MONITORING OF RIPENING AND YIELD OF VINEYARDS IN NEMEA REGION USING UAV

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Abstract:

Context and purpose of the study - Nemea region is the largest POD zone in Greece. Agiorgitiko (Vitis Vinifera L. cv.) is the most cultivated variety in Greece with significant wine potential. Due to the extension of the area there is a great variability of soil content and climatic conditions. Seven vineyards in the POD zone were selected and monitored for ripening evolution and yield of vine plots using UAV through the extraction of vegetation indices (NDVI, NDRE, GNDVI and OSAVI). Grapes were harvested at maturity and the enological potential was estimated. Winemaking was applied in order to evaluate the potential of each sub-zone and in order to search if any connection with the vegetation indices. The aim of this study is to research the "terroir" impact in Agiorgitiko grapes and compare the quality features in order to split the Nemea region in subzones.

Material and methods - Four flights took place during the summer of 2018. The UAV platform used was the DJI Matrice 100 and was equipped with the Parrot Sequoia camera. The collected images were combined into orthosmosaics and further analysis was made by combining these mosaics and extracting vegetation indices. From each vineyard grapes were sampled to be analyzed for their physicochemical properties (sugar content, total acidity, pH, YAN, color characteristics). Furthermore, grapes from each vineyard were harvested on the technological maturity level. The same vinification protocol was applied in all samples. After the alcoholic fermentation was conducted the wines were inoculated with lactic bacteria for malolactic fermentation. Classical analysis was performed in all samples.

Results - Vegetation indices (NDVI, NDRE, GNDVI and OSAVI) showed significant differences in each vineyard. Also, significant differences were observed in grapes and wines originated from different vineyards. Phenolic and anthocyanin profile indicated a greater potential in wines from vineyards in higher altitude.

Keywords: Agiorgitiko, Remote Sensing, Ripening Monitor, Vegetation Indices, Wine Analysis

1. Introduction

Varieties of Vitis vinifera have the ability to adapt and thrive in different types of soils. All soil properties, such as depth, texture, structure, porosity, temperature, pH, conductivity and amounts of macroelements and trace elements, influence the development and behavior of the vine (Kalivas D., 2003). Latitude and altitude may also affect the concentration of phenolic components. Studies have shown an increase in the concentration of anthocyanins and flavones in northern vineyards at high altitudes (Bertelli A., et al., 2008), possibly due to prevailing mesoclimate conditions. In addition, the quality of the grapes was increased and had a higher concentration of sugars and anthocyanins in vineyards on hill peaks (Nadal M., 2008).
The wine-growing zone of Nemea has a total area of about 27,000 acres and is the largest PDO wine production area in Greece that extends on an altitude of 200 m to 850 m. Due to its large extent, it is highly varied. For this reason, it is subdivided into three sub-areas with differences in both climate and topography. Wines from different zones have differences in their organoleptic characteristics. The three zones are differentiated by altitude to: i) Lowland, with an altitude of up to 350 m, including the plain of Nemea

(Xerokampos) and the area of Ancient Nemea., (ii) Semi-mountainous, with an altitude of 350 m to 600 m, including the slopes of the hills surrounding the plain and, (iii) Mountainous, with an altitude of 600m and above, and mainly includes the western highlands of Nemea and the foothills of Killini (Ziria).

2. Materials and methods

Grapes and wines analysis - During ripening period, sampling of berries was conducted. The same protocol was established for every sampling. Berries were analyzed for sugar content (Brix), pH, total acidity (g/L expressed in tartatic acid), color intensity (sum of OD420, OD520 and OD620), hue (OD420 divided by OD520) and total phenolic index (OD280). Also Yeast Assimilable Nitrogen (YAN) was measured in the grapes (Scheiner D., 1976, Dukes B. and Butzke C., 1998). After harvest the grapes were vinificated with the same fermentation protocol. All wines were analyzed for pH, total acidity (g/L expressed in tartatic acid), color intensity (sum of OD420, OD520 and OD620), hue (OD420 divided by OD520) and total phenolic index (OD280).

