Application of dGPS to Harvesting Date and Precision Viticulture in Slovenia

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Abstract. In 2002, the maturity of grapevine was researched on the basis of sugar content, total titratable acidity and pH at seven locations with an undulating topography in four varieties 'Chardonnay', 'Riesling', 'Welschriesling' and 'Sauvignon'. All sampling points were geo-referenced simultaneously with DGPS for creating sugar maps. The significant relationship between the varying altitude above sea level (from 395 m to 505 m) and the concentration of sugar and the total titratable acidity of grapes was estimated during the maturity. The results of the study indicate that a great improvement of the grapevine quality is possible in the future by harvested it separately on the basis of site-specific maps.

Keywords: vineyard, sugar map, GIS, GPS

1 Introduction

Precision agriculture has been described as a continuous cyclical process of data collection, followed by interpretation and evaluation of the information acquired and implementation of management decisions in response to it (Cook and Bramley 1998). The chosen technologies vary greatly depending on demands of individual farms (Blackmore 1994).

Recently, only a few studies have been reported concerning the opportunities of precision viticulture to adapt production of grapes and wine according to the vineyard performance and desired goals in terms of yield and quality, although the altitude, orientation of the slope and its angle was already reported to affect the heat gain significantly (Horney 1973; Becker 1978; Hoppmann 1978; and Hoppmann et al. 1997).

The grape wine quality and its interaction with yield and soil properties is of greater importance than might occur in arable farming (Bramley and Proffitt 1999, 2000). Therefore, management strategies need to be developed so both yield and quality can be optimized. The first investigation of relationships between the yield, grape berry quality and soil properties, studied at two vineyards, showed that an improved understanding of the input to the grape production system was required. For mapping of selected soil and vine indices Bramley (2001) used a modification of the HarvestMaster grape yield monitor. In another study, Bramley and Williams

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(2001) successfully implemented a protocol for grape yield map production for two years in Coonawarra, Australia. However, it was proved that the commercial yield monitoring equipment has not been matched for making useful maps, because of the lack of associated support tools. Thus, it is suggested for wine producers to apply robust methodologies for production of yield map and other vine attributes.

In Europe, as the most important vine producer in the world, the vineyard managers still have not access to a reliable methodology for updating their inventories of vineyard distribution on their territory and technical means to exploit this knowledge for supporting their decision in land management in grape producing (Montesinos 2002). To develop a methodological approach for defining and testing a vineyard database structure and spatial analysis procedures between years 2002 and 2005 the EU has founded the BACCHUS project.

Regrettably, till now, no comparable research has been conducted in Slovenia neither our wine producers are jointed in European projects, because the holdings are extremely fragmented and most of them are less than five hectares. However, although Slovenia is one of Europe's smaller countries, the landscape and climate is very diverse, causing by the variety of climatic (Alpine, Panonian, Mediterranean and transitional) and geological conditions which contribute to the use of a wide variety of grapevines and consequently a large assortment of vines in our wine–growing regions.

The eastern Slovenian region contains about 9000 ha of vineyards, with good yields, but the individual vineyards are small too, with very steep slopes that influence times of ripening of grapes. Nowadays, when, according to the applied technology, the whole area of each vineyard is harvested manually at the same time, substantial loss of quality may result. Namely, as shown for the sub-alpine vineyards by Bertamini et al. (1999) and Rusjan (2002) for western Slovenian vineyards, the significant influence of increasing altitude on the sugar content of grapes was detected due to the increasing hours of day sunshine on well exposed south- and west-facing. However, the positive correlation was not found for the vineyards lying higher as 550 m.

The main objective of our investigation was to produce a vineyard data base structure and to investigate the possibility of a site-specific determination of optimal maturity of grape berries with the respect to the varying altitude of the vines above mean sea level (MSL).

2 Site description and sample collection

The area selected for this study was the 20.0 ha Faculty vineyard, Meranovo (Lat = 46º 02' 53.27004" N, Lon = 14º 32' 37.36262" E). The site is divided into nine parcels lying on differently oriented terraces and is roughly 900 m long (east-west) by 650 m wide (north-south). It is characterized by an undulating topography with a difference of 98 m in altitude between the highest (505 m) and lowest point (407 m). As clearly seen from Fig. 1, rows of grapes are oriented up and down the south ('Sauvignon'), south-east ('Welschriesling' and 'Riesling') as well as south-west facing slopes ('Chardonnay'). However, in the very near history all rows were oriented across the slope as it can be still noticed in the middle of the old ortho-photo map before the last vineyard reconstruction was conducted two years ago.

