MAPPING THE SPATIAL VARIABILITY OF SOIL PROPERTIES AND CROP YIELDS FOR SITE-SPECIFIC NUTRIENT MANAGEMENT

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WORLD FROM SPACE

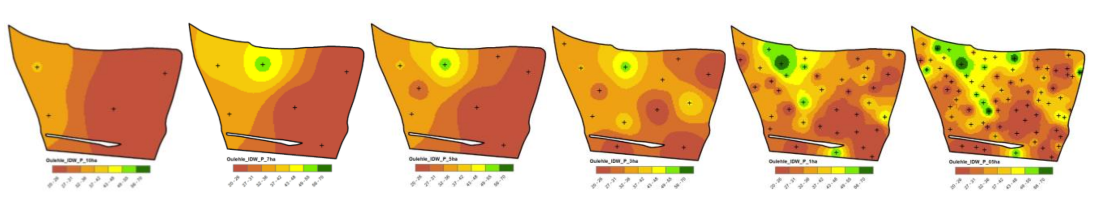
The heterogeneity of soil properties is the one of the main reason for the spatial distribution of crop yields within the plots of arable land. These are mainly differences in agrochemical soil properties and soil moisture availability, which can be a limiting factor for crop yield. With regard to the time and cost labor for traditional soil mapping, more effective methods are evaluated to capture the field spatial variability with high reliability, informative value and optimized costs for soil sampling.

The aim of the study was to assess the spatial variability of soil nutrients properties by the combination of soil sampling with proximal and remote sensing. The research activities were realized in the years 2021 to 2023 with the support of the research project NAZV QK21010247 on the area of 3,250 ha arable land within farm ROSTENICE a.s. (Czech Republic).

The experimental part of the projects was divided into two areas: (1) digital soil mapping at the farm scale by combination of optimized soil sampling, on-the-go measurement of soil electrical conductivity and satellite remote sensing
(2) analysis of crop yield zones and its inter-annual variability for implementation into nutrient balance models.

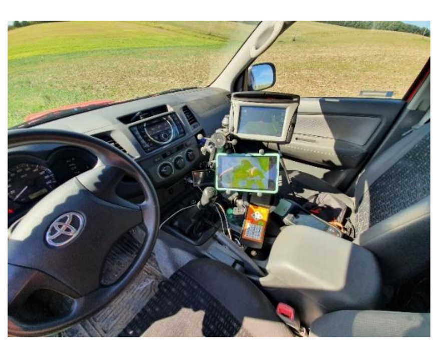
Digital soil mapping

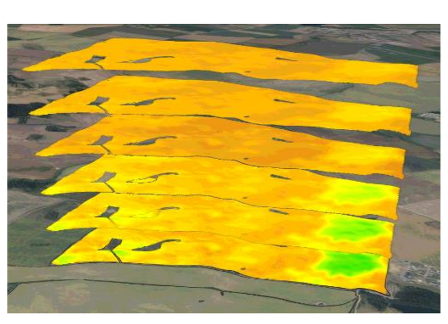
For the purposes of digital soil mapping, proximal and remote sensing methods are combined to design directed soil sampling and to refine the estimation of soil properties. Spatial prediction of soil properties is based on methods of digital soil mapping using data-oriented machine learning approaches (regression trees, neural networks, including convolutional and combined ensemble methods).

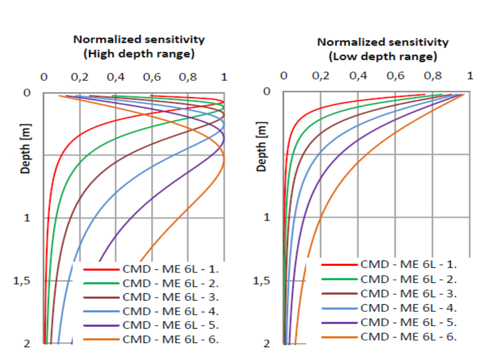


Effect of various soil sampling density on the interpolated maps of P content in soil. Black crosses represent initial soil sampling points.

This step also includes the implementation of soil moisture surface analysis from the Sentinel-1 SAR radar data and the identification of the basic topsoil properties from the Sentinel-2 optical data. Initial research results indicate the robust prediction capability for assessment of soil texture and soil organic matter content from multispectral images of Sentinel-2. At the same time, the underlying area maps from satellite data and DMT are used to optimize the distribution of sampling points across the fields.







Correlation analysis of soil sampling results and on-the-go measurement of soil electrical conductivity (EMI).

