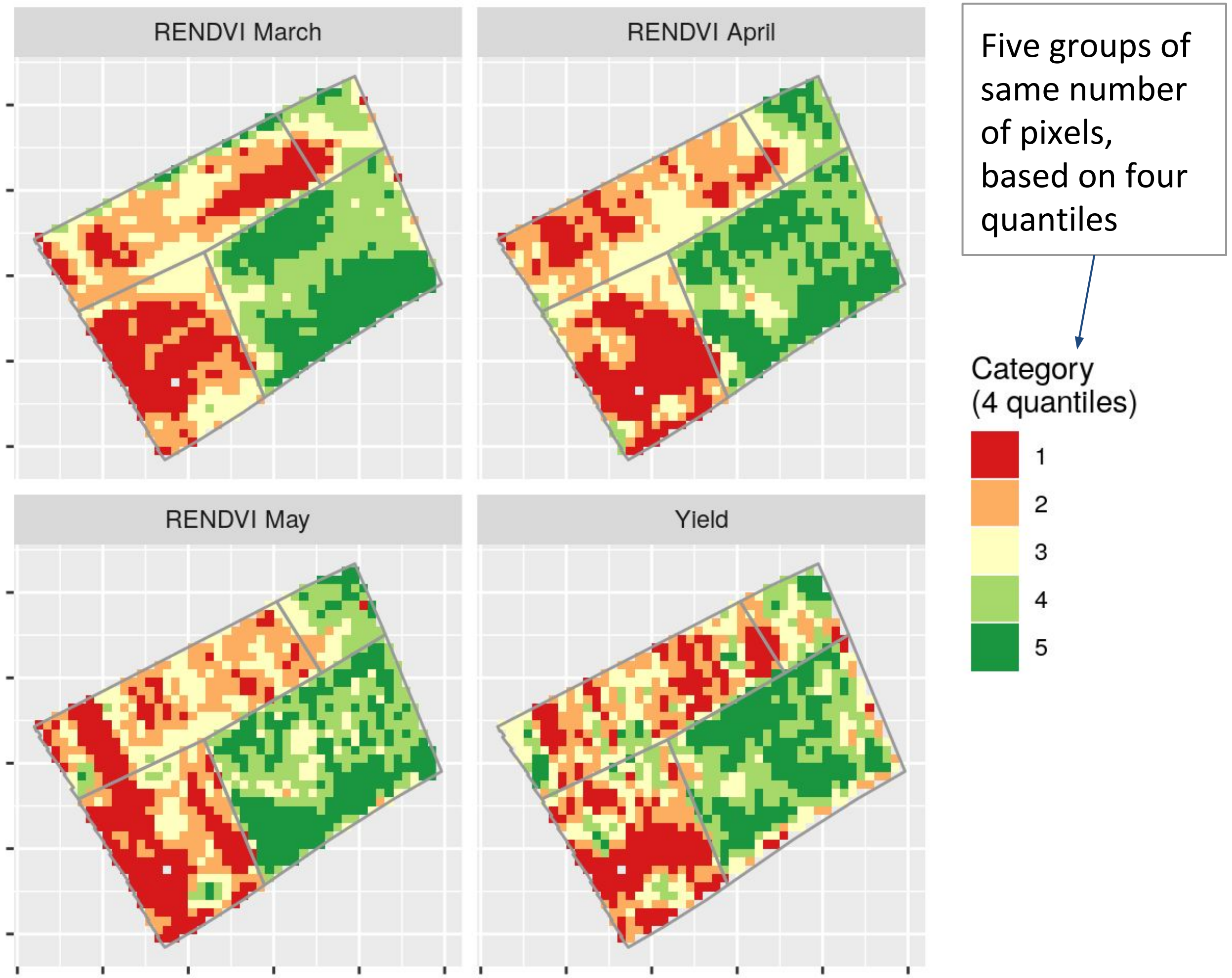
- Clear effect of former field lay-out
  ⇒ higher biomass and yield in B and D parcels

