Study of Field Production for the Introduction of Precision Viticulture Technology

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Abstract

The wine market had in the last few years deep changes which are due principally, to the always biggest attention of the consumers towards to the wine good quality. The aim of the work is to analyze the spatial variability of the viticulture production and to evaluate the use of a main grid to be used in the control, in order to be able to identify homogeneous zones of production with a sampling methodology. The used sampling scheme is a regular grid with transepts of dimension equal at 10 mt and in total were sampled about the 3% of the plants in production and georeferenced (GRS1 of TOPCON) using a GPS device and, before the vintage, were evaluated the number, the bunch weight and the total production for plant. The data shown a variability of production between various field zones and among the single plants sampled in the biennium. The average production estimated for plant was of 2,77 kg for 2008 and 2.03 kg for 2009 while the total production was ranging from 5,3 t for 2008 to 4,09 in 2009. The productions changes between esteemed crops and the ones truly realized are of 2,0% for the first year of sampling and 2,6% for the second year even if causes of the variability of bound production to the ground and the cultivation management were not explained in adequate way.

Keywords: precision viticulture, field production, grape

Introduction

Precision agriculture (PA) is no longer a new term in global agriculture. It has been the subject of numerous international and European conferences for the past decade. Currently the best definition is "an integrated information- and production-based farming system that is designed to increase long term, site-specific and whole farm production efficiency, productivity and profitability while minimizing unintended impacts on wildlife and the environment". Simplified, PA is an application of new information technologies applied together to maximize production efficiency and quality while minimizing environmental impact and risk. Advances in technology, especially georeferencing systems, have allowed agriculture to move back towards site-specific agriculture and involve the use of any emerging information technology other than just yield sensors. Precision Viticulture (PV), is dependent on the existence of variability in either or both product quantity and quality. Some variables may also be temporarily variable but have a stable spatial pattern, for example climatic variables such as incident radiation and temperature. Viticulture is intensive, highly mechanized, has high value-added potential and is dominated by large companies. The most compelling argument for the adoption of PV is the variability that has been shown in vegetative, yield and quality mapping over the past few years (Bramley, 2004, Hall *et al.*, 2002). Since variability exists in quantity and quality there is an opportunity for site-specific management to improve the efficacy and profitability of production. The objectives of precision viticulture will differ depending on the market for wine and, for example, the use of selective harvesting may also be utilized to optimize quality (Bramley et al., 2003). In the last few years the wine market has undergone profound changes which are due principally to the increasing attention of consumers towards good quality wine. Thus winemakers, need to produce grapes that maintain certified characteristics of good quality over the years and reduce, with specific site methodologies, the interventions now required. In viticulture, vegetative indices derived from canopy imagery at veraison, a few weeks before harvest, are used to identify areas of different vigor within blocks. Grape quality within these different vigor zones is tested using a targeted sampling scheme, and the results are used to formulate differential harvest strategies (Bramley et al. 2005; Best et al. 2005). When maps are delivered, farmers receive a large amount of data which has to be analyzed rapidly. This means that the decision as to whether or not it is appropriate to apply site-specific management (SSM) has to be made in a few days. This step is even more critical in viticulture when the information is delivered and analyzed at the cooperative level. In this case, more than a hundred blocks may have to be analyzed by a viticulturist within a short timeframe of two to three days. The primary technological advance that made precision agriculture feasible is the yield map, which enables the farmer to estimate crop yields for sections as small as a few square yards and to display the collection of these estimates in color-coded maps (Fig. 1). Any area can be mapped. Growers can identify high- and low-yielding regions of the field and precisely quantify the differences between them. Yield mapping is based on three basic technologies: yield monitors, GPS and GIS.

Yield monitor. A yield monitor is a device that periodically (generally about once per second) measures the mass or flow rate of harvested material, and based on this measurement computes an estimate of crop yield. In a combine harvester, the estimate is obtained by measuring the force of the grain against a plate. GPS. The global positioning system, or GPS, uses triangulation of signals from a constellation of satellites to identify the location of the GPS on the Earth's surface, generally within about 1 yard. A fully functional yield-monitoring system includes a GPS that tags each yield estimate with the current location in the field so the data can be matched with the location. These data are stored in a file that can be downloaded after harvest. GIS.

