Target-oriented spectral index distribution parameters for estimating leaf chlorophyll content from 3D-RGB point clouds in an olive orchard in Tunisia

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Leaf chlorophyll and nitrogen content are crucial parameters in the site-specific management of an olive orchard. Non-destructive, ground-based measurements can be taken using the transmission-based SPAD 502+ chlorophyll meter. However, conducting ground measurements at high density across an orchard can be tedious and time-consuming. To address this, the present field study aims to model these parameters using spectral indices derived from low-cost RGB imagery captured by unmanned aircraft systems (UAVs).

1. Test site and measurements

- Field experiments took place in July 2022 in an olive orchard in Toukaber (36°42°22 "N 9°30'38 "E, governorate of Beja, Tunisia) with a size of 0.73 ha covering 72 trees.
- A Mavic 2 Enterprise Dual (DJI, China) with a 1/2.3" CMOS 12MP sensor chip (RGB) was used for the drone flight campaign at an altitude of 30 m.
- The ground sampling distance was about 2.5 mm and the images were taken with an 80 % overlap.
- On the same day, reference measurements for SPAD data, mainly influenced by leaf chlorophyll and nitrogen, were taken on 16 trees using a chlorophyll meter (SPAD 502+, Spectrum Technologies Inc., USA).
- This indirect SPAD parameter was subsequently defined as the target parameter for the model estimation.

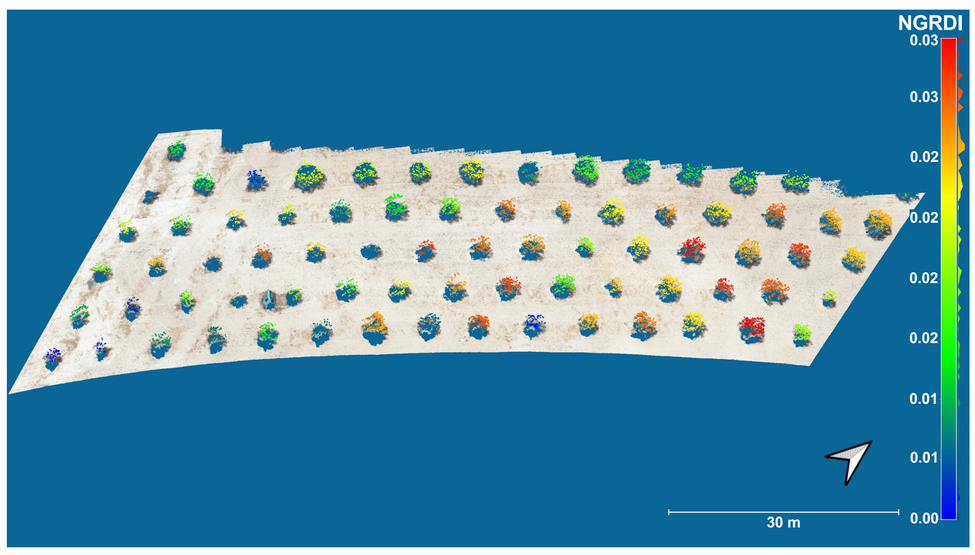

Figure 1 Toukaber olive tree test site as 3D point cloud model with colorized NGRDI values

2. Data analysis

- A point cloud was derived photogrammetrically from the UAV image data set. From the point clouds, individual tree crowns were separated automatically and point-based spectral indices were calculated. Namely the normalized green red difference index (NGRDI) and the green leaf index (GLI) were calculated.
- This dataset was used to perform analysis of statistical distribution parameters for both spectral indices per tree crown.
- All parameters were then applied individually to model the mean SPAD value per tree crown.
- In a second step a stepwise forward multiple regression was used to model the mean SPAD per tree crown.

