WITHIN-FIELD CORRELATION BETWEEN SATELLITE-DERIVED VEGETATION INDICES AND GRAIN YIELD OF WHEAT

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INTRODUCTION

One of the most common precision agriculture techniques is yield monitoring and mapping which can be useful for revealing the spatial and temporal variability in crop yields. Such an approach enables the development of spatial maps of yields that have a great impact on the decision-making process. Often, this data is combined with the data derived from satellite images by calculating vegetation indices (VIs) which are used to assess the health condition of crops during different phases of plant growth.

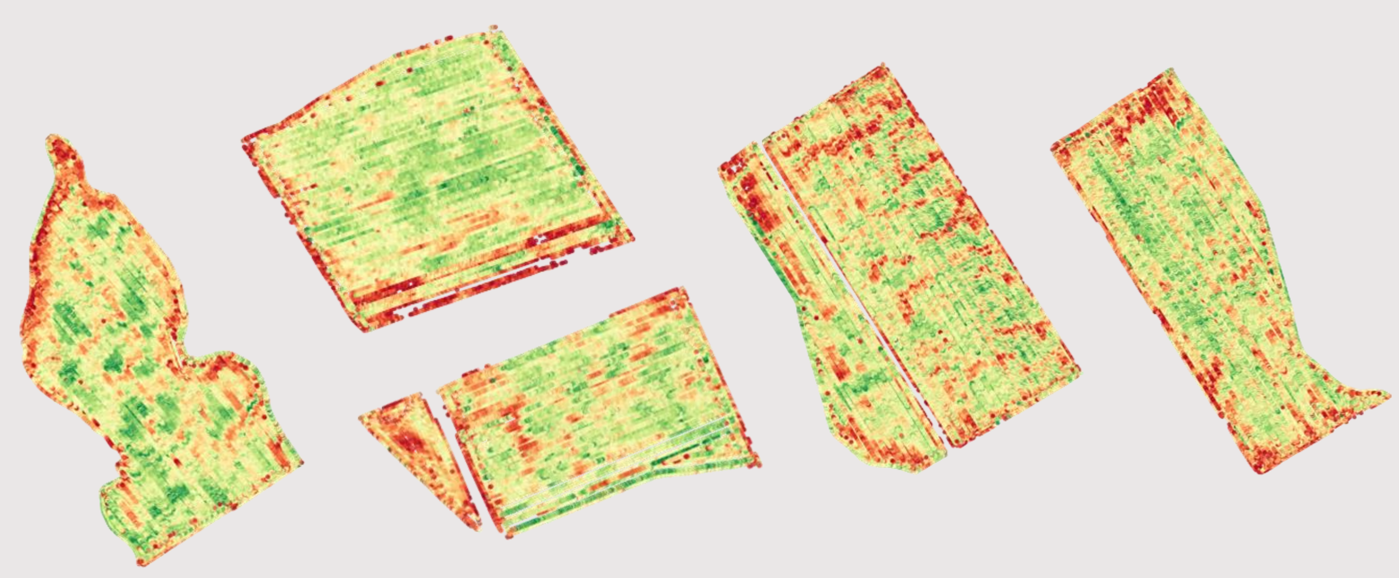

Figure 1. Fields

MATERIALS AND METHODS

For the purpose of this study, two types of data were used: satellite-based vegetation indices and crop yield data. The Sentinel-2 satellite images were selected based on crop growth stages[1] from the end of tillering phase (beginning of March 2019) until the full ripening (end of June 2019). These images were used for the calculation of twelve VIs across 10 growth stages, applying specific mathematical formulas (Table 1). Yield observations were performed at harvest on five fields of wheat (Figure 2). To designate their correlation and dependence, the Pearson's and Spearman's correlation coefficients were calculated, and their statistical significance was tested using p-value (at p=0.01, p=0.05). The structure of the methodology is shown in the Figure 2.

