Geographical features such as slope and exposure are terroir elements influencing grape quality

Elena Mania[1], Luca Gangemi[1], Mauro Piazzi[2] and Silvia Guidoni[1a]

[1]Department of Agricultural, Forest and Food Sciences. Università degli Studi di Torino. Via P. Braccini 2 - 10095 Grugliasco (TO), Italy
[2]Timesis srl, Via Niccolini 7, San Giuliano Terme (PI), Italy
[a]corresponding author: silvia.guidoni@unito.it

Abstract. The hilly landscape is characterized by high geospatial heterogeneity. In this context elevation, slope, aspect and geographic coordinates are able to affect climate at meso scale level.. Based on this assumption, we hypothesized that vineyards geographical features may also influence grape quality. In order to verify this hypothesis the Barolo wine production area (North-West Italy) has been selected because its vineyards are homogeneous from pedological point of view and for the agronomic techniques adopted, but different for site features. The 17 chosen vineyards have been classified into 3 geomorphological/mesoclimatic units after detecting their geographical traits such as elevation, exposure, and slope and calculating incident solar radiation. Bioclimatic indexes were calculated using data from meteorological stations located within each unit. The grape ripening was monitored in two subsequent seasons (2012-2013). Relations between these parameters were studied using multivariate statistics. An interaction of the site and meteorological characteristics on plant vigour, grape yield and quality emerged. The south-east facing vineyards were more vigorous, had higher productivity and lower berry sugar and anthocyanins concentrations than those of south- or west-facing vineyards. The accumulation of anthocyanins was particularly sensitive to season, vineyard exposure and incident solar radiation: in both years their concentration achieved higher amount in west exposure and lower in those east-facing.

1. Introduction

Landforms are natural physical features of the landscape; hill is the typical landform were viticulture find its own best expression. The hilly landscape is characterized by a high geospatial heterogeneity giving rise to quite different environments in term of the elevation, slope and aspect whose synergic action may influenced water flow, weather, intercepted solar radiation and climate at meso scale level. For these reasons is valuable to take into consideration the geospatial variables when studying the elements of terroir. Based on these assumptions, we hypothesized that site characteristics could also influence grape quality. To verify this hypothesis a suitable area has been identified in the production area of Barolo wine, about 2100 ha of cv. Nebbiolo vineyards in North-West Italy

2. Material and methods

A complex hilly system characterizes the study area where altitude and exposure of the slopes varies considerably due to the typical morphology of the territory and the remarkable gradient of the slopes. On the contrary, the soils are relatively uniform both from a geological and taxonomy point of view. This area is sited on marine grey marls *(Marne di Sant'Agata Fossili*) and the soils belong to the inceptisols or entisols, mainly poorly evolved being affected by high erosion rate due to the steep slopes and soil management practices [1, 2, 3]. Also in term of texture, pH, organic matter, limestone content, the soils are quite homogeneous (silt loam to silty clay loam texture, pH > 8, organic matter generally lower then 1.5%, and total limestone ranging between 14 and 27%). The techniques adopted for trellis system, pruning, canopy and soil and weed management of Nebbiolo vineyards are part of the local skills and know-how, thus they are quite homogeneous in all the region. In that area, the vineyards of Nebbiolo for Barolo wine production occupy slopes facing north-east to north-west with an altitude above sea level ranging between 250 and 450 m. For this study, 17 vineyards have been chosen aiming to represent all the possible exposure and altitude range (Table 1).

The geographical features of the vineyards, such as slope, altitude, exposure and GPS coordinates have been assessed and intercepted surface solar radiation has been estimate by using the tool "Area Solar Radiation" of ArcGIS Pro 2.1 software (ESRI, US). The main bioclimatic indexes related to the vine vegetative period were calculated for the MUs using data from meteorological stations located within each of them

The grape ripening has been monitored in two subsequent seasons (2012-2013) analysing the main technological parameters of the musts, such as sugar concentration (Brix), titratable acidity (mg/L of tartaric acid), pH, malic and tartaric acids (mg/L), potassium (mg/L), yeast available nitrogen (YAN), skin total anthocyanin content (mg/L). The vine vigour and yield have been also assessed during vegetative period and at harvest, respectively.