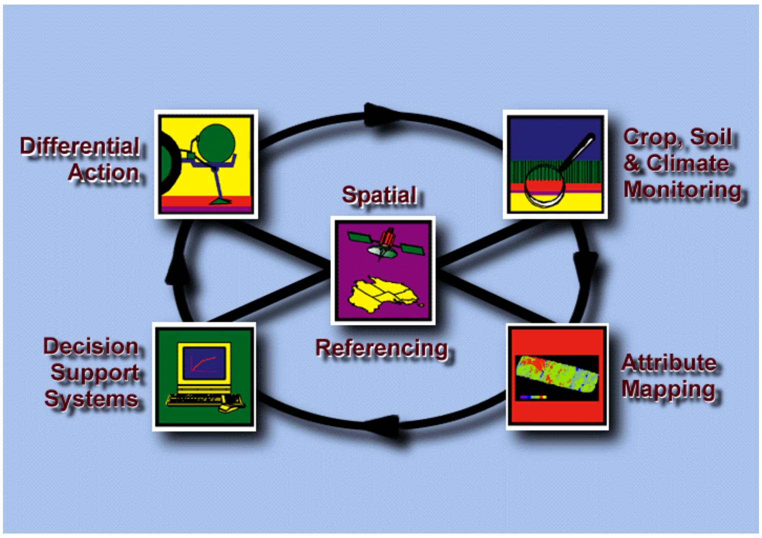

Figure 1. The Precision Agriculture wheel model showing the five main processes for a site-specific management system (Courtesy of the Australian Centre for Precision Agriculture).

A geographic information system, or GIS, is a computer program that combines database-management systems with graphics. It can accept data from an assigned location and generate a thematic map showing the spatial distribution of the data. Data from a yield monitor is downloaded into a GIS and converted into a color coded yield map that displays yield levels throughout the field. A typical yield monitor includes a data card to transfer files from a personal computer.

Aim of the work.

The aim of this work is to analyze the spatial variability of viticulture production and to evaluate the use of a main grid for use in control, so as to identify homogeneous zones of production with a sampling methodology. The monitoring of the grape components during two years of vintages will allow us to verify, through systems of statistical and geostatistical analysis, what may be the most probable factors that affect the variability of the yields obtained in two consecutive years.

Methods

Harvest criteria

This study was undertaken in a commercial "Semidano" vineyard block (0.5 ha) in the municipality of Mogoro (Sardinia, Italy) during the summers of 2008 and 2009. The experimental field is flat; it is prevalently sandy and has a fixed drop irrigation system. Vines were trained on a rammed cord and vine spacing was 2.5 m between rows and 1.0 m within rows (146 plants per row). The number of rows was 13 for a total of 1898 plants, the number of the sampled plants harvested was 64, equal to 3% of the total. During the vintage we verified total vineyard production and Yield production (Yp). The procedure for calculating Yp is described below. Before vintage, we observed the number of bunches, bunch weight, average bunch weight and total production per plant. An average number of bunches per vine and an average bunch mass were calculated. An estimated Yield production (Yp) for the site was calculated with the formula (1) as follows:

(1) **Yp = average number of bunches per vine x average bunch mass x number of vines.**

The vine was harvested following a regular grid (Fig. 2) with transepts having a dimension of 20 m, a plant every 20 in the first and second cases.

