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Article

Assessment of Laser Scanner Use under Different Settings in Two Differently Managed Vineyards for Estimating Pruning Wood Parameters

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Abstract: Precision viticulture employs various sensors for assessing nondestructively key parameters in vineyards. One of the most promising technologies for this purpose is the laser scanner sensor. Laser scanner uses the LiDAR (Light Detection And Ranging) method for the calculation of the distance from the sensor. However, the number of cultivation operations affects the credibility of sensors such as the laser scanner. The main aim of this study was to assess a laser scanner sensor at different measurement settings for estimating pruning wood parameters on two wine grape cultivars (Sauvignon Blanc and Syrah) that received different numbers of farming interventions. The experiment was conducted in the two vineyards situated in the same farm for two successive years (2014 and 2015). The results indicated that the use of a laser scanner in the Syrah vineyard presented more accurate results (r = 0.966 in 2014 and r = 0.806 in 2015) when compared to the Sauvignon Blanc one (r = 0.839 in 2014 and r = 0.607 in 2015) regarding pruning wood parameters estimation. Different measurement settings and weather conditions had different effects on the accuracy of the sensor. It can be concluded that the laser scanner is a very helpful sensor for estimating pruning wood parameters in vineyards.

Keywords: LiDAR; laser scanner; vineyard pruning; precision viticulture; Sauvignon Blanc; Syrah

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1. Introduction

Precision viticulture is the application of precision agriculture in viticulture [1]. Precision viticulture, like precision agriculture, is a circular process that entails data collection, data analysis, decision making about management, and evaluation of these decisions [2]. The goal of precision viticulture is the delineation of management zones inside the vineyard that have the same soil characteristics (soil texture, topography, electrical conductivity, etc.) and the same crop characteristics (vigor, yield characteristics, quality characteristics, etc.). In this way, the advantages of the vineyard's variability in favor of the producer are fully exploited [3].

The delineation of management zones requires the collection of information. These measurements could be carried out with destructive or non-destructive methods. The non-destructive methods for the determination of management zones are carried out more often nowadays because of the advantages of georeferencing every measurement, the ability of measuring the entire extent of the field, the lowest related cost, etc. These methods include the use of multispectral and hyperspectral cameras, thermal cameras, electromagnetic sensors, canopy sensors, laser scanners, etc. These sensors can be carried on many platforms, such as agricultural tractors, UAVs, UGVs, satellites, etc. [4–7].

One of the key sensors that is used in precision agriculture is the laser scanner sensor. The laser scanner uses the LiDAR (Light Detection And Ranging) method for the calculation of the distance from the sensor. Based on this method, various crop parameters can be measured non-destructively in both arable and permanent crops (orchards and vineyards). More specifically, Paulus et al. used the laser scanner for the non-destructive evaluation of canopy architecture in barley [8]. Sanz et al. used a laser scanner in order to define the density of the foliage in orchards [9]. Tsoulias et al. used a laser scanner to estimate canopy parameters of apple trees, such as canopy volume, height, and stem diameter [10]. Chatzinikos et al. used the laser scanner in order to measure the biomass and height of soybean, sunflower, and durum wheat plants [11].

Regarding vineyards, Llorens et al. used the laser scanner in order to define the leaf area index (LAI) at different growing stages in different vine cultivars [12]. Tagarakis et al. correlated the measurements of the laser scanner to winter pruning wood weight, vegetation index NDVI and yield [13]. Siebers et al. developed a laser scanner based phenomics platform for assessing grapevine traits such as pruning wood weight and vine wood volume [14]. Grocholsky et al. coupled a laser scanner sensor with a camera to estimate the balance between canopy volume and crop yield in a vineyard [15].

However, researchers have found that the number of farming practices in the vine canopy (e.g., trimming, etc.) affects not only the measurements of the vegetation index NDVI, but also its credibility in the delineation of management zones in vineyards [7,16,17]. Knowing that pruning wood is a parameter that can be added in models delineating management zones to increase their accuracy, the purpose of this work was to evaluate a laser scanner sensor for estimating pruning wood parameters in vineyards under different number of farming interventions. For this reason, different settings were applied regarding moving speed, angular resolution, and measurement surface.