3. Results

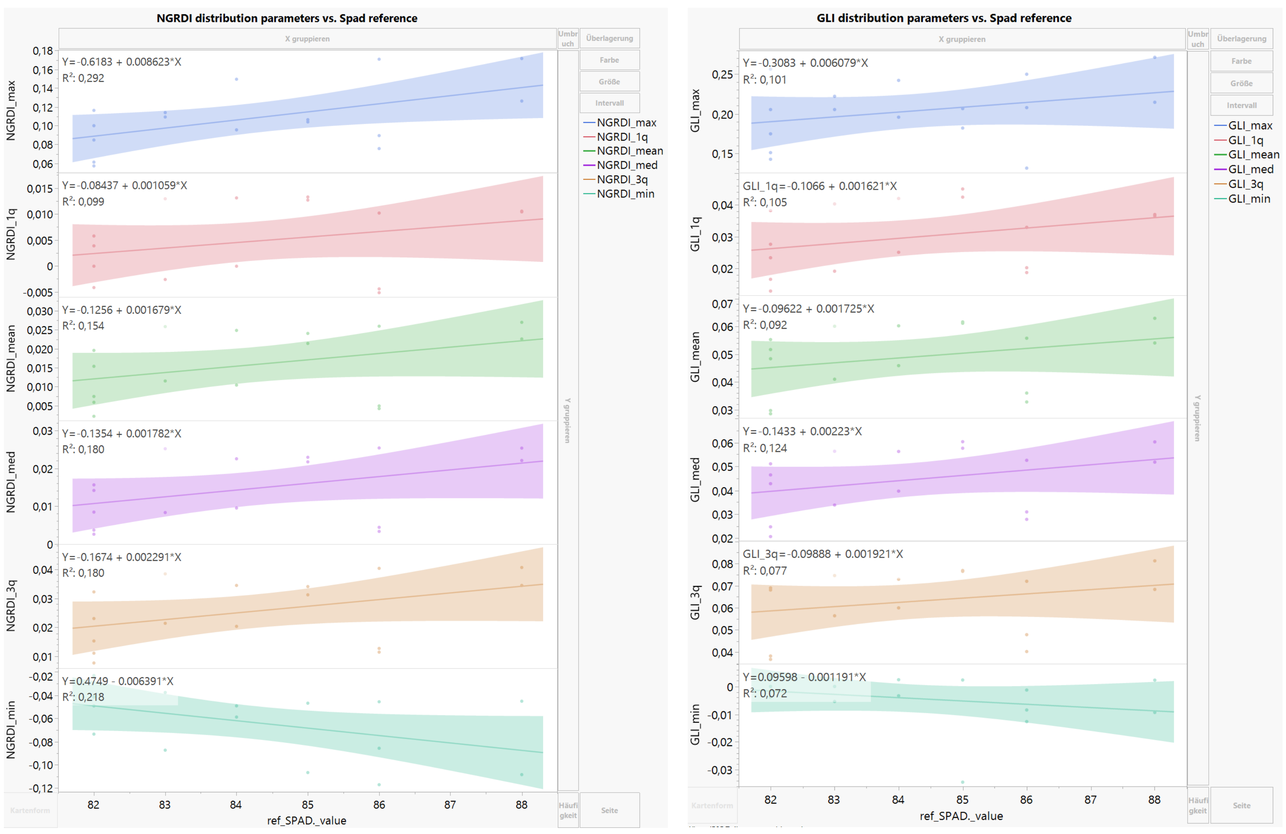

Figure 2 SPAD delineation models based on different statistical parameters from NGRDI and GLI calculations per tree crown

- Figure 2 illustrates the model derivations of the SPAD value from individual statistical distribution parameters of the calculated spectral indices.
- The results show that, when considered separately, these parameters exhibit low coefficients of determination, ranging from 0.10 to 0.29 for the NGRDI and from 0.09 to 0.12 for the GLI.
- It can therefore be concluded that none of these individual parameters per tree crown alone can be used to derive the SPAD value.
- However, if various statistical parameters are combined in a model, it is possible to derive the SPAD value. The optimal model found for this data set uses 6 different parameters, as shown in Equation 1.

$$SPAD = m_1 * NGRDImax + m_2 * NGRDI_{1.\,quantile} + m_3\,GLI_{1.\,quantile} + m_4 * GLImean + m_5 * GLImedian + m_6 * GLI_{3.\,quantile} + n \quad (1)$$

- For an optimal fit the maximum and the lower quantile NGRDI as well as both quantiles, the mean and the median of the GLI are used.
- The combined model has a corrected coefficient of determination of 0.57.
- Due to the small number of trees tested and the fact that the data only represent one field and one season, no conclusion on generalizability can be drawn from this data set.

It has been demonstrated that SPAD values can be derived from drone-based low-budget RGB imagery for this dataset. The optimal model fit uses six parameters from tree crown-derived point cloud distributions and achieves a corrected r² of about 0.57. With the derived model, the SPAD value can be estimated for each tree at the test site. It remains to be researched whether the model is stable in between locations and seasons.

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