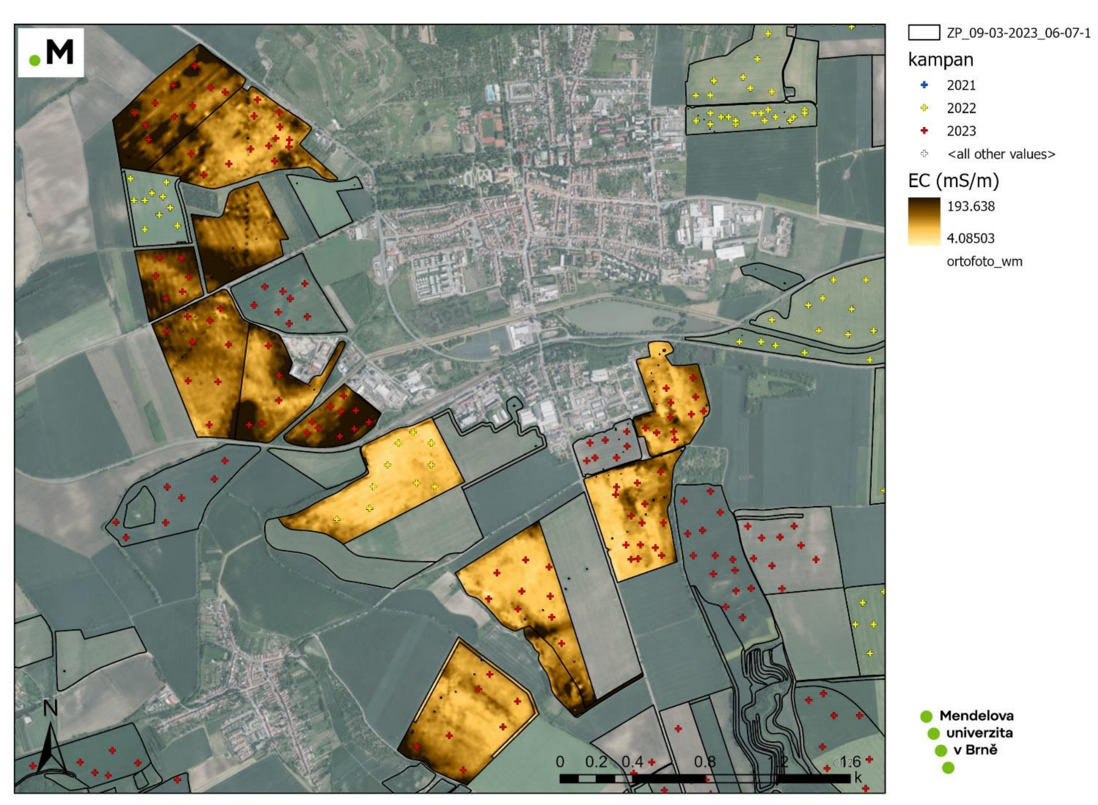
EC	2301/15	2401/10	2401/12	2401/9a	2401/9b	3411	5301/4	5601/4	All
pH	0.237	-0.243	-0.208	0.188	0.135	-0.189	-0.245	0.202	-0.110
P	0.228	0.134	-0.092	-0.111	0.331	-0.282	0.270	0.296	-0.120
K	0.028	**0.691**	**0.295**	-0.099	0.319	0.166	**0.605**	0.261	0.002
Mg	0.205	**0.562**	-0.032	-0.155	0.326	**0.633**	-0.309	0.213	0.008
Ca	-0.213	0.113	**-0.260**	0.060	0.460	0.313	-0.483	-0.069	-0.060
SOM	-0.166	0.144	**0.356**	0.021	0.353	0.076	-0.293	**0.589**	0.064
Clay	0.334	**0.473**	**0.545**	0.348	**0.598**	**0.542**	0.107	**0.568**	**0.265**
Silt	**-0.523**	0.196	-0.094	0.184	0.150	0.011	0.340	**-0.517**	**0.194**
Sand	0.159	-0.370	**-0.343**	-0.291	-0.381	-0.264	-0.439	-0.254	**-0.336**

Soil sampling

A total number of 1848 soil samples were taken during the summer and autumn 2021-2023 from a depth of 30 cm with the sampling density 1.75 ha. The sampling points were distributed based on the crop yield potential maps by using a stratification algorithm.

Semi-automatic sampling machine Nietfeld N2006 used for soil sampling at farm Rostenice a.s.

Soil samples were analysed for the macro-nutrient content, soil pH and texture. The results showed very high variability of available phosphorus (CV = 92 %), potassium (CV = 53 %) and calcium (CV = 55 %). Values of soil pH (CaCl2) ranged from 3.79 to 7.94.



