UPSCALING AND VALIDATION OF RTK-DIRECT GEOREFERENCED UAV-BASED RGB IMAGE DATA WITH PLANET IMAGERY USING POLYGON GRIDS FOR PASTURE MONITORING

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ABSTRACT:

The monitoring of managed grasslands with remote sensing methods is becoming more important for spatial decision support. Various remote sensing data acquisition techniques are applied for that purpose in different spatial resolutions ranging from UAV-borne to satellite-based remote sensing. In the last decade, UAV-borne imaging and analysis techniques or in the focus of crop and grassland monitoring and provide very high spatial resolutions. In contrast, satellite data are only available in high to moderate spatial resolutions. In this contribution, we introduce direct georeferenced data acquisition with a Phantom 4 RTK for pasture monitoring and investigate the upscaling of the cm data to satellite resolutions using polygon grids.

INTRODUCTION

Proximal and remote sensing technologies play a vital role in precision agriculture (Mulla 2013). For managed grasslands, monitoring approaches face more difficulties due to higher spatio-temporal variations in floristic composition and canopy traits (Schellberg et al. 2008). However, multitemporal satellite remote sensing and UAV-based sensing approaches are suitable to monitor grasslands (Rango et al. 2009, Reinermann et al. 2020). While proximal sensing with manual or tractor-based devices does not provide spatial coverage, optical remote sensing in spatial resolutions below 10 m is often limited due to cloud cover. UAV-based monitoring seems to fit well for these requirements providing very high spatial resolutions whenever necessary in terms of phenology or management, almost on daily base. A limitation for UAV-based approaches to monitor grasslands is costs. Therefore, fully automated UAV data acquisition and analysis workflows are required. For the latter purpose of developing analysis approaches towards a fully automated workflow, only RTK-direct georeferenced image data has the potential to provide desired spatial accuracy to derive spectral and structural canopy traits. Therefore, the objectives of this study are (i) the accuracy evaluation of RTK-direct georeferenced RGB image data, (ii) the upscaling of such data using polygon grids, and (iii) evaluation against high-resolution optical satellite data.

METHOD

The UAV campaign was carried out at the pasture field experiment “Forbioben”. The grazing trial is conducted by the Institute of Grassland Science at the Georg-August-University Göttingen, Germany, and is described in detail by Tonn et al. (2019). In 2002, the field experiment was established. Overall objective is the investigation of patch-grazing patterns. The experiment consists of 9 single 1 ha large paddocks in three intensity repetitions.

For the UAV data acquisition, a DJI Phantom 4 RTK (P4RTK) was used on 05 June 2020. The data acquisition was obtained from 40 m and 45 m above ground resulting in a spatial resolutuion of 0.013 m. The P4RTK is equipped with a 1” CMOS sensor capturing RGB images with 20 megapixels. Stereo photogrammetric analyses using Structure from Motion and Multiview Stereopsis (SfM/MVS) were done with Agisoft Metashape. The SfM/MVS analysis result, the Digital Orthophoto (DOP), was exported in a GIS. For the latter ESRI ArcGIS was used.

For sward growth analysis, the single RGB bands of the DOP were further analysed in ArcGIS. Using the raster calculator function, the vegetation index RGBVI which was introduced by Bareth et al. (2015) and by Bendig et al. (2015), was computed.

$$RGBVI = \frac{G^2 - B * R}{G^2 + B * R} \tag{1}$$

The final step of the UAV data processing was the computation of zonal statistics using a 10 m polygon grid which was generated in ArcGIS. In Fig.1, the generated DOP and the 10 m polygon grid are shown. Additionally, the layout of the grazing experiment can be seen in Fig.1. The nine 1 ha large paddocks are visualized in black bold outlines and the GCPs are colored in red.

