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Assessment of Spatial Heterogeneity in Maize Crops Using the dSAVI, NDVI, SAVI, OSAVI, and MSAVI Indices

***N. Bonchkovska, V. Zatserkovnyi, V. Vorokh, O. Liashchenko** (*Taras Shevchenko National University of Kyiv*), **L. Ilyin** (*Lesya Ukrainka Volyn National University*)

SUMMARY

This study explores the applicability of the dSAVI, NDVI, SAVI, OSAVI, and MSAVI vegetation indices for assessing the spatial heterogeneity of maize crops at early growth stages using Sentinel-2 data. The analysis was performed in the Google Earth Engine environment using the AUTO_q7 classification. Agricultural zone maps were generated for the study field, and their areas, mean index values, and spatial distributions were compared. A similar spatial structure of the agricultural zones was observed across all examined indices. The most comparable results were obtained using dSAVI, MSAVI, and SAVI, whereas NDVI exhibited a different proportion of agricultural zone areas. The relationship between dSAVI and MSAVI was found to be nearly linear within the study area.

Keywords: Maize; Remote sensing (RS); Sentinel-2; Vegetation indices; Agricultural zones; Spatial heterogeneity; Precision agriculture.

Corresponding Author: natalibonchkovska@gmail.com

Introduction

At early maize growth stages, within-field variations in vegetation cover conditions are observed, which are reflected in the spatial distribution of vegetation index values. Remote sensing (RS) data enable the identification of these differences and the assessment of within-field crop heterogeneity (Mulla, 2013; Radočaj et al., 2023).

Vegetation indices are widely used to assess crop conditions. However, at early growth stages, NDVI is strongly affected by bare soil reflectance (Huete, 1988). The SAVI family was developed to reduce the influence of the soil background on vegetation assessment (Qi et al., 1994).

Sentinel-2 imagery provides spectral data for vegetation index calculation and within-field crop variability analysis (Drusch et al., 2012). At early growth stages, the dSAVI index reduces the influence of bare soil on vegetation assessment (Zatserkovnyi et al., 2026).

The aim of this study is to assess the spatial heterogeneity of maize crops at early growth stages using the dSAVI index based on Sentinel-2 data and field surveys. The results were compared with NDVI, SAVI (L = 0.5;1.0), OSAVI, and MSAVI.

Method and Theory

Sentinel-2 Level-2A imagery acquired between May 15 and 26, 2026, together with field survey data collected on May 23, 2026, was used to assess maize crops at the early growth stage. Satellite data were processed in Google Earth Engine (GEE). Cloud-contaminated pixels were excluded using the QA60 quality mask. The NDVI and dSAVI vegetation indices were calculated from the Sentinel-2 spectral bands. The dSAVI index was computed according to the approaches proposed by Huete (1988), Qi et al. (1994), and Zatserkovnyi et al. (2026) using the following equation:

$$\boldsymbol{dSAVI} = \frac{\boldsymbol{NIR\text{-}RED}}{\boldsymbol{NIR+RED+L}}\ (\boldsymbol{1+L}) \tag{1}$$

where L=1-$NDVI^2$
(NDVI) = min {max (NDVI, 0), 1}
and NIR = ρ_B8, RED= ρ_B4 represent the surface reflectance values from Sentinel-2 L2A in the respective bands.

The spatial distribution of vegetation index values was analysed using thematic maps classified by the AUTO_q7 method. Field observations were used to interpret the vegetation index maps and assess the spatial heterogeneity of maize crops (Bannari et al., 1995; Mulla, 2013; Radočaj et al., 2023).

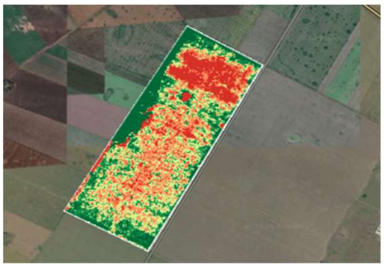
Object of study

The study was conducted on a commercial field located within Boryspil Raion of Kyiv Oblast, near the settlement of Soshnykiv. The field is used for growing agricultural crops, and its total area is 241.53 ha.

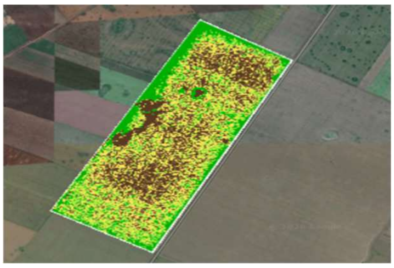
The spatial position of the site was determined by the coordinates from the field survey: 50.138163-50.139776° N and 31.142457-31.145283° E. The object of study is represented by maize crops at early growth stages. At the time of the field survey on 23.05.2026, the plants were approximately in the 2-4 leaf stage. The analysis of the site was performed on the basis of the Sentinel-2 data and the results of the field survey.