- Temporal stability of the patterns



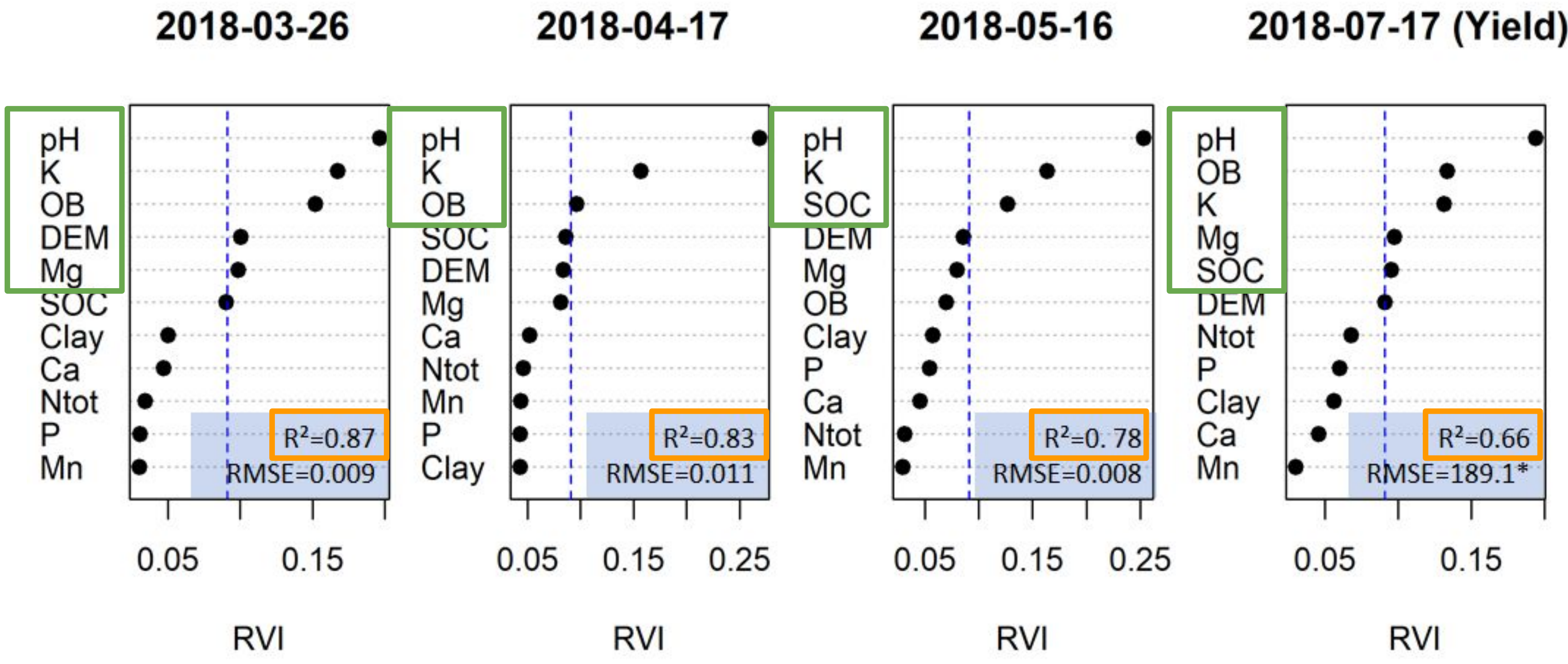
Crop variables classified maps

- Correlation between each RENDVI ≃ 0.8
- Correlation between each RENDVI and yield ≃ 0.7
- Heterogeneity within each former field



Contribution of soil properties, DEM, and former field layout to crop growth heterogeneity

- Model performance decreases over time → annual variability
- K and pH are the most important variables
- Not important = not limiting growth because not inducing heterogeneity



Main conclusions

- In case of land consolidation, the historical management determines the heterogeneity of several soil properties
- Kriged soil property maps are consistent regarding the relative RMSEcv (except for Na)
- Crop growth is well characterized by UAV RENDVI and is well correlated with final grain yield
- CI-forest algorithm is useful to determine the soil properties influencing the crop growth heterogeneity and can be used as a tool for a better fertilizer application
- pH and K were the more important factor explaining crop growth heterogeneity

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