Besides the UAV-derived RGB DOP, a high resolution multispectral satellite image was obtained for further analysis. A high-resolution satellite image was acquired by one of Planet's Scope CubeSats on 02 June 2020. The image has a spatial resolution of ~3 m and consists of four spectral bands (Blue: 455–515 nm, Green: 500–590 nm, Red: 590–670 nm, NIR: 780–860 nm). It was provided by Planet orthorectified and with an applied atmospheric correction (Planet Team 2017). From the Planet data, the vegetation indices RGBVI and NDVI were computed:

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$$NDVI = \frac{NIR - R}{NIR + R} \tag{2}$$

Bareth et al. (2016) introduced for upscaling UAV-derived data in ultra-high-spatial resolution the usage of continuous polygon grids and zonal statistics. Zonal statistics are an established GIS functionality which is used to compute descriptive statistics and/or histograms for certain selected zones. To our knowledge, the usage of zonal statistics for a continuous vector grid, the polygon grid, is not applied and provides interesting solutions for upscaling UAV data.. In this approach, every single vector cell serves as a unique zone. The vector grid size can be adjusted to the desired resolution very easily. So, both data sets, the UAV-derived RGBVI and the RGBVI/NDVI from the Planet image were upscaled by using a 10 m polygon grid. In Fig.1, the DOP and the 10 m polygon grid are shown.

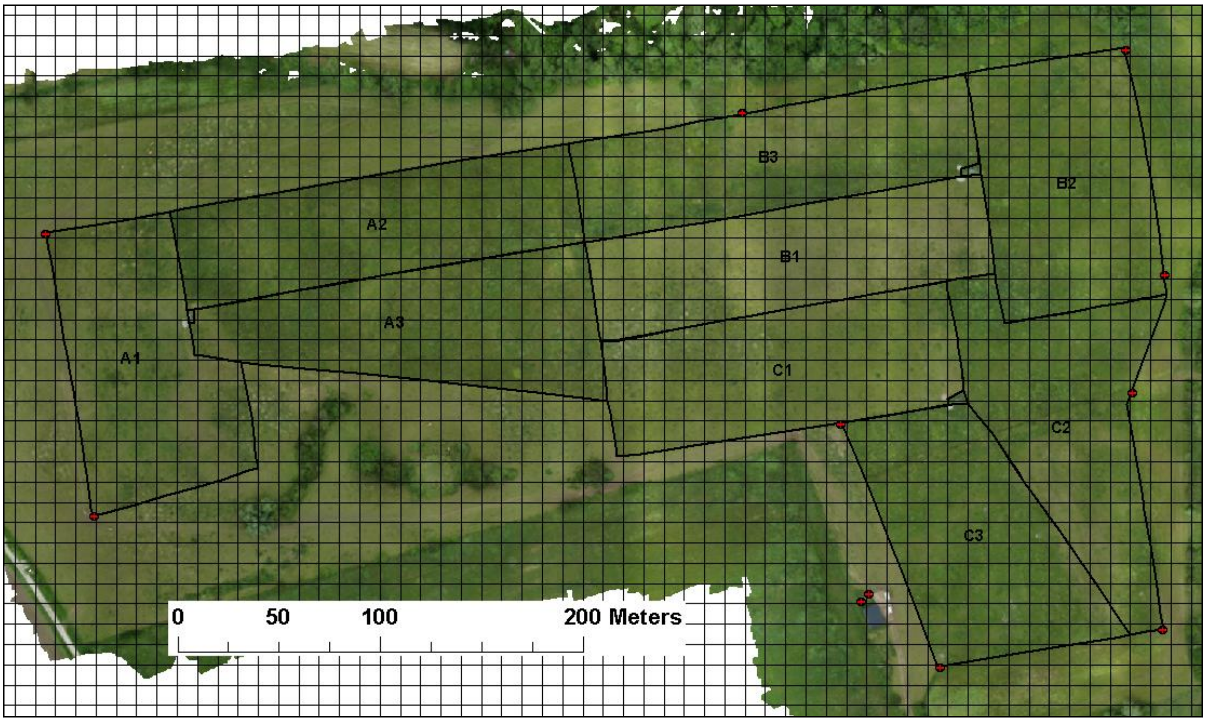

Figure 1. UAV-derived orthophoto of the grazing experiment "FORBIOBEN" and the 10 m polygon grid. The pasture experiment is conducted by the Institute of Grassland Science, University of Göttingen.