Results

The automated AUTO_q7 classification was performed based on the percentile distribution of vegetation index values within the study field. Percentiles p5, p18, p31, p44, p57, p70, p83, and p95 were utilized to define the class boundaries. The resulting intervals formed seven classes (0-6), where class 0 corresponds to the lowest index values and class 6 to the highest ones. The use of percentiles mitigates the influence of extreme values and local anomalies that may arise due to the characteristics of satellite data or surface heterogeneity. For further analysis, these classes were grouped into three agricultural zones: low, intermediate, and high vegetation cover. This approach allows for the comparison of different vegetation indices regardless of the range of their numerical values and facilitates the assessment of the spatial distribution of crop conditions within the field.

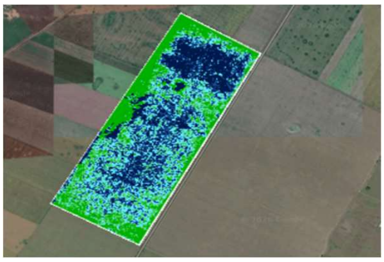


a) – Map of agricultural zones based on the dSAVI index

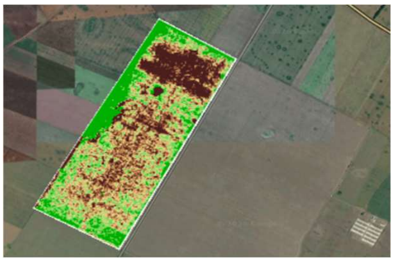


b) – Map of agricultural zones based on the NDVI index

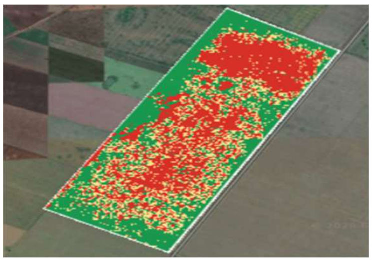
c) – Map of agricultural zones based on the SAVI-0.5 index



d) – Map of agricultural zones based on the OSAVI index



e) – Map of agricultural zones based on the MSAVI index



f) – An integrated map of agricultural zones based on the mean values of the indices

Figure 1. *Spatial distribution of agricultural zones derived from the AUTO_q7 classification results for the following indices: a – dSAVI; b – NDVI; c – SAVI (L = 0.5); d – OSAVI; e – MSAVI; f – an integrated map of agricultural zones based on the mean values of the indices*

Figure 1 presents the results of field classification based on the values of the dSAVI, NDVI, SAVI (soil correction factor $L = 0.5$; L = 1.0), OSAVI, and MSAVI vegetation indices. The agricultural zones were classified using the AUTO_q7 method, which is based on dividing index values into percentile intervals. In terms of agricultural zone area, the most similar results were obtained for dSAVI, MSAVI, and SAVI-0.5, while in terms of mean index values, the closest results were for dSAVI, MSAVI, and SAVI-1. In the northern part of the field, areas with lower index values predominate, whereas in the central and southern parts, areas with higher values are observed. The dSAVI, SAVI, OSAVI, and MSAVI indices generate a similar spatial structure of the agricultural zones, whereas NDVI exhibits a slightly different area distribution among the classes. The spatial distribution of the mean index values confirms the presence of within-field crop heterogeneity and differences in vegetation conditions within the study area.

According to the results of the AUTO_q7 classification, the field area is 241.53 hectares. For all indices studied, zones with low and high vegetation density account for the largest share of the territory, whereas the area of zones with medium vegetation density is smaller (Table 1).

The largest area of the low vegetation covers agricultural zone, as determined by the SAVI index ($L = 1.0$), is 110.45 ha (45.73 % of the field area). The smallest area of this zone, as determined by the NDVI index, is 85.72 ha (35.49 %). For dSAVI, OSAVI, MSAVI, and SAVI ($L = 0.5$), the value ranges from 92.81 to 97.98 hectares.

The largest area of the intermediate zone was recorded for NDVI (96.56 hectares), which significantly exceeds the corresponding values for the other indices. Conversely, the smallest value for the intermediate zone was obtained for OSAVI – 54.24 hectares.