NDVI – Normalized Difference Vegetation Index NDVI = (NIR - RED) / (NIR + RED)	**OSAVI – Optimized Soil-Adjusted Vegetation Index** OSAVI = 1.5 * (NIR - RED) / (NIR + RED + 0.16)
SAVI – Soil-Adjusted Vegetation Index SAVI= ((NIR - RED) / (NIR + RED + 0.428)) * (1+0.428)	**ARVI – Atmospherically Resistant Vegetation Index** RB = RED - (BLUE - RED); ARVI = (NIR - RB) / (NIR+RB)
MSAVI2 – Modified Soil-Adjusted Vegetation Index MSAVI2 = (2*NIR + 1 – sqrt((2*NIR + 1)^2 – 8*(NIR – RED)))/ 2	**GCI – Green Chlorophyll Index** GCI = (NIR / GREEN) - 1
IPVI – Infrared Percentage Vegetation Index IPVI = NIR / (NIR + RED)	**DVI – Difference Vegetation Index** DVI = NIR - RED
TVI – Transformed Vegetation Index TVI = sqrt(((NIR - RED) / (NIR + RED)) + 0.5)	**CVI – Chlorophyll Vegetation Index** CVI = (NIR * RED) / (GREEN)^2
EVI – Enhanced Vegetation Index EVI = 2.5 * ((NIR - RED) / ((NIR + 6 * RED - 7.5 * BLUE) + 1))	**GNDVI–Green Normalized Difference Vegetation Index** GNDVI = (NIR - GREEN) / (NIR + GREEN)

Table 1. Vegetation indices and mathematical formulas [2]