RESULTS

The first objective of this contribution is the accuracy evaluation of the RTK-direct georeferenced RGB image data. The spatial accuracy was evaluated using ten Ground Control Points (GCPs) directly located at the outlines of the paddocks and very close to the base station. (see Fig.1). The RMSE for x and y is 0.047 m. The results are visualized in Fig.2 for GCP1 and GCP3.

The RGBVI was computed on the 0.013 cm DOP and was upscaled via zonal statistics to the 10 m polygon grid. In Fig.3, the computed RGBVI in DOP resolution is shown while in Fig.4, the result of the upscaling of the UAV-derived RGBVI in 10 m is presented. It is very well recognizable that there is a significant spatial heterogeneity of the pasture and the overall spatial pattern of the two very different spatial resolutions is preserved. However, as expected is the upscaled pattern of the 10 m polygon grid significantly smoothed in comparison to the original resolution of the DOP.

In Fig.5 and Fig.6, a similar pattern can be observed for the Planet RGBVI and NDVI data. The Planet NDVI is also upscaled on the 10 m polygon grid using zonal statistics. Again it is clearly visible by comparing Fig.3, Fig.4, Fig.5, and Fig.6 that the spatial pattern of the UAV-derived RGBVI in DOP resolution of 0.013 cm and in 10 m is given in the Planet data as well.

Finally, the results of the Planet-NDVI are plotted cellwise against UAV-RGBVI (n = 994). The two datasets correlate well, having a high R^2 of 0.81.

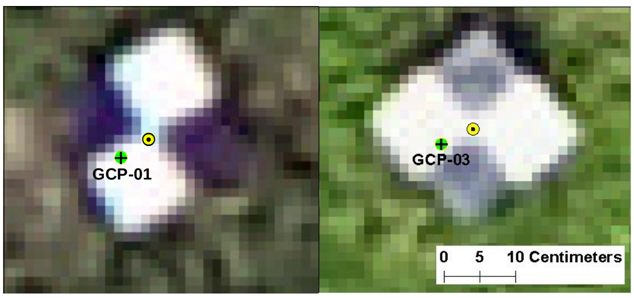

Figure 2. Spatial accuracy of the DOP (yellow) against two RTK-GPS measured markers (green) for June 5th, 2020 (x,y-RMSE for all ten markers is 0.047 m).

