Sentinel-2 imagery utilization for small-plot agricultural studies

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Abstract. In terms of mitigation the negative aspects of agriculture on the environment, various advancements were achieved during the past few decades. Precision agriculture and related remote sensing enable canopy properties to be monitored and evaluated timely and non-destructively. Although remote sensing is nowadays widely utilized in agricultural studies with significant results, there are still certain constraints. The spatial resolution of source imagery is one of them. This study deals with this issue by evaluating Sentinel-2 imagery and it's utilization on a small-plot experiment. Four spectral indices were derived using open-source software SNAP and compared with leaf chlorophyll content data obtained during terrestrial measurements. Correlation analysis gave ambiguous results ranging from $r = 0.64$ (Green Chlorophyll Index) to $r = -0.47$ (Triangular Chlorophyll Index). Based on this observation it was concluded that this issue requires to be investigated more thoroughly to define the relation of pixel size and size of the surface unit.

1. Introduction

Current agriculture faces considerable transformation related to the growing population and the necessity to provide a sufficient amount of high-quality food. The knowledge of land variability and the actual crop conditions becomes key for sustainable production. This knowledge, which was essentially usual among small farmers, is today provided by various techniques and technologies, being called the Precision Agriculture (PA). Remote sensing is one of the key technologies for PA. Spatially related data help with investigating, evaluating, analysis, and finally agricultural management[1]. Moreover, remotely sensed data is today commonly used to predict crop yield [2]. For evaluation of vegetation conditions, handheld devices may be used within small areas, respectively areas which are within the sensor's field of view. For larger areas aerial and satellite platforms are utilized[3][4]. Sentinel-2, consisting of two identical satellites (A and B) is the satellite platform provided by the European Space Agency (ESA) under the space program Copernicus. This platform is equipped by Multispectral Instrument sensor, which senses the surface in 13 different spectral bands. The spatial resolution depends on the spectral band and varies from 10 m to 60 m per pixel[5]. There are currently several options for obtaining remote sensing data free of charge. When combining satellite images from Landsat-8 and Sentinel-2, the average temporal resolution reaches2.9 days [6]. Several studies were dealing with this specific issue in the past considering other satellite platforms. It was stated that Landsat-5 imagery (30 m/px) can be used to predict the yield of 11.5 ha field among various crops, namely wheat and oat[7].Vegetation indices, as a specific kind of spectral indices, are used to assess the condition and agronomic parameters like crop type, leaf area, crop biomass and nutrients status [8]. Nowadays, there are open-source alternatives to commercial software used to process the remotely sensed data. Using these alternatives, PA concept becomes open to a wider spectrum of final users[9]. However, there are still many constraints that must be dealt with. A possible interpretation of the data within small areas is one of them[10]. This study aims to evaluate the utilization of Sentinel-2 data to describe leaf chlorophyll content in crops of a small-plot agricultural experiment.

2. Material and methods

2.1. Experimental Area

This study was conducted within an experimental field of the research institute Agrovýzkum Rapotín that is located in Rapotín, near the Šumperk town in the Olomouc region of the Czech Republic (49° 59' 8.8296" N, 16° 59' 47.0904" E). The experimental field area is 13.26 ha in total, however, it is divided into smaller units. Primarily, this site aims to serve as a source of data for studies dealing with soil activators and various fertilizing management. Nonetheless, in the frame of this study, different small-plot management is considered as a source of data variability that might reveal the rate of studied sensor sensitivity. Nine small-plots (15 x 30 m) on which maize variety LAVENA (FAO 250) was grown in 2018 growing season (sown on the 26th April 2018 and harvested on the 27th August 2018) were selected.

2.2. Data Acquisition

Terrestrial measurements of leaf chlorophyll content (LCC) using CCM 300 sensor (OptiSciences) were undertaken during the season, since it is commonly known that chlorophyll concentration is closely related to general plant health status. 81 measuring points were created within nine small-plots and GPS information was recorded simultaneously with LCC measurements. For this study, dataset from the 3rd July 2018 was chosen to be compared with satellite imagery from the 5th July 2018.At this point, canopy was in the growing stage of stem elongation (BBCH 32). Sentinel-2 imagery, provided by ESA was utilized as a source data to derive spectral indices, since it is the major open-source of remotely sensed data with suitable spectral (13 bands) and spatial (10 m/px) resolution. Satellite data processing was performed in SNAP open-source software (ESA). Three spectral indices designed to be sensitive to leaf chlorophyll content were calculated using specific of 13 spectral bands that Sentinel-2 imagery contains. Concurrently, Normalized Difference Vegetation Index (NDVI) was derived as the staple vegetation index providing the information about vegetation general greenness. Table 1 gives detailed overview of the spectral indices utilized in this study.