Image Analysis - Remote Sensing Data were acquired using the UAV DJI Matrice 100 and the multispectral Parrot Sequoia Camera which has 4 spectral bands (Green, Red, Red Edge and Near Infra-Red). In order to reduce the variation the images taken were a part of 0,2 hectares from each vineyard. The vineyard plots located in 3 different altitudes. Alecati, Archaies Cleones and Houni were in about 250 m, Mourteriza, Ripes and Gymno were about 450 m and Asprokampos about 800 m from the sea level. The images taken from the 4 flights were combined into Orthomosaics using the Pix4D Mapper 4.3 software. Then four vegetation indices were calculated in ArcMap 10.6 GIS software using the Raster Calculator tool. The Normalized Difference Vegetation Index (*NDVI = (NIR - Red) / (NIR + Red)*) was created in 1974 with the aim of separating vegetation from soil luminosity using Landsat MSS satellite data (Rouse et al., 1974). The Green Normalized Difference Vegetation Index (*GNDVI =NIR - Green) / (NIR + Green*)) is a variant of the NDVI vegetation index using the green spectrum instead of the red. According to GNDVI surveys, it has been shown that this indicator better estimates fluctuations in chlorophyll concentration in vegetation compared to NDVI, yielding better results (Gitelson et al., 1996, Gitelsonand Kaufman, 1998) The Normalized Difference Red Edge (*NDRE = (NIR – Red Edge) / (NIR + Red Edge)*) is similar to NDVI but uses the ratio of Near-Infrared and Red edge. Red edge refers to the region of rapid change in reflectance of vegetation in the near infrared range of the electromagnetic spectrum (Seager et al, 2005).The Optimized Soil-Adjusted Vegetation Index (*OSAVI = (NIR - Red) / (NIR + Red + 0,16) × 1,16*) is a vegetation index similar to NDVI and it has been created to reduce the effects of soil background (Steven, 1998).

Statistical analysis - Significant differences among wines and for each variable were assessed by analysis of variance (ANOVA). Tukey's HSD test was used to separate the means ($P<0.05$) when the ANOVA test was significant. This analysis was conducted using Statgraphics XVI.I.
Using GIS spatial analysis tool (zonal statistics), the mean values of vegetation indices for each vineyard were calculated. These values were correlated (Spearman correlation coefficient) with altitude, weight of 50 clusters, Brix, pH, total acidity, colour intensity, hue, total phenolic index and YAN. Finally the Coefficient of Variation (CV) for each vegetation index was also calculated.

3. Results and discussion

Wines analysis - The highest pH was observed in the wines of Archaies Kleones and Anaskelo (3.86 and 3.85) and the lowest pH on Asprocampos wine (3.45) with statistical significant difference ($p < 0.05$)(Figure 1). Asprocampos wine had the higher total acidity (7.27 g of tartaric acid/L) and the lowest acidity was measured on Anascelo wine (6.27 g of tartaric acid/L) (Figure 2). Color intensity and hue of wines also marked differences among the wines from different vineyards. Asprocampos wine had the highest color intensity (8.1) and the lowest hue (0.58), while the lowest color intensity was measured on Alecati wine (5.1) and the highest hue on Houni wine (0.79) (Figure 3). The total phenolic index of wines indicated that

Asprocampos wine had the higher value for this specific characteristic (41.1) while Alecati and Anascelo wines had the lowest value (31.3 for both wines)(Figure 4).

Image Analysis - The maximum values of the 4 vegetation indices were found on Asprokampos (NDVI = 0.705, GNDVI = 0.611, NDRE = 0.168, OSAVI = 0.561) (Figure 5) at grape harvest (17/9/2018) and the minimum values of all indices were found on Archaies Cleones (NDVI = 0.378, GNDVI = 0.414, NDRE = 0.111, OSAVI = 0.336) (Figure 6) also at grape harvest (3/9/2018). The highest Coefficient of Variation was found on OSAVI (41.56 %) and the lowest on GNDVI (24.39 %). The Spearman Bivariate Correlation showed significant correlations only between Colour Intensity and YAN with vegetation indices and altitude. All indices except NDRE showed significant correlations with colour intensity. OSAVI had the highest correlation: ($r = 0.849$, $p = 0.008$) and NDVI the lowest ($r = 0.786$, $p = 0.021$). OSAVI also showed the highest correlation with YAN ($r = -0.753$, $p = 0.031$) and NDVI the lowest ($r = -0.729$ and $p = 0.04$). Altitude also showed significant correlation with colour intensity ($r = 0.815$, $p = 0.014$) and YAN ($r = -0.744$, $p = 0.034$). The other physicochemical properties showed no significant correlations with any of the vegetation indices.

4. Conclusions

Berries and wines from different areas of Nemea region indicated differences on their qualitative features. In wines from higher altitudes higher phenolic and anthocyanin content was observed, indicating a greater aging potential. The differences above were also confirmed with vegetation indices. Further research and analysis could provide more information about the vine and wine possibilities of Nemea region.