2. Materials and Methods

2.1. Experimental Fields

The study was conducted in North Greece (Drama) in 2014 and 2015, in two 10-year-old commercial vineyards. The first vineyard was planted with the cv. Sauvignon Blanc (*Vitis vinifera* L.) (41°5.5′ N, 23°55.8′ E) and the second with cv. Syrah (*Vitis vinifera* L.) (41°5.8′ N, 23°56.7′ E), in an area of 2.5 and 1.7 ha, respectively. The vineyard planted with the Sauvignon Blanc cultivar was in a sandy loam soil with a slope gradient of 8%, while the vineyard of the Syrah cultivar was in a sandy clay loam soil with a 5% inclination. Both cultivars were grafted on 1103 Paulsen rootstock, trained on a similar bilateral cordon and a planting distance of 1.2 × 2.2 m. Nevertheless, the management of the vineyards was different between the two areas in order to achieve the optimum leaf-to-fruit ratio [18]. Thus, the Sauvignon Blanc vineyard received more water through irrigation (~300 mm) than the Syrah vineyard (~80 mm) in both years following conventional irrigation scheduling practices. As a result, the vines of the Syrah cultivar are characterized by lower vigor and a smaller total canopy area due to the need for a lower leaf-to-fruit ratio compared to Sauvignon Blanc [18]. As a consequence, the vineyard of Sauvignon Blanc received more trimming and leaf plucking in order to adjust to the more vigorous vegetation, while Syrah received a smaller number of such treatments. Thereby, Syrah vineyard canopy characteristics were a more direct result of the actual soil conditions than in the Sauvignon Blanc one.

For the purposes of this experiment, each vineyard was divided into cells of 0.1 ha each and had a stable width of 33 m, corresponding to 15 vine rows. Thus, the Sauvignon Blanc vineyard was separated into 24 cells, while Syrah was separated into 17 cells (Figure 1). During the winter pruning, measurements with the laser scanner, the weight of the pruning wood, and the number of canes per vine were taken in 10 central vines of each cell.