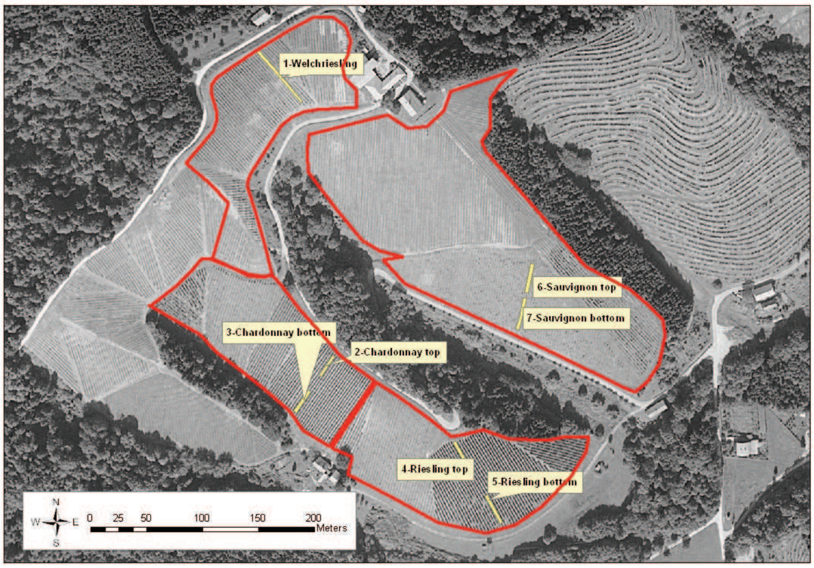

Fig. 1. Position of the monitoring locations in vineyards

For investigating the influence of differences in height above mean sea level (MSL) on the ripening of grape berries, four different parcels planted with varieties 'Chardonnay', 'Riesling', 'Welschriesling' and ‘Sauvignon’ were selected. As seen from Tab. 1, three of those parcels were divided into a top and bottom area, while the 'Welschriesling' parcel remained undivided.

Table 1: Data of the monitoring locations

Location	Variety	Area [ha]	Row orientation	Mean altitude [m]
1	Welschriesling	0,0161	South-east	505
2	Chardonnay top	0,0055	South-west	458
3	Chardonnay bottom	0,0061	South-west	440
4	Riesling top	0,0070	South-east	435
5	Riesling bottom	0,0076	South-east	410
6	Sauvignon top	0,0041	South	423
7	Sauvignon bottom	0,0047	South	395

The quality analysis including the content of sugars (deg Brix), total titratable acidity (g/l) and pH were performed to evaluate the effect of MSL on the process of ripening, whereas the content of sugar was the most important parameter for the vine producer.

On locations 2-7, every seven days, between August 8th 2002 and the grape harvest determined on the sugar content of each variety separately, four samples of each variety were taken (two from the top part of each parcel and another two from the bottom part). Each sample included 100 randomly collected grape berries from 25 grapevines i.e. two berries from the sunny side and two from the shadow side of each selected grapevine. The grape berries were weighed prior the pressing and the grape juice was later analysed in the laboratory on the content of sugars (deg Brix) refractometrically, total titratable acidity (g/l) and pH (with pH meter Mettler Toledo M120).