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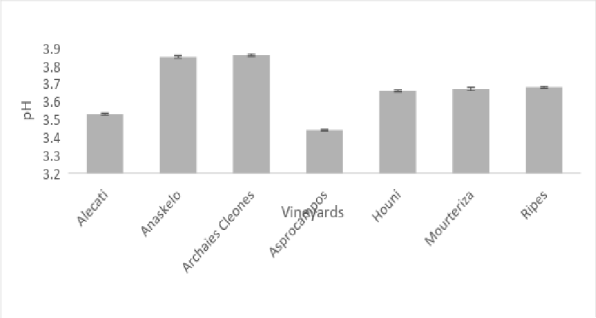

Figure 1: Wines pH values.

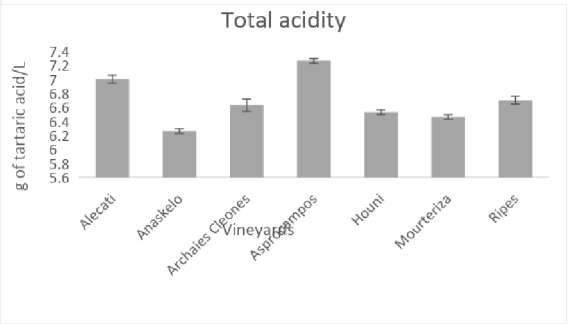

Figure 2: Total acidity expressed in g of tartaric acid/ L.

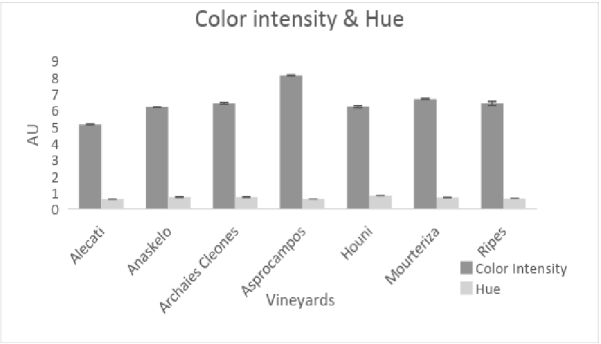

Figure 3: Color Intensity and Hue of wines.

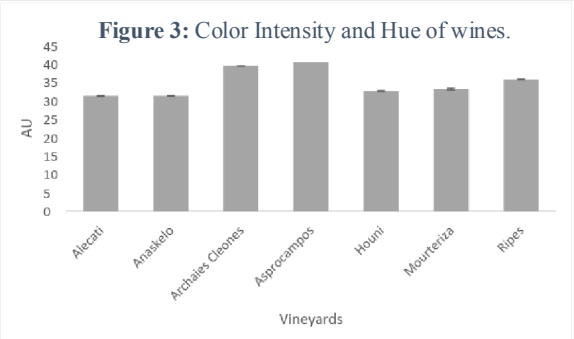

Figure 4: Total phenolic index (TPI) of wines

The symbol ± indicates the standard error of the means.
Values marked with different letters indicate that wines are statistically significant different (Tukey's HSD test, $p<0.05$)

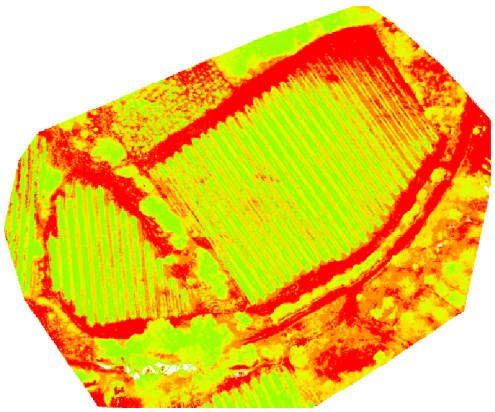

Figure 5: Asprocampos NDVI.

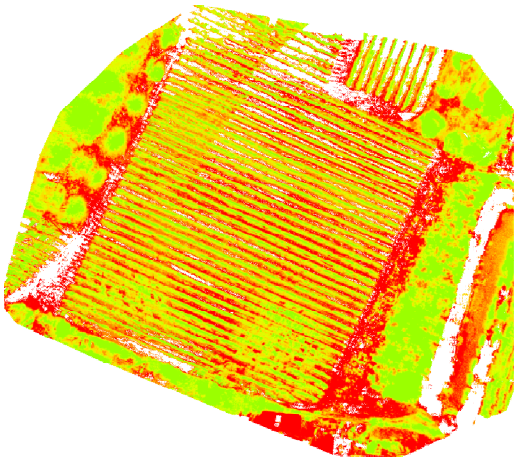

Figure 6: Archaies Cleones NDVI.

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