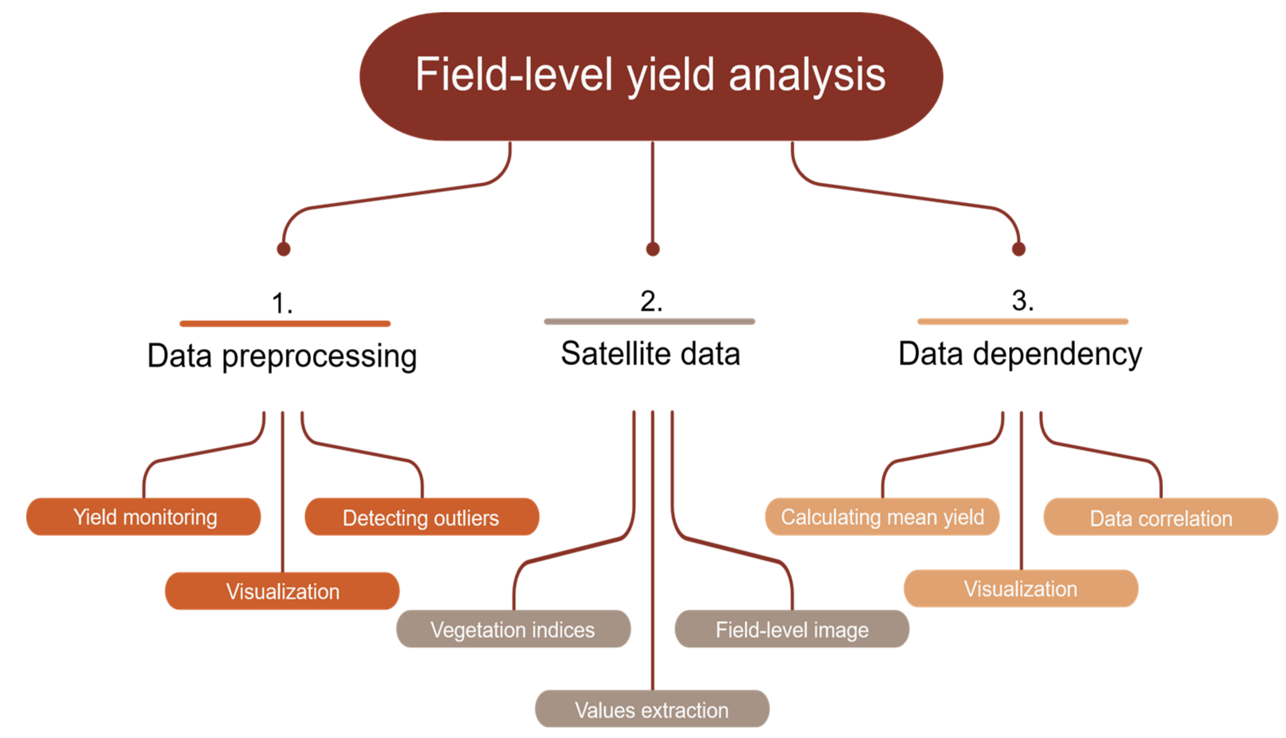

Figure 2. Methodology structure

RESULTS AND DISCUSSION

According to the crop growth stages, the highest correlation coefficients were detected from the early boot stage (BBCH 41) until the middle of development of the fruiting stage (BBCH 73 – early milk). In that period the correlation coefficients varied from 0.39 to 0.84 depending on the field (Table 2). Based on the location, the highest correlation coefficient values for all 12 indices were recorded for the parcel named C-6 (April 15), and the lowest values for the parcel named C-10 (June 29). Most of the indices showed statistically significant dependence (at the p<0.01 and p<0.05 significant levels) on the yield in the first five growth stages except the chlorophyll vegetation index (CVI) for the parcel named C-11 (p=0.21, p=0.39).

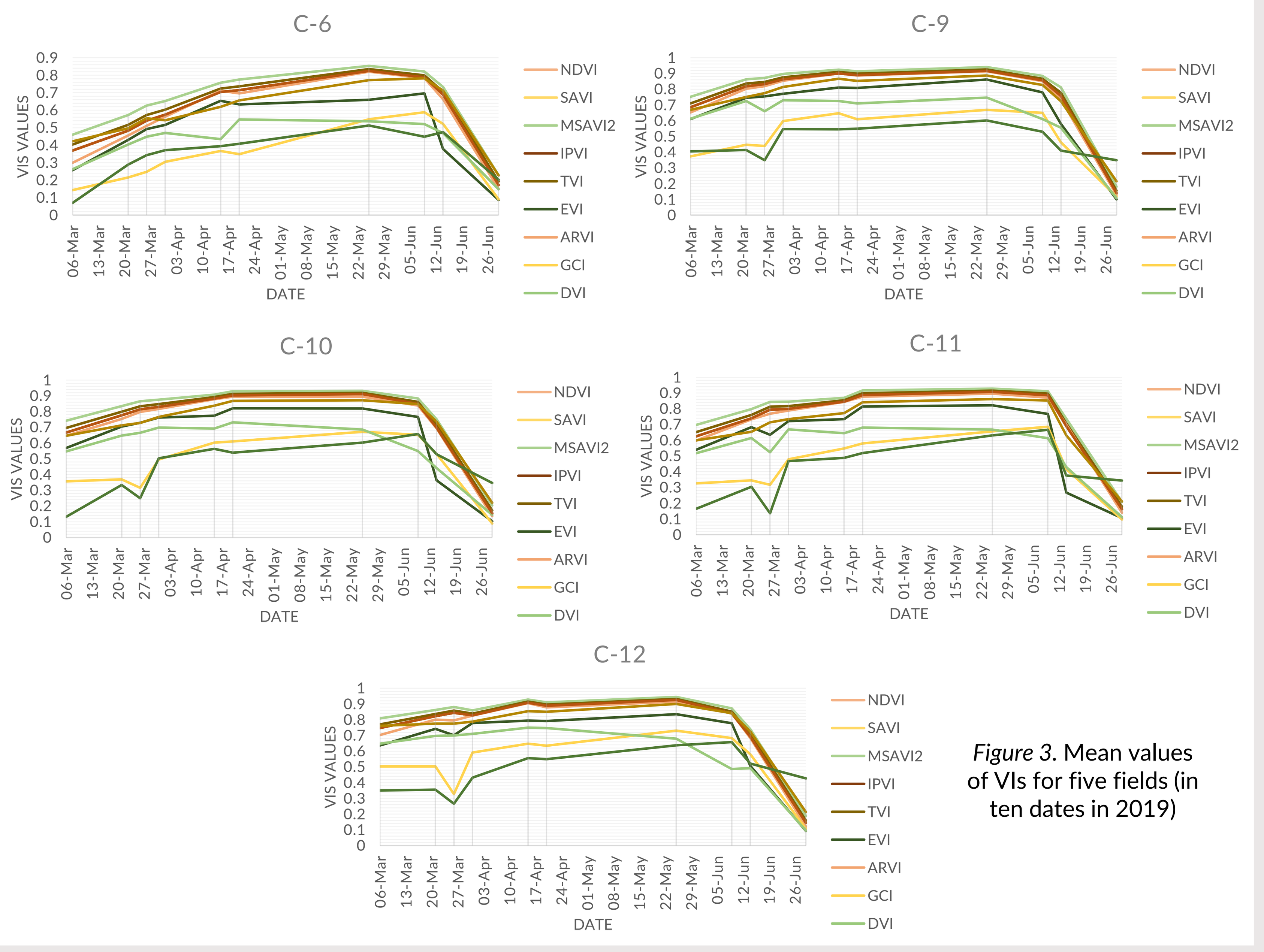

Figure 3. Mean values of VIs for five fields (in ten dates in 2019)