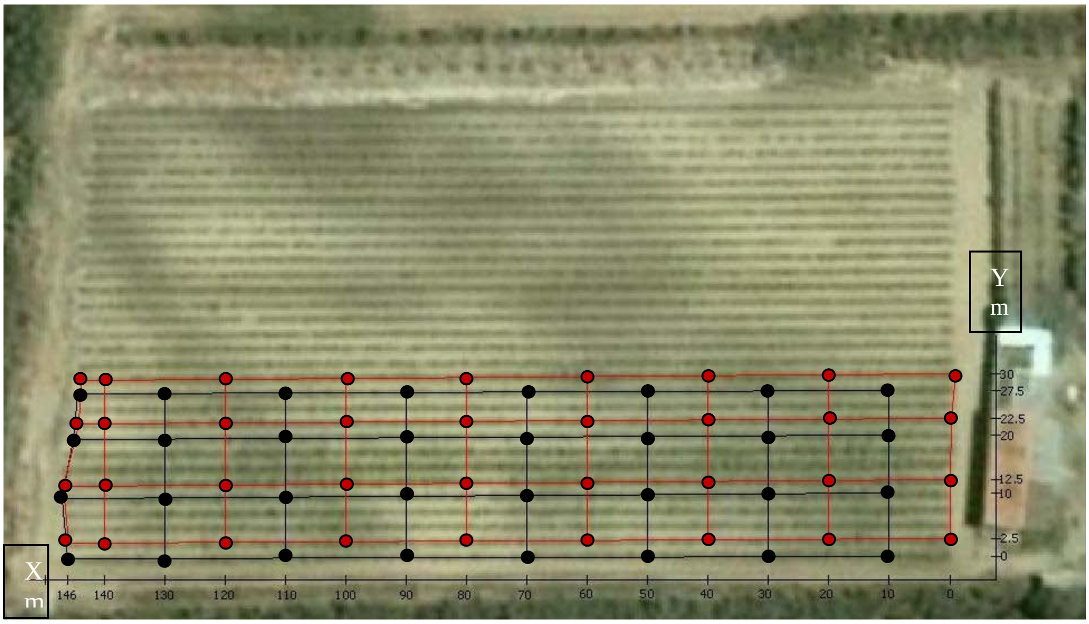

Figure 2. Grid of spatial distribution of the 64 sampling locations within the vineyard in 2008 and 2009.

The plants in production were sampled and georeferenced (GRS1 of TOPCON) using a DGPS device to obtain a yield map of production. The sampling strategy used was a regular grid based on the row and specific vine spacing, with a sampling intensity of approximately 64 vines per hectare. The yield maps of the three variables was obtained with a multivariate geostatistical analysis using ISATIS software (Geovariances). Beyond the numbers, other variables did not have normal distributions and all the variables were normalized and standardized to average 0 and variance 1. Modified two-range structures = 0.09 and 0.34 m with short range change.

Results and discussion

All measured vine properties show significant year-to-year variability in production between various field zones and among the single plants sampled (Tables 1 and 2). From the data observed in the field in terms of production per plant, the weight of the different bunches sampled showed a high variability for single plants in the 2008 vintage, ranging from 0.6 kg/plant (plant number 130 row 1) to 6.2 kg/plant (plant number 90 row 5). The high variability discovered in production between plants and rows in this vintage, is to be attributed to several factors such as the way of pruning, the presence of irrigators arranged at the beginning of rows 1, 7 and 13 which intersect among them every 15 plants on the row from plant number 17 to plant number 136 and finishes 5, 6 stumps to the vineyard head (140 to 146).

Table 1. Results of production by row and plants sampled during the 2008 vintage

Row 1		**Row 2**		**Row 5**		**Row 6**		**Row 9**		**Row 10**		**Row 12**		**Row 13**	
plant n°	kg/ plant	**plant n°**	kg/ plant	**plant n°**	kg/ plant	**plant n°**	kg/ plant	**plant n°**	kg/ plant	**plant n°**	kg/ plant	**plant n°**	kg/ plant	**plant n°**	kg/ plant
10	1.0	**1**	1.5	**10**	1,5	**1**	1,6	**10**	2,9	**1**	4,2	**10**	4,6	**1**	2,4
30	0.5	**20**	0.8	**30**	6,3	**20**	1,6	**30**	3,2	**20**	1,4	**30**	3,2	**20**	6,4
50	1.7	**40**	2.0	**50**	4,8	**40**	2,9	**50**	2,2	**40**	2,8	**50**	2,6	**40**	2,6
70	0.8	**60**	4.5	**70**	4,5	**60**	3,6	**70**	3,5	**60**	3,0	**70**	4,2	**60**	4,8
90	0.7	**80**	1.6	**90**	6,2	**80**	1,6	**90**	2,9	**80**	2,6	**90**	4,0	**80**	3,8
110	1.2	**100**	2.9	**110**	2,7	**100**	1,8	**110**	2,9	**100**	2,6	**110**	2,6	**100**	2,9
130	0.6	**120**	2.3	**130**	5,8	**120**	1,5	**130**	2,9	**120**	2,6	**130**	0,7	**120**	3,8
146	1.8	**140**		**146**	3,0	**140**		**146**	2,9	**140**		**146**	1,6	**140**	
Average production	1.0		2.2		4.4		2.1		2.9		2.7		2.9		3.8

