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Analysis of the relationship between the volumetric soil moisture content and the NDVI from high resolution multi-spectral images for definition of vineyard management zones to improve irrigation

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As suggested by previous research in the field of precision viticulture, intra-field yield variability is dependent on the variation of soil properties, and in particular the soil moisture content. Since the mapping in detail of this soil property for precision viticulture applications is highly costly, the objective of the present research is to analyse its relationship with the normalised difference vegetation index from high resolution satellite images to the use it in the definition of vineyard zonal management. The final aim is to improve irrigation in commercial vineyard blocks for better management of inputs and to deliver a more homogeneous fruit to the winery. The study was carried out in a vineyard block located in Raimat (NE Spain, Costers del Segre Designation of Origin). This is a semi-arid area with continental Mediterranean climate and a total annual precipitation between 300-400 mm. The vineyard block (4.5 ha) is planted with Syrah vines in a 3x2 m pattern. The vines are irrigated by means of drips under a partial root drying schedule. Initially, the irrigation sectors had a quadrangular distribution, with a size of about 1 ha each. Yield is highly variable within the block, presenting a coefficient of variation of 24.9%. For the measurement of the soil moisture content a regular sampling grid of 30 x 40 m was defined. This represents a sample density of 8 samples ha^{-1}. At the nodes of the grid, TDR (Time Domain Reflectometer) probe tubes were permanently installed up to the 80 cm or up to reaching a contrasting layer. Multi-temporal measures were taken at different depths (each 20 cm) between November 2006 and December 2007. For each date, a map of the variability of the profile soil moisture content was interpolated by means of geostatistical analysis: from the measured values at the grid points the experimental variograms were computed and modelled and global block kriging (10 m squared blocks) undertaken with a grid spacing of 3 m x 3 m. On the other hand, three Quickbird-2 satellite images where acquired and processed to monitor plant vigour. The dates of images acquisition were: 29-07-2004, 13-07-2005 and 13-07-2006. They are within the range of $\pm$2 weeks the moment of veraison, which has been referred to be the optimal time for image acquisition in precision viticulture applications. The normalized difference vegetation index (NDVI) was computed and averaged for the three years. NDVI and soil moisture content were statistically analysed at the sample grid points using Statgraphics Plus 5.1. Previously, average NDVI values were captured and associated to the sample points using ArcGIS 9.1 tools. The objective of the analysis was to determine to what extent NDVI is related to the soil moisture content to use the first variable to establish zones for differential management to improve irrigation in the vineyard block. The results show that there is a significant relationship between the variables expressed by the following equation: avgNDVI = -0.26 + 0.03 avgSMC. The variation of the soil moisture content explains 60.9% of the variability of the vegetation index across the block (p-value $<$0.01). Then, we arrived to the conclusion that detailed NDVI maps at the moment of veraison can be used as basis to identify management zones to adapt the irrigation sectors to the variability of the soil moisture content. Finally, a cluster analysis of the NDVI map using the ISODATA (K-means) algorithm was applied to identify two management zones in the vineyard block. Those zones were used to re-design the irrigation sectors to adapt them to the variability expressed in the two zones.