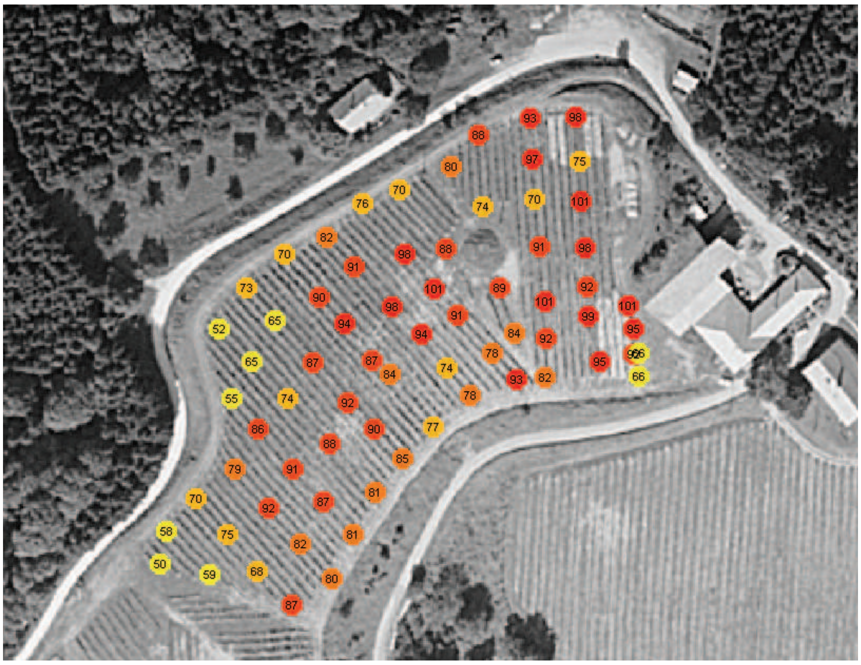

Fig. 2. Position of sampled points on the ‘Welschriesling’ variety parcel

On the location 1, planted with the ‘Welschriesling’ variety the influence of undulating topography on the sugar content of grape berries was evaluated only at the harvest. A regular grid (5x5 m) sampling strategy based on the row and grapevine spacing was used (Fig. 2). On that way, approximately 1% of the total number of grapevines was sampled. All sampling points were geo-referenced with DGPS. For each sample, five grape berries were collected from the middle bunch growing on the sunny side of the grapevine and five grape berries from the shadow side, respectively. Berry quality was assessed in the same way as on the other six areas. The DGPS measurements data (±0,5 m) were acquired using a GPS receiver CMT

MARCH II (Corvallis Microtechnologies Inc.). Additionally, an associated local base-station GPS (GSR1 located in Ljubljana (Slovenia) (Lat = 46º 02' 53.27004" N, Lon = 14º 32' 37.36262" E, h = 351.6585 m) was used to supply differential data to correct the coordinates of the data from the receiver. The ground control location was referenced to a Gauss-Krieger projection.

All map production and spatial analysis was conducted using the ArcView as well as the PC-GPS software.

3 Statistical analysis

To examine the relationships between quality parameters of each grape variety measured at different times during the ripening and the altitude (MSL), on 'Chardonnay', 'Riesling', 'and ‘Sauvignon’ parcels a correlation and linear regression analysis as well as paired samples t-test were calculated. Contrary, on the parcel planted with ‘Welschriesling’ only the correlation and linear regression analysis between different altitudes across the whole area and the sugar content were investigated. For performing the statistical analysis the SPSS Package Program was applied.

4 Results and discussion

Changes of the content of sugar (deg Brix), total titratable acidity (g/l) and pH for all selected varieties are represented in Fig. 3 to 5.

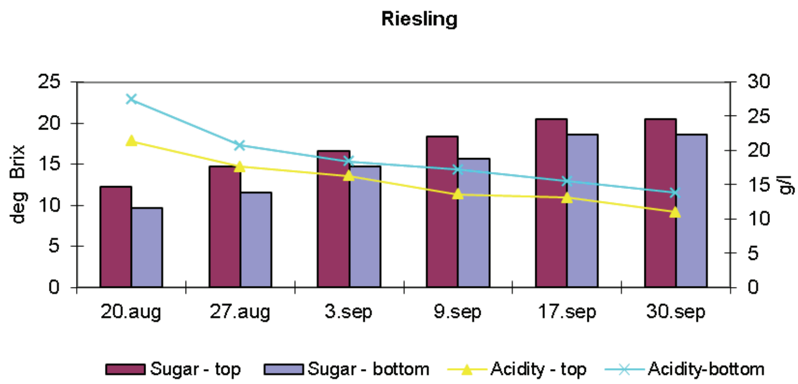

Fig. 3. The sugar content (deg Brix) and total titratable acidity (g/l) of the ‘Riesling’ variety from the top and the bottom of the row

As seen from Figure 3, showing changes in the 'Riesling' variety during August 8th and September 30th, lower quantities of the sugar content and higher quantities of the total acidity were detected from the bottom part of the parcel, while higher quantities of the sugar content and lower quantities of the total acidity were measured on the top part of the parcel.