Table 1. *Distribution of agricultural zone areas based on the results of the AUTO_q7 classification*

Index	*Vegetation density zone, ha*			*Share of the high vegetation cover zone (%)*	*Mean index value*
	Low (classes 0-2)	*Intermediate (classes 3-4)*	*High (classes 5-6)*		
dSAVI	95.18	65.85	80.50	33.33	0.099
NDVI	85.72	96.56	59.27	24.53	0.254
SAVI (L = 0.5)	97.98	62.58	80.98	33.52	0.121
SAVI (L = 1.0)	110.45	65.47	65.62	27.16	0.096
OSAVI	95.58	54.24	91.73	37.98	0.175
MSAVI	92.81	67.95	80.78	33.44	0.100

Based on the classification results, using the OSAVI index, the largest area of the high vegetation cover agricultural zone was identified – 91.73 hectares, or 37.98 % of the field area. For SAVI (*L* = 0.5), MSAVI, and dSAVI, the area of the high vegetation cover zone is approximately 80-81 ha (33.3-33.5 %). The smallest area of the high vegetation cover agricultural zone was determined using the NDVI index – 59.27 ha (24.53 %).

The mean index values range from 0.096 for SAVI to 0.254 for NDVI. The most similar values were observed for dSAVI (0.099), MSAVI (0.100), and SAVI (*L* = 1.0) (0.096), indicating a similar response of these indices to the vegetation conditions within the study field. The highest mean value was obtained for NDVI, followed by OSAVI as the second highest (0.175).

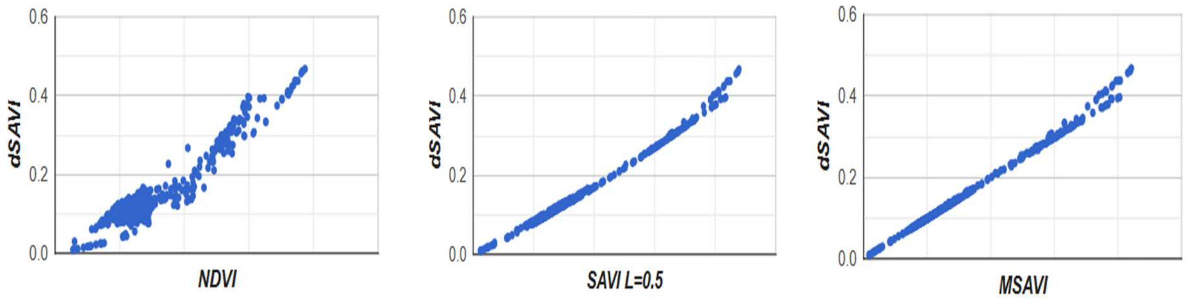


Figure 2. *Relationship between dSAVI values and NDVI, SAVI (L = 0.5), and MSAVI within the study area*

A comparison of the agricultural zone areas reveals that OSAVI yields to the largest area for the high vegetation cover zone and one of the smallest areas for the intermediate zone. The dSAVI, SAVI (*L* = 0.5), and MSAVI exhibit comparable results in terms of both agricultural zone areas and mean index values. For the dSAVI-MSAVI pair, a nearly linear relationship is observed across the entire range of values, indicating a high degree of consistency between the two indices.

Conclusions

Within the study field covering 241.53 hectares, the spatial heterogeneity of maize crops was assessed using the dSAVI, NDVI, SAVI (*L* = 0.5), SAVI (*L* = 1.0), OSAVI, and MSAVI indices. The AUTO_q7 classification, based on the percentile distribution of values, enabled the delineation of agricultural zones with low, intermediate, and high vegetation cover.

A similar spatial distribution pattern of the agricultural zones was observed for all indices studied. Zones with low vegetation cover are mainly concentrated in the northern part of the field, whereas areas with high vegetation cover are located along the field periphery and in isolated clusters in the central part.

The largest high vegetation cover area was determined using the OSAVI index (91.73 ha; 37.98 % of the field area). For dSAVI, MSAVI, and SAVI (L = 0.5), the corresponding areas were 80.50 ha (33.33 %), 80.78 ha (33.44 %), and 80.98 ha (33.52 %), respectively. The smallest high vegetation cover area was obtained using the NDVI index (59.27 ha; 24.53 %).

The mean values of the indices are as follows: NDVI – 0.254; OSAVI – 0.175; SAVI (L = 0.5) – 0.121; MSAVI – 0.100; dSAVI – 0.099; SAVI (L = 1.0) – 0.096. The closest mean index values were observed for dSAVI, MSAVI, and SAVI (L = 1.0).

Scatter plots show a strong correlation between dSAVI and both the SAVI (L = 0.5) and MSAVI indices. The dSAVI – MSAVI pair exhibits a nearly linear relationship across the entire range of values. Consequently, in terms of agricultural zone areas and spatial distribution patterns, the most similar results were obtained for dSAVI, MSAVI, and SAVI (L = 0.5), whereas in terms of mean index values, the closest results were observed for dSAVI, MSAVI, and SAVI (L = 1.0).

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