Map of soil sampling campaigns (color crosses) and results of soil EC measurement for a specific part of farm area

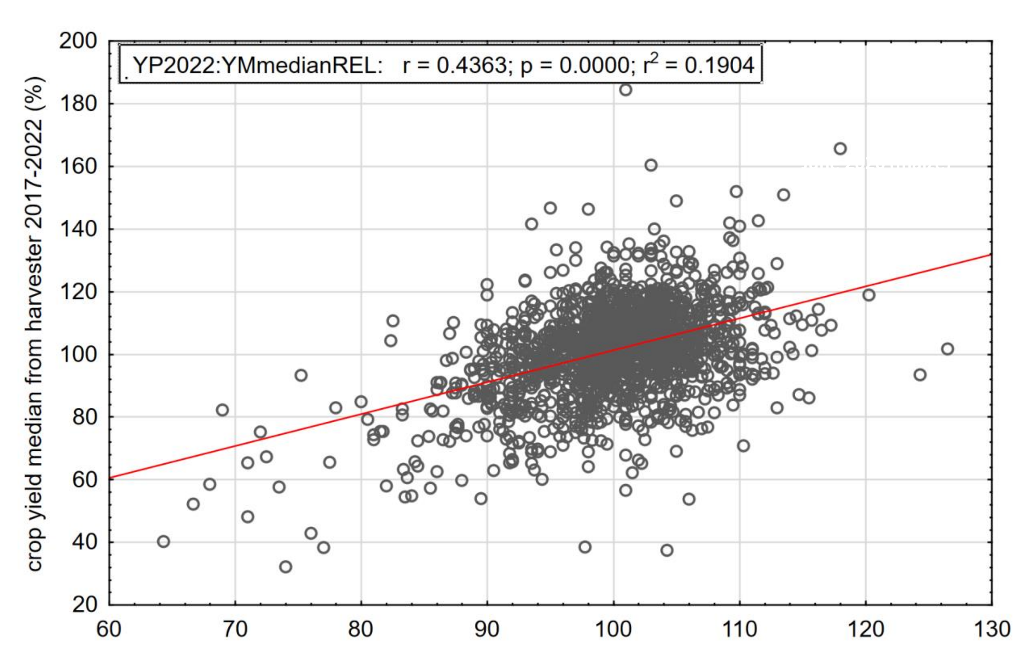
Basic statistical parametrs of soil sampling results

	pH_CaCl2	P_corr	P_Olsen	K	Mg	Ca	CaCO3
average	7.06	72.45	23.16	273.77	344.15	7189.02	4.27
median	7.45	62	20	237.5	321	7043	1.88
std.	0.83	61.94	17.67	145.31	119.58	3988.61	5.26
CV	11.78	85.49	76.27	53.08	34.75	55.48	123.09
kurtosis	1.97	118.94	121.26	16.06	13.43	8.73	3.70
skewness	-1.67	8.73	8.09	2.82	2.69	2.11	1.56
range	4.15	1100	318	1687	1469	37460	49.22
min	3.79	6	4	40	63	395	0.05
max	7.94	1106	322	1727	1532	37855	49.27
n	1848	1848	1393	1848	1848	1848	1823

Analysis of crop yield zones by EO data

Information on the spatial distribution of **crop yield zones** is elementary to **refine nutrient balance models**. For this, the implementation of **yield records** obtained by harvesters or **production zones/yield potential** derived from the time-series of Sentinel-2 and PlanteScope multispectral data are verified. The results of yield maps analysis for pilot farm Rostěnice a.s. showed high differences of relative crop yield within the fields (from 45 to 140 %) which reflects the topography and soil type condition within the selected region of interest. Final application rates of P, K, Mg and Ca fertilizers are determined by the combination of soil maps and distribution of yield zones with a final adjustment respecting the of settings of application machinery.

Map of relative yield potential for Rostenice a.s. farm estimated from time-series of Sentinel-2 and PlanetScope multispectral imagery data (vegetation index EVI)



Relationship between crop yield maps recorded in 2017-2022 by harvesters (represented in relative values) and production zones (yield potential) derived from EO data

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The research project is focused on the application of new procedures for mapping of the spatial variability of soil condition by using Earth Observation data. Their implementation in the form of site-specific crop management can lead to reduction of excessive use of agrochemical inputs and optimal land use while maintaining the soil productivity and ensuring the production of quality agricultural commodities with minimal impact on the environment.

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