Multivariate statistical analysis (Principal Component Analysis, PCA) has been performed by SAS 9.4 for Windows (SAS Institute, Cary, USA).

3. Results and discussion

On the base of the result of the PCA analysis carried out on the geographic variables, the 17 vineyards have been classified into 3 geomorphological units (MU). The incident solar radiation (correated with Prin1) and exposure (correlated with Prin2) were the most discriminant variables allowing this classification (Figure 1). Vineyards belonging to MU1, MU2 and MU3 were averagely exposed towards south south-west, west north-west and east south-east respectively.

Table 1. Vineyard codes, municipalities, GPS coordinates and mesoclimatic units for the 17 vineyards investigated during 2012 and 2013, in Barolo wine production area (N-W Italy).

Vineyard codes	Municipality	GPS coordinates		MU
273	Novello	44°35’04.55’’N	7°55’27.69”E	1
274	Novello	44°34’54.29’’N	7°55’42.86”E	1
289	Serralunga	44°37’07.94’’N	7°59’53.03”E	1
290	Sinio	44°36’04.28”N	8°00’33.16”E	1
291	Sinio	44°36’00.54”N	8°00’45.35”E	1
284	Barolo	44°36’55.13”N	7°57’22.72”E	2
285	Castiglione F.	44°37’30.09”N	7°57’58.10”E	2
286	Castiglione F.	44°36’56.67”N	7°58’03.10”E	2
287	Castiglione F.	44°36’58.60”N	7°58’00.41”E	2
288	Serralunga	44°37’40.17”N	7°59’28.39”E	2
283	Barolo	44°36’50.05’’N	7°56’34.22”E	3
292	Diano d'Alba	44°39’22.10”N	8°00’37.26”E	3
293	La Morra	44°39'55.87"N	7°56'50.99"E	3
294	La Morra	44°38’13.56”N	7°57’53.23”E	3
295	Verduno	44°39’34.74”N	7°55’46.20”E	3
296	Verduno	44°40'23.49”N	7°56’23.64”E	3
297	Verduno	44°40’30.12”N	7°56’51.69”E	3

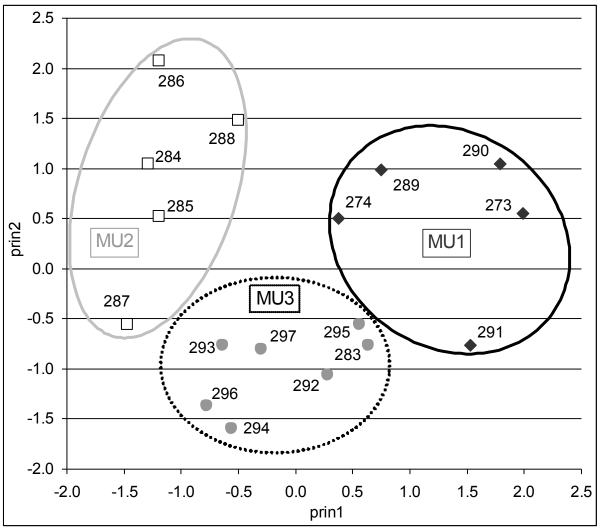

Figure 1. Distribution of the vineyards based on the PCA model considering the geographical variables and aiming to discriminate the mesoclimatic units (MU) where cv. Nebbiolo is cultivated: ◆vineyards belonging to MU1, ☐vineyards belonging to MU2, ● vineyards belonging to MU3.

Bioclimatic indexes (Table 2) of a period of five years (2012-2016) have been used to perform another PCA analysis . On the X-Y plot individuated by the first two Principal Components the MUs maintained a similar relative spatial order regardless the vintage (Figure 2). The variables more effective in discriminating the vintages were the minimum temperatures of April and August, and rainfall of August and September, correlated with Prin1. More effective in discriminating the MUs the variables associated to the Prin2: the maximum temperature of August and September and the days with temperature exceeding 30 °C (Table 2). In all the seasons, the points related to MU1 and MU3 were positioned above and below to the ones related to MU2, respectively. This evidenced that MU1 was generally warmer than MU2 and MU3 that, in turns, was generally the coolest.