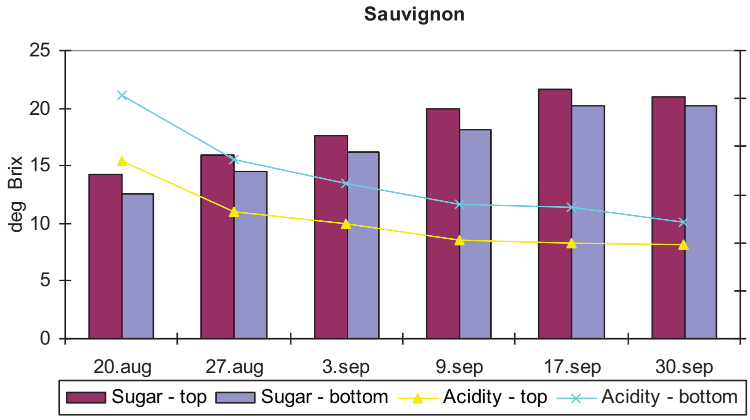

Fig. 4. The sugar content (deg Brix) and total titratable acidity (g/l) of the 'Sauvignon' variety from the top and the bottom of the row

The main reason for differences in crop maturity between the top and bottom of the slope was due to the temperature differences affected by the higher sunshine hours. Secondly, according to Žiberna (1992) a phenomena of the 'warm thermal belt' lying 20-30 m above the lowest point of the vineyard, was found to be the most important factor influencing the temperature differences in the night between the upper and lower part of vineyards in the eastern Slovenia.

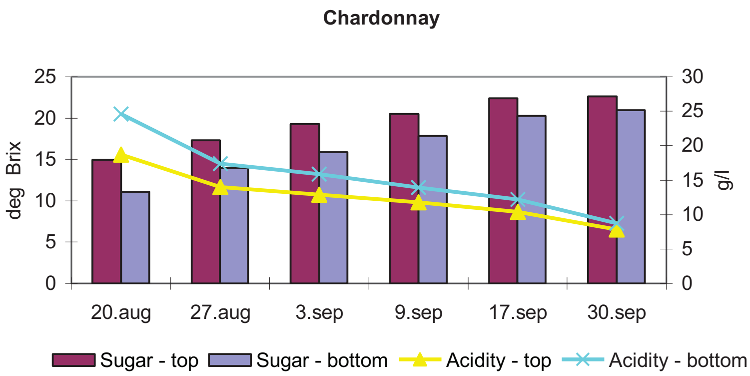

Fig. 5. The sugar content (deg Brix) and total titratable acidity (g/l) of the 'Chardonnay' variety from the top and the bottom of the row

Furthermore, the same interaction of slope angle, facing and altitude and their effect on heat gain was also reported by Bertamini et al. (1999) for vineyards in the Trento region (Italy) and Hoppmann (1978) for Rheingau and Baden vineyards in Germany.

For the 'Sauvignon' and 'Chardonnay' varieties the same pattern in the development of sugar and total acidity content was detected (Fig. 4 and Fig. 5), showing the influence of the different altitude above the sea level on the ripening of grapes.

With additional paired samples t-test statistics given in Tab. 2, 3 and 4, the significantly higher values of sugars were analyzed from the top sub-parcels than from the bottom ones in all grapevine varieties proving again the dominant influence of the higher temperature on the ripening of grape berries.

Table 2: Paired sampled statistics for sugar content (deg Brix)

Pair	Mean	Paired differences					
		Mean	Std dev	Std Error	Df	t	p
Chardonnay top-Chardonnay bottom	19,51 16,72	2,78	0,78	0,22	11	12,33	0,001
Riesling top-Riesling bottom	17,61 15,44	2,16	0,69	0,18	13	11,63	0,001
Sauvignon top-Sauvignon bottom	18,38 16,91	1,46	0,44	0,13	11	11,40	0,001

Table 3: Paired sampled statistics for total titratable acidity (g/l)