Furthermore, if we analyze the results in terms of average weight per bunch, rows 2, 6, 9, 10 and 12 show comparable data; rows 5 and 13 show greater productivity and row 1 has the lowest production (1.0 kg/plant). This is a row on the field border which is also more shaded by the presence of high windbreaks (about 3 mt) a few meters away (about 3 m). The average number of bunches varied from 4.75 to 10.4 (1st and 5th rows, 2008 vintage) and form 6.75 to 10.13 (9th and 10th rows) in the 2009 vintage. Annual variation in bunch weight followed a different pattern and it was largest in 2008. The average bunch weight went from 0.25

kg/plant to 0.50 kg/bunch in 2008 and from 0.19 kg/bunch to 0.33 kg/bunch in 2009. The average production estimated per plant was 2.77 kg for 2008 and 2.03 kg for 2009 while the total production ranged from 5.3 t in 2008 to 4.09 in 2009 which, if reference is made to the grapes directly conferred to the cellar by the same grower and the same field was to be 5.4 t in 2008 and of 4.2 t for the next year. The changes in production between estimated crops and those actually produced were 2.0% for the first year of sampling and 2.6% for the second year. The causes of the variability in production connected with the ground and cultivation management were not explained adequately (Table 4).

Table 2 Results of production by row and plants sampled during the 2009 vintage

Row 1		**Row 2**		**Row 5**		**Row 6**		**Row 9**		**Row 10**		**Row 12**		**Row 13**	
plant n°	kg/ plant	**plant n°**	kg/ plant	**plant n°**	kg/ plant	**plant n°**	kg/ plant	**plant n°**	kg/ plant	**plant n°**	kg/ Plant	**plant n°**	kg/ plant	**plant n°**	kg/ plant
10	1.1	**1**	2.4	**10**	0.6	**1**	2.6	**10**	1.2	**1**	3.4	**10**	2.5	**1**	2.1
30	1.6	**20**	0.3	**30**	2.9	**20**	0.8	**30**	0.9	**20**	2.7	**30**	4.6	**20**	3.9
50	3.3	**40**	2.0	**50**	1.8	**40**	3.2	**50**	0.7	**40**	2.1	**50**	0.3	**40**	3.8
70	3.1	**60**	3.0	**70**	1.8	**60**	1.1	**70**	3.1	**60**	2.0	**70**	0.0	**60**	1.4
90	3.4	**80**	2.5	**90**	2.6	**80**	3.3	**90**	1.5	**80**	2.9	**90**	2.0	**80**	3.2
110	0.8	**100**	1.8	**110**	0.8	**100**	0.8	**110**	1.4	**100**	1.8	**110**	2.3	**100**	1.8
130	2.3	**120**	6.4	**130**	2.2	**120**	2.6	**130**	0.5	**120**	1.4	**130**	1.3	**120**	0.0
146	2.2	**140**		**146**	1.7	**140**	1.2	**146**	1.4	**140**		**146**	1.2	**140**	
Average production	2.2		2.6		1.8		1.9		1.3		2.3		1.8		2.3

Table 3 Average number and weight of bunches per plant in the 2008 vintage

Row number	**Bunches average number**		**Bunch average weight**	
	Vintage 2008	**Vintage 2009**	**Vintage 2008**	**Vintage 2009**
1	4.75	8.50	0.25	0.33
2	6.71	8.29	0.35	0.22
5	10.38	8.63	0.46	0.30
6	6.57	8.71	0.46	0.22
9	5.25	6.75	0.50	0.21
10	8.25	10.13	0.33	0.22
12	8.63	8.63	0.38	0.23
13	7.88	8.13	0.29	0.19

Table 4 Comparison between estimated and conferred production in two years of vintage (2008-2009)

Vine	**Vintage**		**Differences**
Semidano	**estimated production yield**	**production conferred to wine cellar**	**(%)**
	(ton/ha)	**(ton/ha)**	
Year 2008	5.40	5.30	-2.0
Year 2009	4.20	4.09	-2.6

Data were obtained with the following formula (1): Yp = average number of bunches per vine x average bunch mass x number of vines.

