Using high-resolution drone data to assess apparent agricultural field heterogeneity at different spatial resolutions

A case study from a canola field in Switzerland

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Abstract: Fertilizer distribution can be improved by the use of variable rate technology with which plants only receive the amount of fertilizer they actually need. This amount is often calculated with vegetations indexes, such as the NDVI. The NDVI can be derived from drones or satellites. Drones offer more high-resolution imagery than satellites, but satellite data is more readily available. This study focuses on the spatio-temporal difference of apparent field heterogeneity at different spatial resolutions, resampled to 0.5 m and 20 m from high-resolution drone data, throughout the vegetation period and the error induced by low-resolution image data.

Keywords: spectral imaging, drone-based systems, low-altitude remote sensing, field heterogeneity, variable rate technology, return of investment

1 Introduction

Agricultural fields are seldom completely homogenous. Soil, slope, and previous management decisions can influence the conditions under which a crop grows and determine its nutritional needs. However, in current farming situations in Switzerland, fertilizer is still spread largely subjectively, according to the knowledge of the field manager. It is crucial that fertilizer is applied at the right time and in the right place. This prevents over-fertilization of the field as well as fertilizer run-off, and saves fertilizer [Ar21]. Variable rate technology (VRT) can help to apply fertilizer according to the actual need of the plants. VRT can be based on field imagery as input for fertilizer calculation – this imagery can be obtained with hand or tractor mounted sensors, drones or satellites [Wa17]. However, VRT in combination with sensors is very expensive. It is estimated that the use of VRT and sensors only pays off once a certain threshold of heterogeneity in the

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field is reached [SHF21]. Yet, data on field heterogeneity is scare. Further, it is unclear which measuring device captures the in-field variability reliably in small scale fields. Therefore, an experiment was implemented to investigate i) the heterogeneity within a field, ii) the changes of the field heterogeneity throughout the season, iii) the differences in information quality of data sources with different ground sampling distances. In this contribution, results of a pilot study to test the speed and reliability of the analysis procedure are introduced and used to give a preliminary answer to the research questions.

2 Material and Methods

2.1 Field site

The data collection was carried out in north east Switzerland, near the plant research station of ETH Zürich (47.44952°N, 8.68214°E, 553 meters above sea level). The study area included a diverse set of crops, ranging from winter wheat, canola, maize, sugar beet, sunflower to grassland and vegetables of approximately 50 ha. The field for this case study was randomly chosen. The 2.7 ha field was managed according to good agricultural practices by an experienced farmer. By the time of data collection, winter canola was grown on the field. This crop is generally sown in August/September.

2.2 Data collection procedures

The data was collected with a fixed-wing drone (WingtraOne). The drone was equipped with a multi-spectral camera (Red-Edge M, by Mica Sense). The multispectral cameras captured data in 5 bands of the RGB and near infrared spectrum and offered a resolution of 6 to 8cm.

2.3 Data processing and analysis

Orthophotos were stitched together to form an orthomosaic with Agisoft Metashape Professional [Ag21]. The data was radiometrically corrected using the inbuilt downwelling light sensor and a small correction panel provided by the manufacturer. In order to investigate the influence of the ground sampling distance (GSD), the datasets were resampled to different resolutions and compared. The multiband raster dataset was first resampled to 0.5 m GSD. This resolution served as a baseline for the subsequent analysis. Then the Normalized Difference Vegetation Index (NDVI) was calculated and all other bands were removed from the data set. NDVI is calculated from multispectral imagery as follows:

$$NDVI = (NIR - red)/(NIR + red)$$

The NDVI was chosen as an example vegetation index because it is related to biomass [Ca11]. The exact shape of the field was then extracted from the ortho-mosaic. The shapes of the fields were drawn manually in Arc GIS [ES17], using governmental perimeter data and a recent orthophoto as a basis. Incomplete data, wildflower strips or ecological compensation area were excluded. The 0.5 m GSD file was then resampled using a bilinear resampling method to 20 m GSD, respectively 10 m GSD to mimic the resolution of Sentinel-2, a common data source of satellite imagery. The resampled versions were then compared to the original 0.5 m. The relative difference was obtained by dividing values obtained for the 10 and 20 m GSD resolutions by the values obtained from orthophotos of the original 0.5 m resolution. Due to the size of the dataset, the dataset was transferred to a high-performance virtual server running Windows Server 2016 with 40 cores, Intel Xeon Gold 6150 2.7GHz and 500GB RAM, to speed up the data processing and provide efficient parallel processing. The analysis was performed in R version 3.6.1, using the packages “sp”, “rgdal” and “raster” and took approximately 8 min per ortho mosaic.