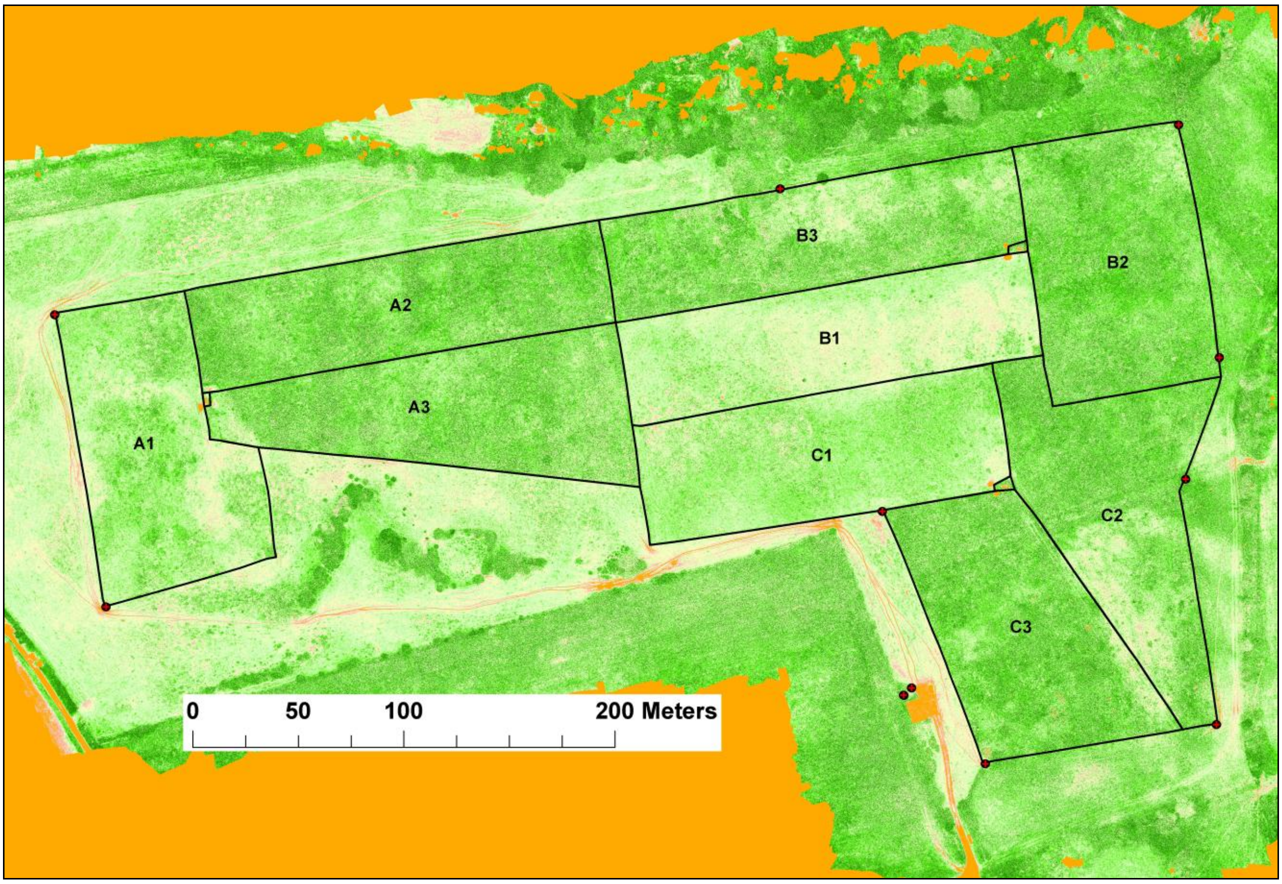

Figure 3. RGBVI analysis of the UAV-derived orthophoto in original spatial resolution of 0.013 m (05 June 2020).