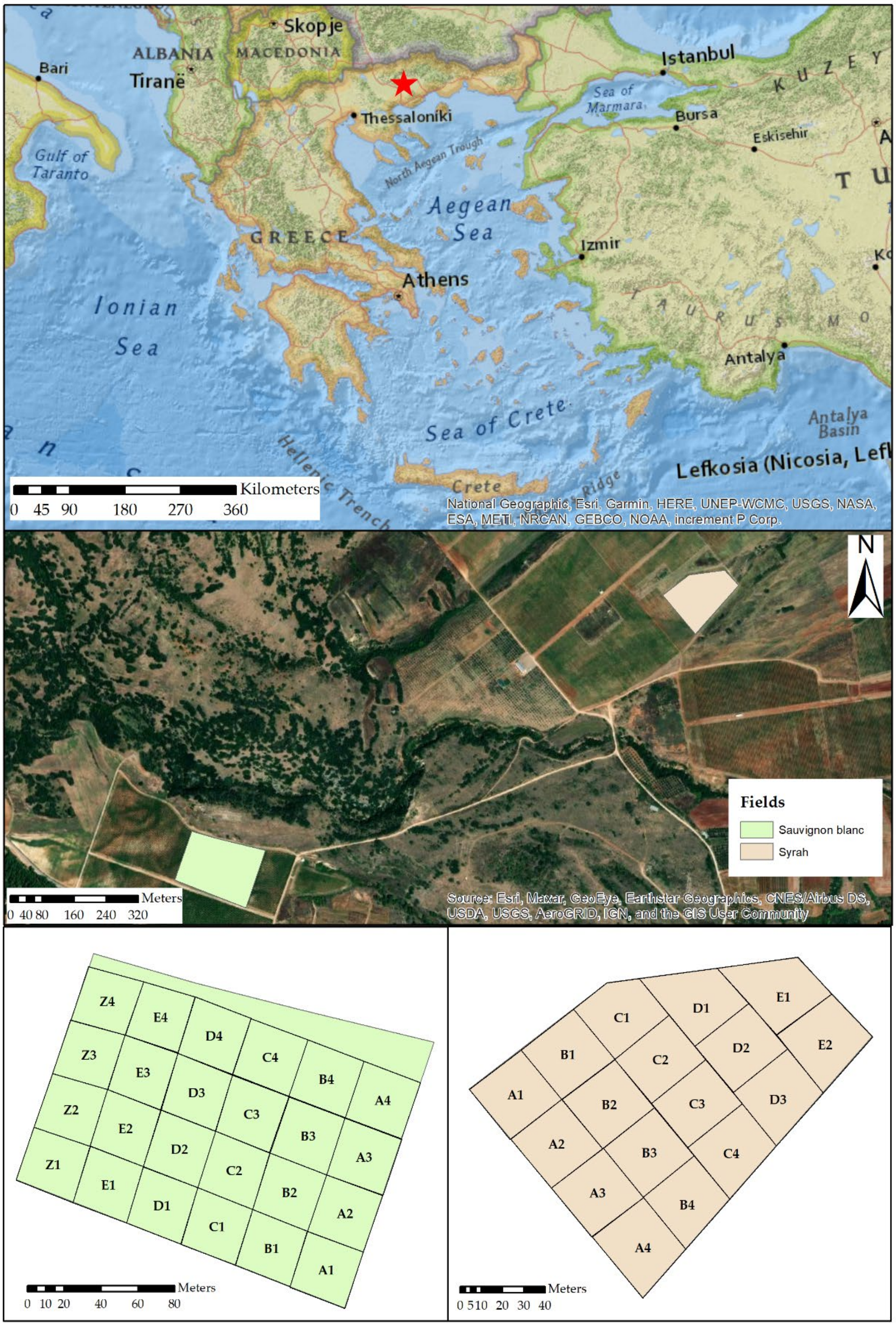


Figure 1. The location of the experimental fields.

2.2. Field Measurements

The laser scanner LMS 200 (Sick A.G., Waldkirch, Germany) was adapted to a vineyard tractor and was used in different settings during the measurements (Figure 2). Specifically, the laser scanner measurements included the measurements of impacts per vine (i) at three different settings of laser scanner's angular resolution (1°, 0.5° and 0.25°), (ii) at two different speeds of the vineyard tractor (2 and 4 km/h), and (iii) at three different measurement surfaces of the pruning wood (the entire pruning wood surface, the upper half of the pruning wood surface, and the lower half of the pruning wood surface). The different measurement settings that were used in this study are presented in Table 1.

Figure 2. Field measurement with the LMS 200 laser scanner with a vineyard tractor.

Table 1. Measurement methods settings for the laser scanner sensor used.

Measurement Method	Sensor Moving Speed	Angular Resolution of Laser Scanner	Measurement of Pruning Wood Surface	Laser Scanner Distance from Pruning Wood	Laser Scanner Distance from Soil
I	2 km/h	1°	Entire pruning wood surface	0.5 m	1.2 m
II	2 km/h	1°	Lower half of pruning wood surface	0.3 m	0.9 m
III	2 km/h	1°	Upper half of pruning wood surface	0.3 m	1.5 m
IV	4 km/h	1°	Entire pruning wood surface	0.5 m	1.2 m
V	2 km/h	0.5°	Entire pruning wood surface	0.5 m	1.2 m
VI	2 km/h	0.25°	Entire pruning wood surface	0.5 m	1.2 m

The results of the measurements of the laser scanner were processed in order to remove the data noise that is created by the distance from the soil and from the adjacent rows. Additionally, the results were normalized in order to retrieve the impacts per vine. Pruning wood weighting per vine measurement was conducted using a portable electronic scale, while the cane number was measured manually.

For the two vine growing seasons, weather data were collected from the openweathermap database [19] to assess the impact of weather conditions on pruning wood weight and the number of canes per vine (Figures 3 and 4). According to the meteorological analysis, 2014 (508 mm) was drier than 2015 (526 mm), while the temperature did not show variation between the two years. Therefore, the Sauvignon Blanc cultivar received approximately 808 mm in 2014 and 826 mm in 2015 of water during its crop growth compared to 588 mm and 606 mm, respectively, in the Syrah cultivar.