Pair	Mean	Paired differences					
		Mean	Std dev	Std Error	Df	t	p
Chardonnay top-Chardonnay bottom	12,61 15,49	-2,87	1,60	0,46	11	-6,21	0,001
Riesling top-Riesling bottom	14,67 17,82	-3,15	1,31	0,35	13	-8,99	0,001
Sauvignon top-Sauvignon bottom	12,27 16,68	-4,41	1,50	0,43	11	-10,18	0,001

Table 4: Paired sampled statistics for pH value

Pair	Mean	Paired differences					
		Mean	Std dev	Std Error	Df	t	p
Chardonnay top-Chardonnay bottom	3,09 3,08	0,003	0,054	0,015	11	0,212	0,836
Riesling top-Riesling bottom	2,88 2,85	0,022	0,049	0,013	13	1,669	0,119
Sauvignon top-Sauvignon bottom	2,91 2,90	0,007	0,062	0,018	11	0,414	0,687

Contrary, total acidities were significantly higher on the bottom than on the top sub-parcels reflecting the much known changes in the sugar and acidity development during the ripening. Aside, the pH values did not differ substantially in any grape vine variety.

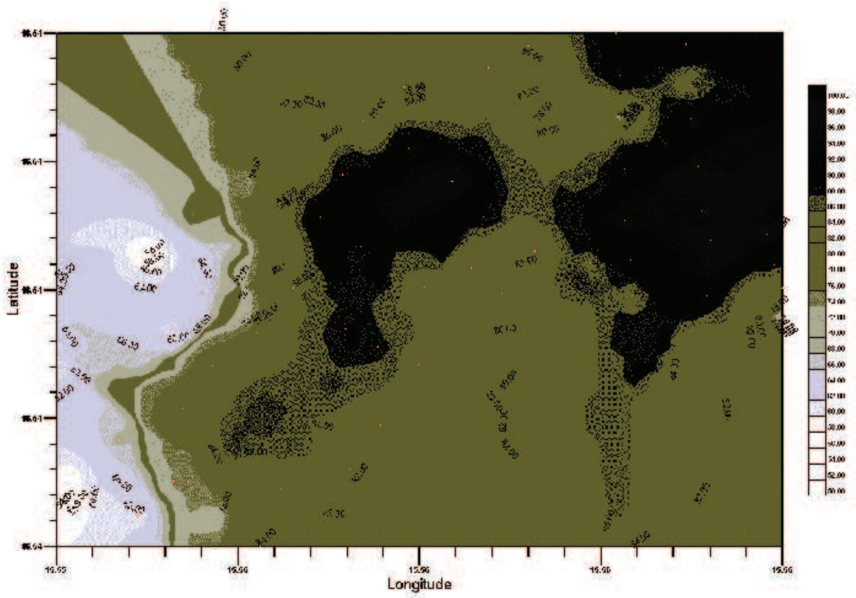

Fig. 6: A sugar map of the 'Welschrisling' variety (Oe)

A sugar map based on measurements in the 'Welschriesling' grapevine variety is shown in Fig. 6. According to the distribution of the sugar content, the influence of the near-by growing forest on the screening from the afternoon sunshine can be seen on the left side of the map. Contrary, the two outstanding picks in the middle of the parcel were detected due to the local depression, causing the mild micro climate, which reflected in the higher sugar concentration during the ripening. However, a statistically significant correlation between the elevation and the sugar content was not estimated, probably because of the insufficient difference between the highest (510m) and lowest measuring point (490m).

4 Conclusions

The proposed geo-referenced monitoring technique based on the GPS data measurements can be employed to provide objective information on the ripening process of grape wines growing on the varying altitude above sea level.

The system was used successfully during the ripening (August-September) in four varieties 'Chardonnay', 'Riesling', 'Welschriesling' and 'Sauvignon'. In all cases when the difference between the top and bottom part of the parcel was over 15 m, the sugar content was significantly higher on the top part of the parcel than on the bottom one, while the total titratable acidity was lower. The results of the research showed that sugar maps could form the basis for forecasting an optimal harvesting time in the future for each part of the vineyards lying on the extremely steep slopes, separately.

However, an enhanced and complex understanding of the interaction between the vineyard, altitude, diseases and the soil variability is necessary to successful adopt the site specific determination of optimal grape harvest, thus further work is needed to study these particular cases also in the other growing areas.

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