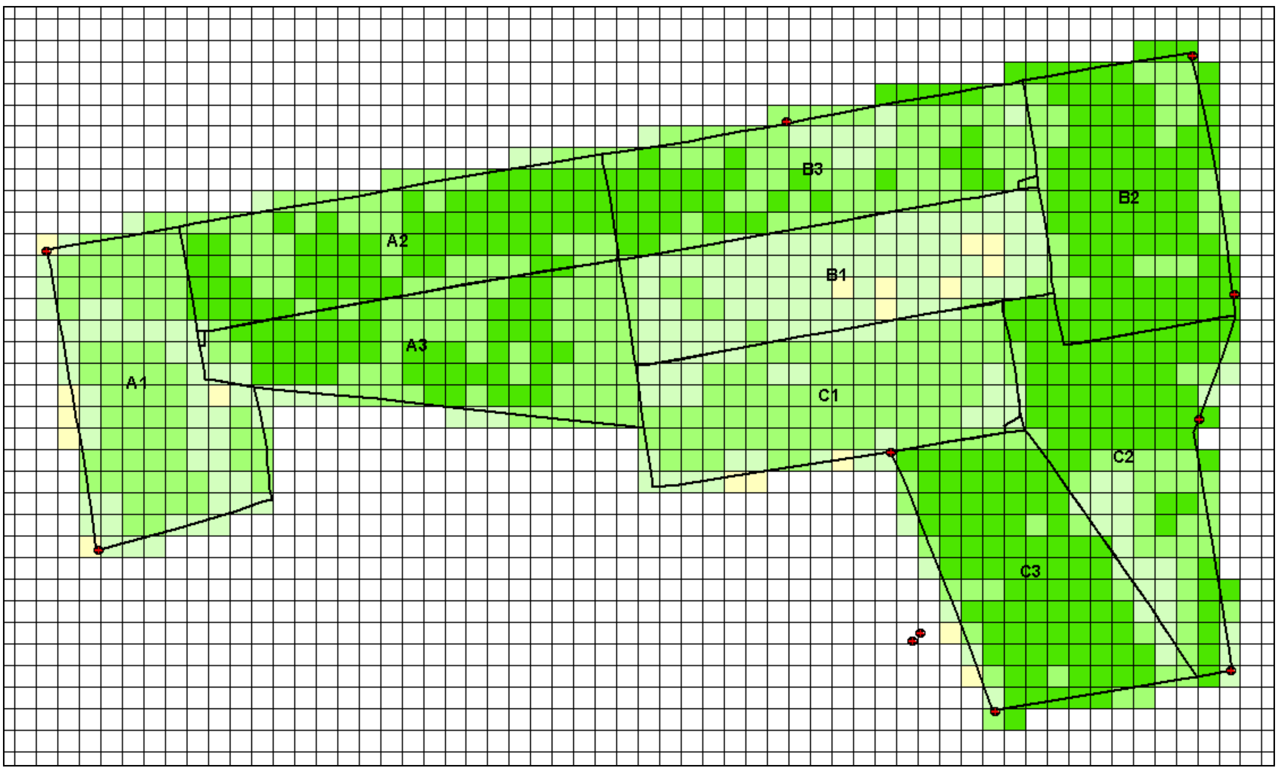

Figure 4. RGBVI analysis of the UAV-derived orthophoto for the 10 m polygon grid (05 June 2020).