3 Results

Figure 1 shows the in-field variation of the NDVI at two dates. Lower NDVI values can be found especially close to the tram lines and predominantly in the lower left corner of the field. The in-field variation is less pronounced later in the season as seen in the second date. Figure 2 displays the same field measured at the same dates but resampled to 20 m GSD to mimic satellite resolution. Due to the lower spatial resolution, the in-field heterogeneity cannot be seen as clearly in the 0.5 m GSD as in the 20 m GSD. Inspecting the early date (2019-03-04) closely, areas with a low NDVI are not visible anymore in the 20 m GSD orthomosaic. Still, the general pattern that shows a gradient of NDVI from west to east is visible. This effect is less prevalent in the later date. Small-scale changes in the field heterogeneity were not captured in the 20 m GSD, which is illustrated in Figure 3. Figure 4 presents the histograms of the differential maps for 10 m GSD and 20 m GSD. Overall, the differences between 10 m GSD and 20 m GSD are not pronounced. Generally, the accuracy was higher for the later date (2019-06-29) than for the date earlier in the season (2019-03-24), where both low-resolution images overestimated the NDVI.

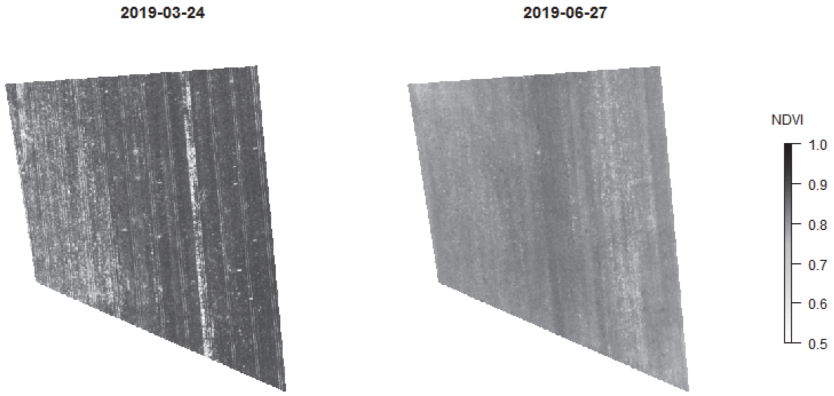

Fig. 1: NDVI orthomosaic taken with fixed-wing UAV of a canola field in north-eastern Switzerland, resolution of 0.5 m for 2 different dates 24.03.2019 and 27.06.2019

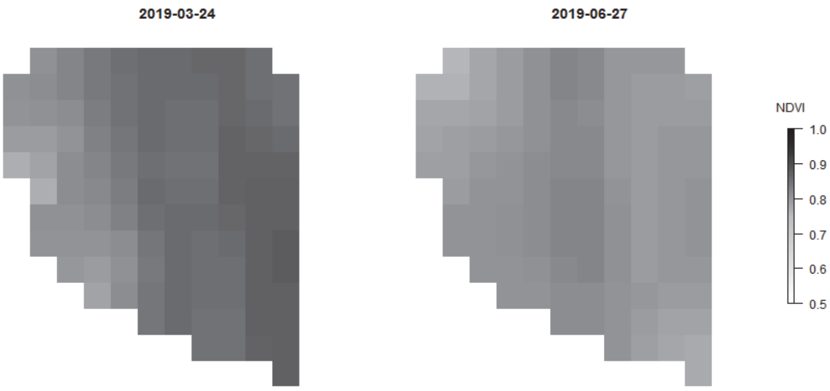

Fig. 2: NDVI orthomosaic taken with fixed-wing UAV of a canola field in north-eastern Switzerland, resampled to a resolution of 20 m for 2 different dates 24.03.2019 and 27.06.2019