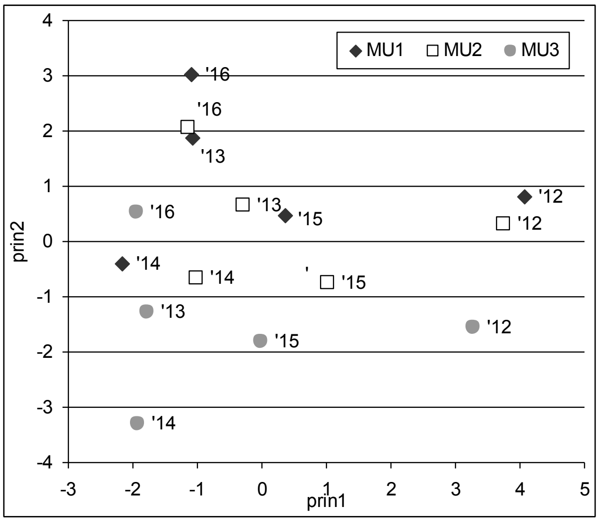

Figure 2. Distribution of the vintages (2012-2016) based on the PCA models carried out on the bioclimatic indexes and aiming to discriminate the mesoclimatic units (MU): ◆vintages of MU1, ☐vintages of MU2, ● vintages of MU3.

Table 2. Eigenvectors of the bioclimatic indexes on the first three Principal Components explaining the vintage distribution of the Figure 2. In bold the variables more correlated to the Principal components.

	Prin1	Prin2	Prin3
Variance explained %	37	23	14
Eigenvalues	4.5	2.7	1.7
April min temperature (minT)	**-0.43**	0.08	-0.19
August minT	**0.45**	0.14	-0.01
September minT	-0.25	0.40	-0.11
August maximun temperature (MaxT)	0.33	**0.42**	0.13
September MaxT	-0.20	**0.48**	0.13
RD, number of rainy days (rain >1mm)	-0.28	-0.27	0.38
Intensity of rainy events (mm/RD)	-0.13	0.20	**0.48**
Days with T exceeding 30°C	0.27	**0.45**	0.03
August rainfall mm	**-0.31**	0.11	-0.07
September rainfall mm	**0.33**	-0.30	0.12
April - May rainfall mm	0.08	-0.03	**0.61**
Consecutive drought days (Max number)	0.15	0.00	-0.39

The berry/must parameters have been assessed at harvest in 2012 and 2013 and the relations among them and vine yield, vine vegetative vigour and solar radiation have been assessed by PCA.

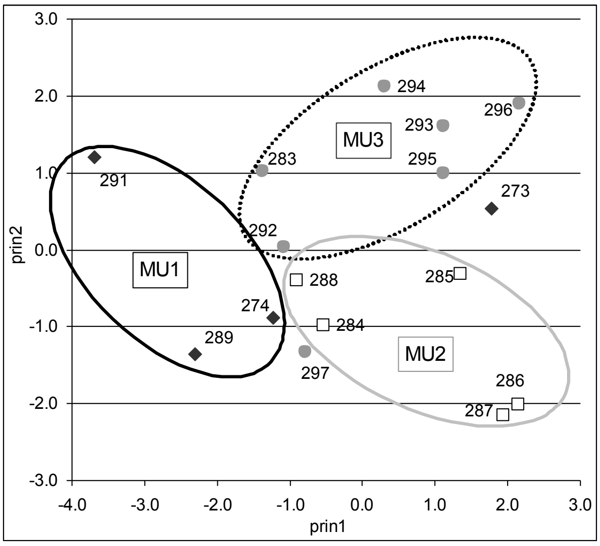

Figure 3. Distribution of the vineyards on the X-Y plot individuated by the two first Principal components carried out in 2012 on the variables reported in table 3. ◆vineyards belonging to MU1, □vineyards belonging to MU2, ● vineyards belonging to MU3.

An effect of MU's characteristics on ripening and composition of grapes emerged (Figure 3 and 4). In 2012, the variables allowing the distribution along Prin1 have been titratable acidity, YAN and the weight of pruning wood (Table 3) evidencing that the vineyard in MU1 were less vigorous than the average of the vineyards in MU2 and MU3. The separation of the MU2 and MU3 was possible by Prin2 to which total anthocyanin concentration (in a negative way) and solar radiation were correlated. Vineyards south-eastern exposed (MU3) received a higher amount of solar radiation but the achieved skin anthocyanin content was lower than in MU2 vineyards. Sugar content and yield (negatively correlated) were able to separated MUs on the Prin3 along with malic acid (Table 3).