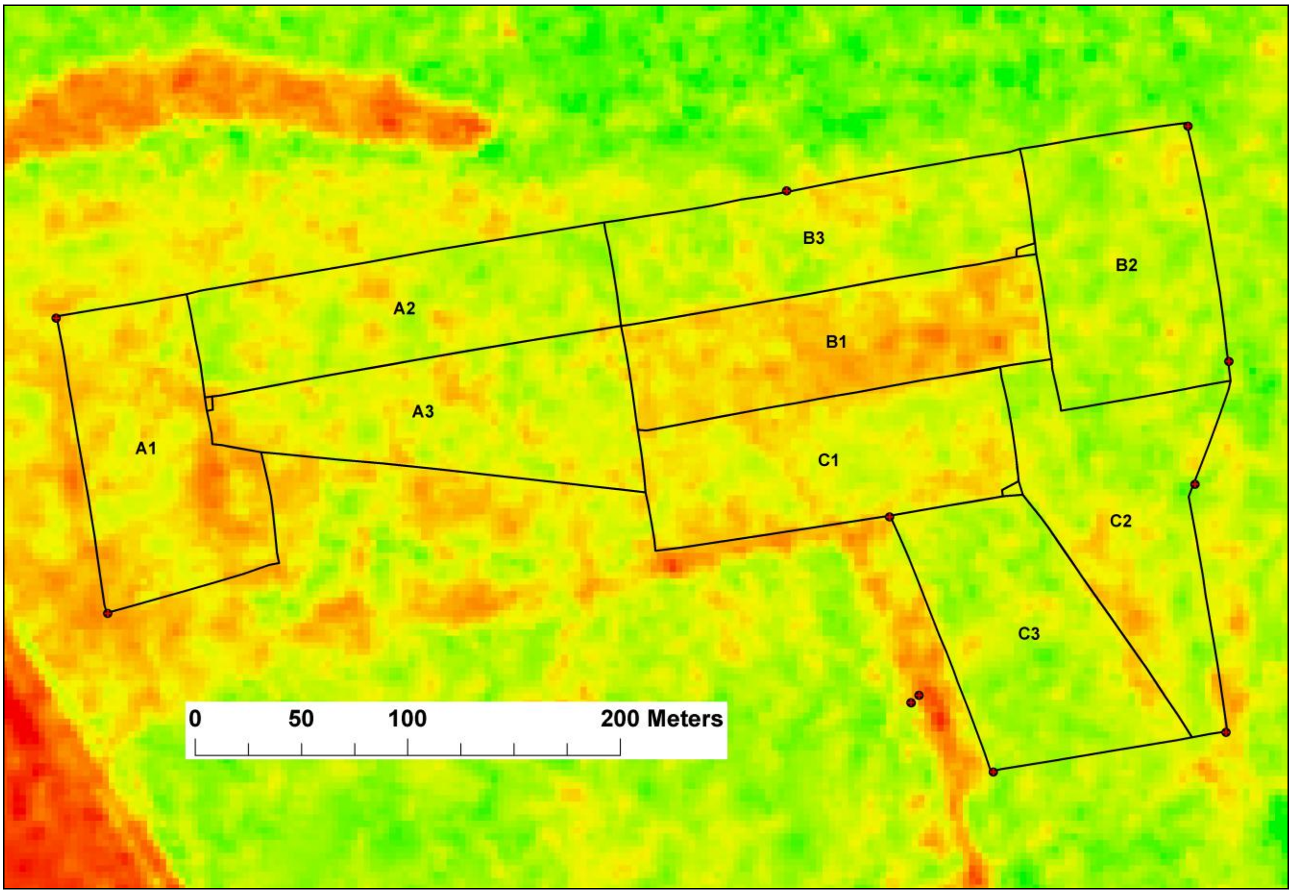

Figure 5. RGBVI analysis of the Planet image in original resolution of ~3 m (02 June 2020).