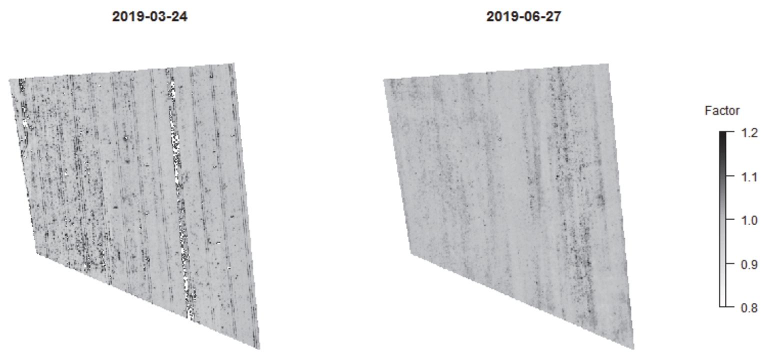

Fig. 3: Differential map generated by dividing the 20 m resolution NDVI map by the 0.5 m resolution NDVI map. Areas where the NDVI is higher in the 20 m resolution image compared to the 0.5 m resolution image have a factor higher than 1, whereas areas with lower NDVI have a factor smaller than 1. Areas which were estimated the same have a factor of 1.

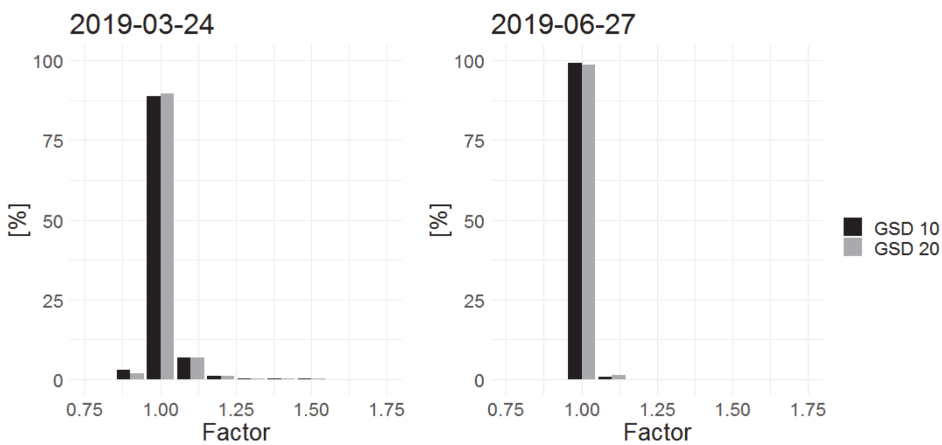

Fig. 3: Histograms of the differential maps for 10 m GSD and 20 m GSD. The bars correspond to the area in percent per factor.

4 Discussion and Outlook

These results confirm that heterogeneity of agricultural fields appear distinct at different spatial resolutions. They further demonstrate that the in-field variability can change over the vegetation period. With high-resolution drone data, the influence of different spatial resolutions and consequently different apparent heterogeneities can be quantified, opening the way to investigate the use of more precise VRT strategy in the future. In particular, this spatially explicit data can be used as a base for economic models [SHF21]. The results also show that in some cases, depending on the crop and the cultivation strategy, more than one data collection needs to be performed in order to capture the heterogeneity correctly. The results also show that for fields with a lot of small-scale variability the satellite loses information and the NDVI can be overestimated. This is especially the case for the early season date, where usually most crop measures take place and application maps are generated. Further studies should explore these effects with other crops, other relevant spatial resolutions and vegetation indices throughout the seasons to investigate the stability of the spatial effects.

5 Conclusion

This study has examined the use of high-resolution drone data to investigate the effect of variable GSD on the NDVI of a canola field at two different dates throughout the vegetation period. The findings indicate that the in-field variability is higher at the beginning of the season and that a higher in-field variability can lead to higher errors when reducing the GSD.

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