Table 3. Eigenvectors of the variable related to the Figure 3 and 4 on the first three Principal Components. In bold the variables more correlated to the Principal components.

	2012			2013		
	Prin1	Prin2	Prin3	Prin1	Prin2	Prin3
Variance explained %	38	24	19	40	29	17
Eigenvalues	3.0	1.9	1.6	3.2	2.3	1.4
Sugar content Brix	-0.35	-0.28	**0.43**	-0.37	**0.41**	0.26
Tritatable acidity g/L	**0.55**	-0.08	0.01	**0.46**	0.31	0.04
Malic acid g/L	0.35	0.27	**0.44**	**0.45**	0.26	0.22
YAN g/L	**0.42**	0.06	**0.44**	0.28	0.37	0.42
Total anthocyanins g/L	0.06	**-0.63**	-0.01	-0.12	**0.50**	-0.39
Solar radiation kW/h/m^2	-0.27	**0.45**	0.40	-0.06	-0.28	**0.70**
Yield kg/vine	0.12	0.45	**-0.51**	0.33	**-0.46**	-0.12
Pruning weight g/vine	**0.42**	-0.17	-0.07	**0.49**	-0.03	-0.21

In 2013, the variables allowing the MUs separation along Prin1 were again pruning weight and acidity. Sugar content, total anthocyanin and yield (negatively correlated) separated MUs by Prin2, whereas solar radiation separated especially MU1 and MU2 along the Prin3 (table 3, Figure 4).

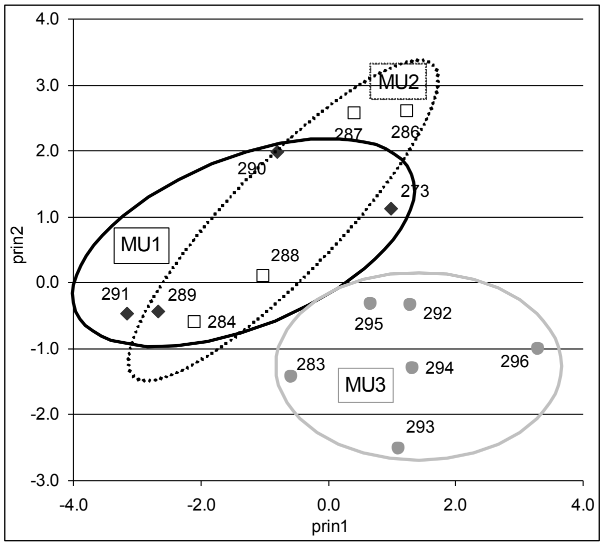

Figure 4. Distribution of the vineyards on the X-Y plot individuated by the two first Principal components carried out in 2013 on the variables reported in table 3. ◆vineyards belonging to MU1, □vineyards belonging to MU2, ● vineyards belonging to MU3.

Climatic differences at meso scale level may justify the differences observed in vineyards in terms of vine vigour and grape quality and confirm results emerged from other research regarding the impact of vineyard aspect on grape carotenoids [4]. The east south-east facing vineyards (MU3) were more vigorous, had higher productivity and lower berry sugar concentrations and anthocyanins than those of south- or west-facing vineyards. In 2012, the warmer, dryer and earlier season minor differences between vineyard exposures emerged, while in the wetter, cooler and later season (2013) the differences were more evident being the east exposure (MU3) more penalized in term of grape quality. The results achieved in the south south-west facing vineyards (MU1) remained more stable over the two years. The accumulation of anthocyanins was particularly sensitive to season, vineyard aspect and incident solar radiation: in both years their concentration achieved higher amount in west exposure and lower in those east-facing.

4. Conclusion

Despite these results shown the potential of the vineyard location in determining the grape quality, winegrower's choices may also contribute to drive grape ripening; winegrowers' know-how, in fact, interacts with the environment footprint and plays a decisive role in refining the potential of viticultural sites; however, it is necessary to improve the plasticity of traditional cultural choices to adapt them to climate changes that, in the study area, become visible in a huge seasonal meteorological irregularity. One factor that should guide the winegrowers' adaptive choices is certainly the vineyard geomorphological traits.

References

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