CONCLUSION

To conclude, the last growth stage named ripening showed the lowest values both for correlation coefficient and statistical significance which means that VIs also had low values because the reflectance is weak in this growth stage and wheat is about to be harvested. In the first five stages, VIs showed significantly high spectral reflectance values since in this period the leaf is full of chlorophyll pigments (Figure 3). Analyzing the correlation coefficient in different stages of wheat growth, we look at the current state of crops and can take appropriate measures in time to increase yields or save inputs at specific locations.

parcel code	Pearson and Spearman correlation		BBCH 29 06.03.	BBCH 30 21.03.	BBCH 32 26.03.	BBCH 37 31.03.	BBCH 41 15.04.	BBCH 49 20.04.	BBCH 65 25.05.	BBCH 73 09.06.	BBCH 83 14.06.	BBCH 89 29.06.
C-6	p	min	0.44	0.67	0.74	0.71	0.72	0.75	0.60	0.48	0.43	0.01
		max	0.73	0.77	0.81	0.78	0.83	0.80	0.81	0.71	0.65	0.24
	s	min	0.54	0.71	0.75	0.72	0.74	0.77	0.54	0.38	0.40	0.08
		max	0.74	0.78	0.82	0.79	0.84	0.81	0.81	0.70	0.64	0.27
C-9	p	min	0.33	0.33	0.21	0.28	0.09	0.22	0.20	0.22	0.11	0.10
		max	0.38	0.38	0.33	0.37	0.39	0.38	0.44	0.50	0.46	0.26
	s	min	0.33	0.33	0.22	0.30	0.10	0.25	0.18	0.23	0.12	0.03
		max	0.37	0.37	0.33	0.38	0.39	0.39	0.43	0.48	0.47	0.35
C-10	p	min	0.21	0.14	0.12	0.18	0.28	0.32	0.36	0.37	0.21	0.01
		max	0.37	0.42	0.43	0.43	0.45	0.45	0.51	0.51	0.50	0.23
	s	min	0.17	0.15	0.15	0.17	0.27	0.29	0.34	0.33	0.17	0.01
		max	0.33	0.37	0.38	0.40	0.43	0.43	0.46	0.45	0.42	0.27
C-11	p	min	0.16	0.02	0.03	0.09	0.29	0.28	0.35	0.26	0.02	0.03
		max	0.42	0.43	0.48	0.43	0.58	0.48	0.62	0.48	0.33	0.26
	s	min	0.21	0.06	0.07	0.17	0.34	0.30	0.27	0.24	0.01	0.01
		max	0.40	0.39	0.44	0.40	0.56	0.50	0.63	0.53	0.38	0.17
C-12	p	min	0.28	0.07	0.07	0.29	0.34	0.35	0.35	0.35	0.20	0.12
		max	0.60	0.54	0.54	0.52	0.56	0.56	0.56	0.58	0.52	0.32
	s	min	0.30	0.09	0.09	0.28	0.32	0.33	0.33	0.34	0.19	0.04
		max	0.52	0.52	0.52	0.51	0.55	0.57	0.57	0.54	0.52	0.28
			End of tillering	Stem elongation			Booting		Full flowering	Early milk	Ripening	

Table 2. The Pearson's and Spearman's correlation coefficients

References

[1] Meier, U. (1997). *Growth stages of mono-and dicotyledonous plants.* Blackwell Wissenschafts-Verlag.

[2] Panek, E., Gozdowski, D., Stępień, M., Samborski, S., Ruciński, D., & Buszke, B. (2020). Within-field relationships between satellite-derived vegetation indices, grain yield and spike number of winter wheat and triticale. *Agronomy, 10*(11), 1842.

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