Yield map production

Using approximately 3.0% of the total number of vines, all yield map production was obtained using ISATIS software (Geovariances, 2000). The yield maps of the three variables (average kg/plant, average number of bunches and average weight of bunch) were obtained with a multivariate geostatistical analysis. Beyond the numbers, other variables did not have normal distributions and all the variables were normalized and standardized to average 0 and variance 1. Modified two-range structures = 0.09 and 0.34 m with short range change (Figs. 2, 3 and 4). At this sampling scale anisotropies are not noticed. The average weight of 2009 has high outliers (Fig 3) compared to the 2008 average weight represented by isolated zones of the yield map in the NW and SW directions. The distribution of the population represented had a not normal distribution and this confirmed the presence of outliers in the map and in the distribution of the population. These considerations can be extended to the other two variables. In fact, the same results can be observed in the other two maps (Figs. 4 and 5) for the two years of vintage, where other zones of high and low production were showed in the same orientation of the maps. The maps did not show any clear space structures nor their persistence in time because the sampled lot did not describe very well the spatial and the temporal variability of the vineyard during the two years of vintage. Furthermore, other variables such as brix° content, pH, phenol content and other important information about the quality of the grapes in the field and of course of the wine at the end of transformation are needed to have a more complete study of the importance of the application of an in-the-field strategy to obtain ~~a~~ high product quality and quantity and implement the connection between the field and the cellar during the vintage.

Conclusion

The variables determined provided reasonable predictions of production. However, considering the small number of samples certain affirmations cannot be stated. It is necessary to increase the number of stumps sampled in the grid (more than a hundred) to define the validity of the model and to investigate the presence of anisotropy in order to reduce the high number of outliers that appeared during the vintage. For these reasons the sampling has to be defined carefully. Our results may improve the knowledge base concerning the possibility of using proximal or remote sensing during the vintage implemented by a harvester to check the production of the vineyard during vintage and this method of investigation can be extended to other crops. The study of attributes and capabilities of active and if necessary passive sensors is a goal that our department is able to organize in future works on precision viticulture. The combination between topographic data used with different types of agronomic information can be very useful in explaining the spatial and temporal variability of yield production, as well as its quality composition at the field level. The analysis of spatial and temporal variability of the grapes and wine during vintage will show in the future that its response is extremely dependent on the annual variation of climatic conditions and agronomic practices, and thus which parameters can be used to explain differences in yield production and chemical composition.

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Figure 3. Yield map of average kg/plant in two years of vintage (2008-2009).

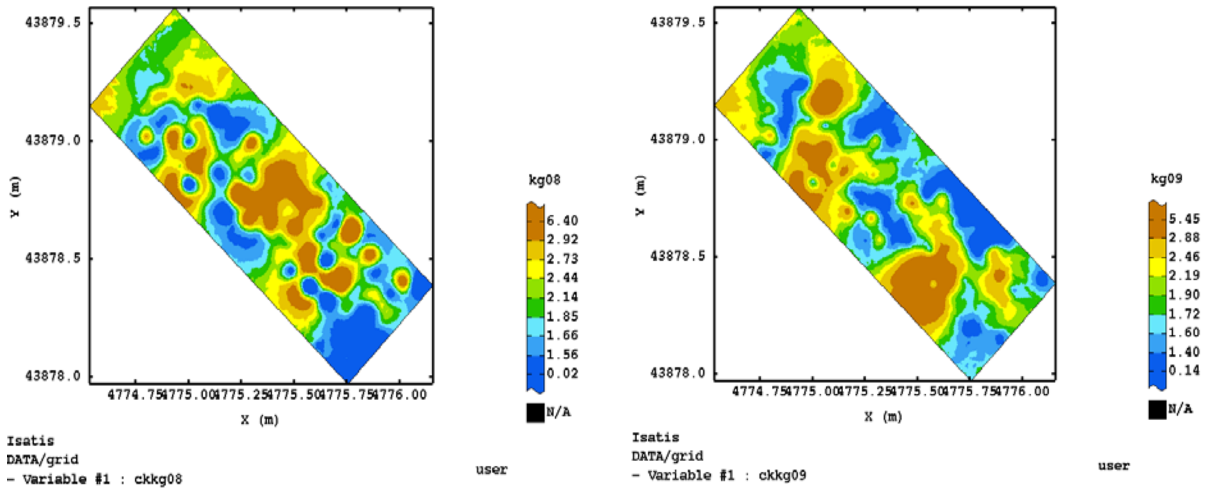


Figure 4 Yield map of number of bunches/plant in two years of vintage (2008-2009).