2.3. Data Processing

Spectral indices were derived from satellite imagery as a raster layer containing the information that is spatially related. Those rasters were processed in QGIS open-source software together with the point layer corresponding to 81 sampling points and containing the information about LCC. Spatially related values of investigated spectral indices were extracted to sampling points and recorded into an attribute table of the point layer. Correlation analysis was undertaken in R [15] open-source software for statistical testing, while the relation between LCC and particular spectral index value was investigated.

Table 1. Spectral indices used in the study to be compared to terrestrial measurements of LCC.

Index	Abbreviation	Formula	Authors
Green Chlorophyll Index	GCI	$\left((NIR)/(GREEN)\right)-1$	Gitelson et al. (2003) [11]
Modified Chlorophyll Absorption in Reflectance Index	MCARI	$[(RedEdge-RED)-0.2\cdot(RedEdge-GREEN)]\cdot(RedEdge-RED)$	Daughtry et al. (2000) [12]
Normalized Difference Vegetation Index	NDVI	$\frac{NIR-RED}{NIR+RED}$	Rouse et al. (1974) [13]
Triangular Chlorophyll Index	TCI	$1.2\cdot(RedEdge-GREEN)-1.5(RED-GREEN)\cdot\left(\frac{RedEdge}{RED}\right)^{-2}$	Hunt et al. (2013) [14]

3. Results and Discussion

Figure 1 represents the trend of indices among 81 sampling points, while figure 2 gives results of correlation analysis; primarily of LCC and index value, however, indices were compared one to each other as well. Both figures indicate substantially ambiguous results, even though the investigated indices are derived from the same source image and might be sensitive to the same vegetation property – chlorophyll content. GCI is the best performing among all investigated indices (r=0.64), however, TCI performs utterly the opposite with negative correlation coefficient (r = -0.47). MCARI and NDVI are the average performing indices indicating slight positive correlation.

Figure 1. Trend of evaluated spectral indices derived from Sentinel-2 imagery and normalized LCC among the number of 81 sampling points.

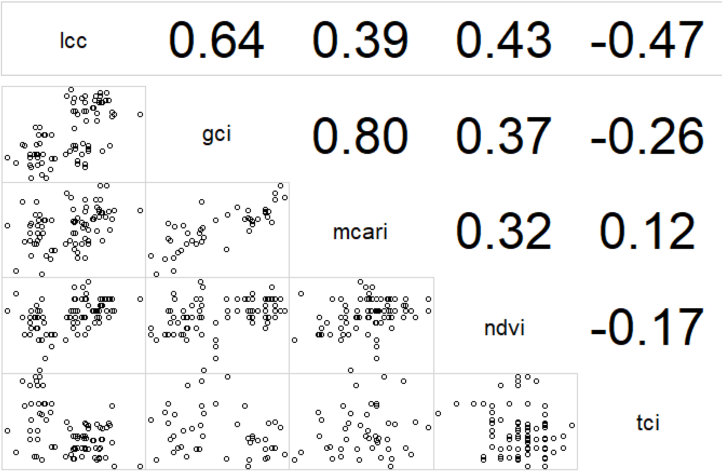

Figure 2. Results of the correlation analysis, where the upper part gives the correlation coefficient and the lower part represents the data distribution at particular analysis level.

The question of usability of Sentinel-2 imagery for describing vegetation properties within small-plots has not been thoroughly investigated yet and it, therefore, remains the subject of debate. However, the study dealing with detecting small water bodies in cities concluded that Sentinel-2 spatial resolution is not sufficient [16]. Sentinel imagery provide free and timely information about the whole Earth surface and is being, still more often utilized for studies in many branches of human life. Possible enhancement might be achieved when combining Sentinel-2 multispectral imagery with radar data from Sentinel-1[17] or with expected launch of another two Sentinel-2 satellites (C and D) that might have finer spatial resolution (5 m/px).

4. Conclusion

The sensitivity of open-source Sentinel-2 satellite imagery was investigated through GCI, MCARI, NDVI and TCI spectral indices. Substantially ambiguous results were acquired leading to the conclusion that the spatial resolution 10 m could not sufficiently describe leaf chlorophyll content on such small agricultural experimental sites. Possible advancement might be achieved by launching Sentinel-2 C and D with finer spatial and temporal resolution.

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