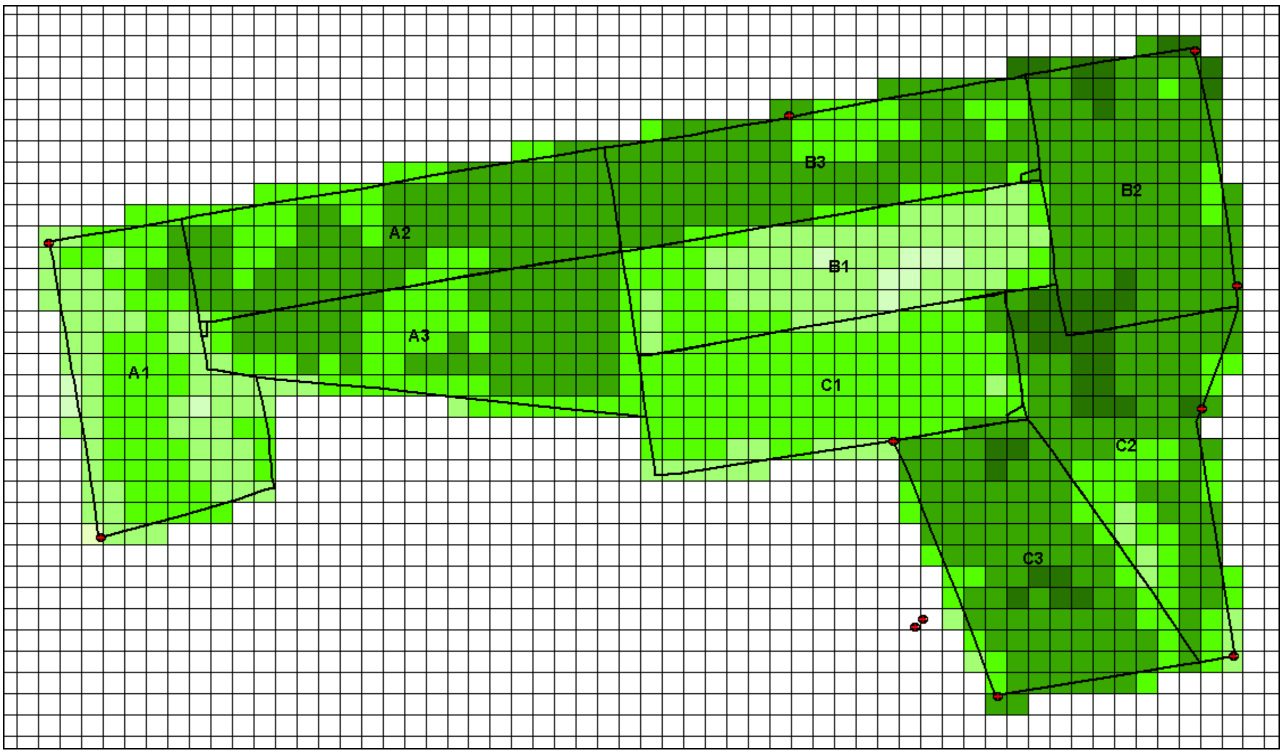

Figure 6. NDVI analysis of the Planet image for the 10 m polygon grid (02 June 2020).

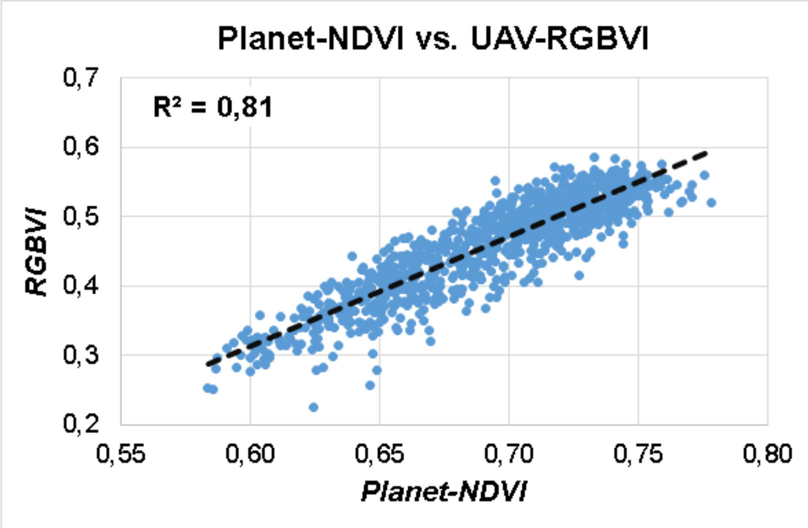

Figure 7. Planet NDVI vs. UAV RGBVI for the 10 m polygon grid (n = 994).

DISCUSSION AND CONCLUSIONS

The three objectives of this study (i) the accuracy evaluation of RTK-direct georeferenced RGB image data, (ii) the upscaling of such data using polygon grids, and (iii) evaluation against high-resolution optical satellite data are investigated. (i) The accuracy evaluation resulted in expected and reported results by the producer DJI (www.dji.com). A x,y-RMSE of approx. 5 cm for direct georeferencing using a base station is satisfying because the goal is to use the UAV derived data in spatial resolutions of 0.5 to 10 m (Bareth 2020; Bareth and Hütt 2020). (ii) The upscaling of the UAV data worked well and the visual spatial pattern seems to be preserved. For further evaluation, (iii) the UAV data was correlated against high resolution satellite data. Plotting the UAV-derived RGBVI against the Planet-derived NDVI in 10 m spatial resolution resulted in a high R^2 of 0.81. The latter is an interesting finding: the radiometrically uncalibrated UAV-RGB image seems to provide similar spatial patterns as the multispectral satellite remote sensing data. Further analysis should be conducted using different satellite data. However, further analysis should also include sward height analysis, which is a robust estimator of forage mass (Lussem et al. 2020) and would enable combined analysis of spectral and structural analysis workflows like the one introduced by Viljanen et al. (2018).

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