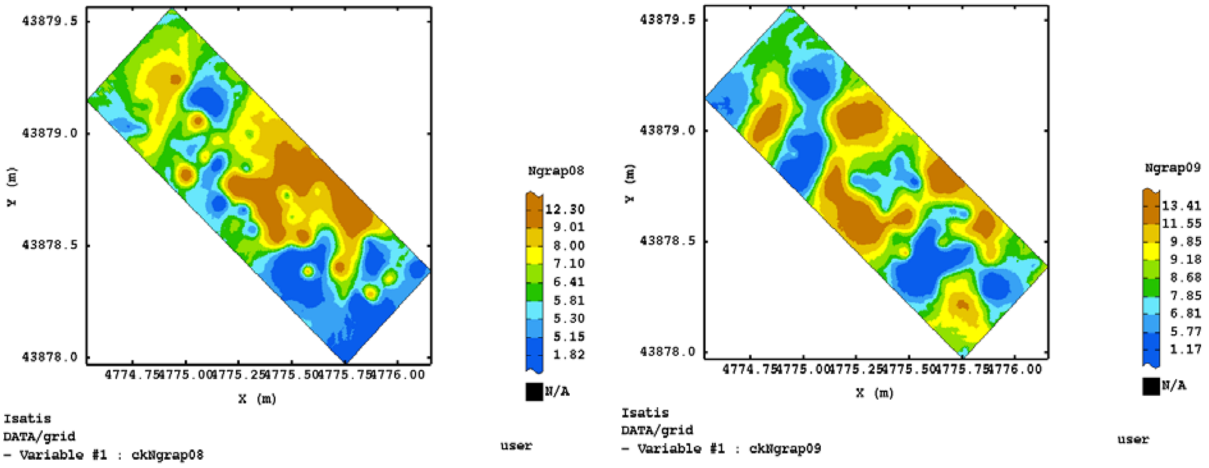
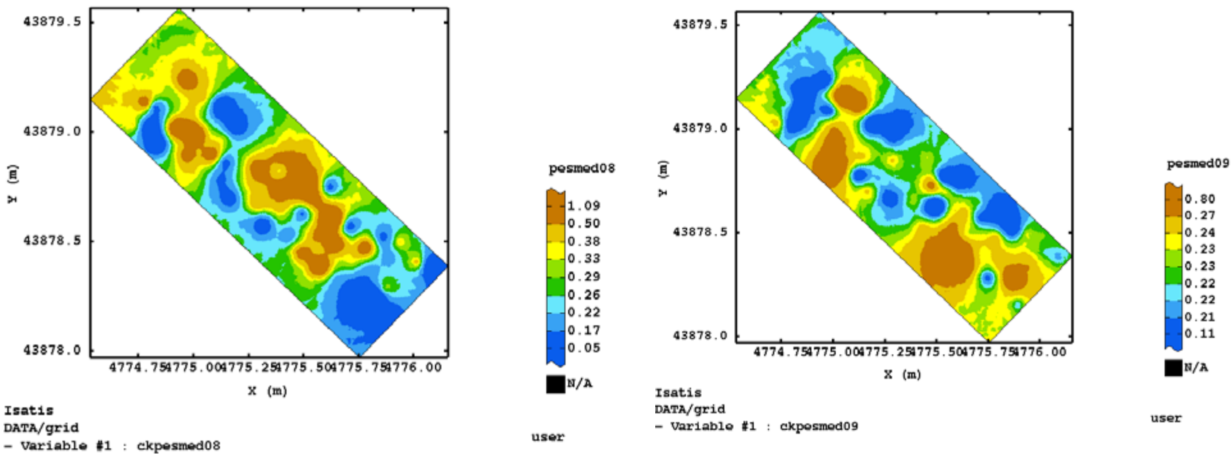


Figure 5 Yield map of average bunch kg/plant in two years of vintage (2008-2009).



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