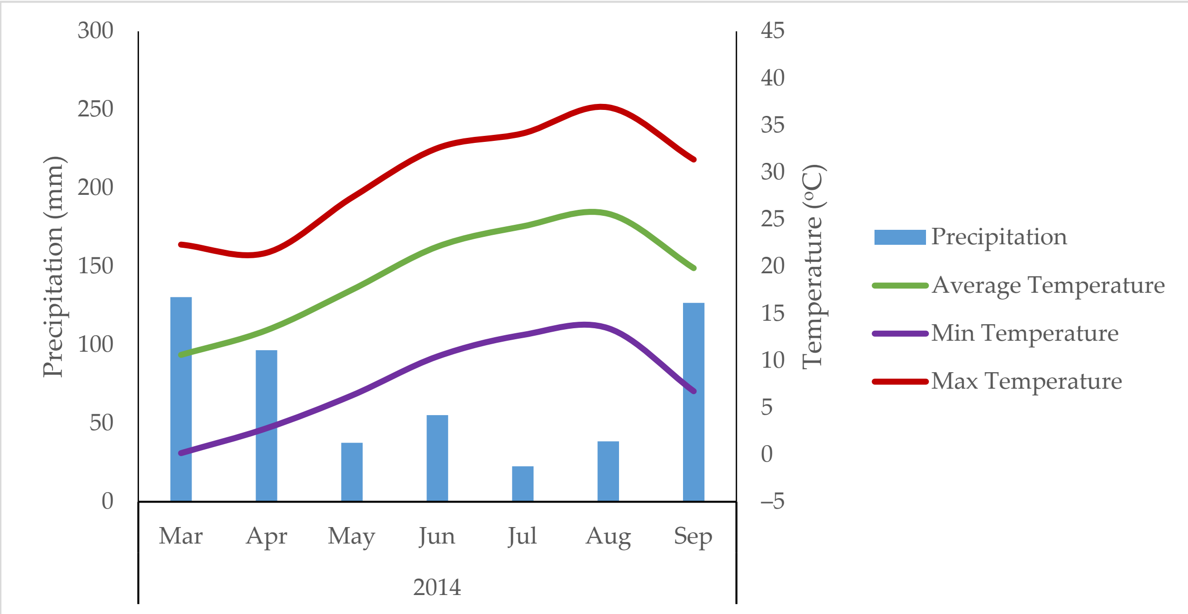


Figure 3. Meteogram of the 2014 vine growing season. Precipitation is expressed monthly, and resolution of temperature is not precise.

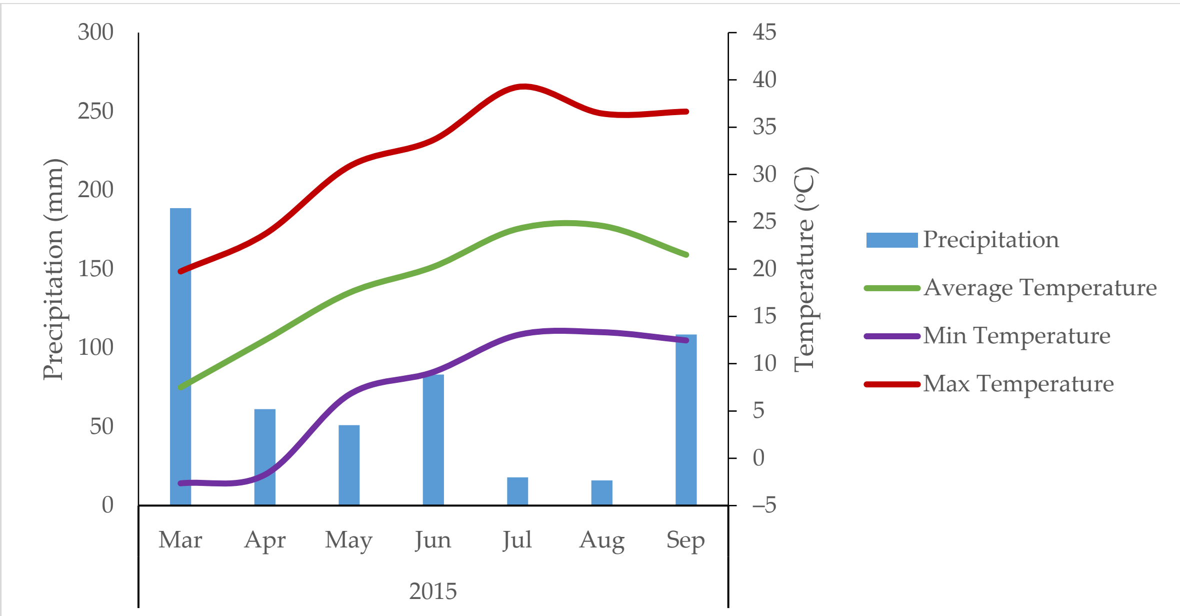


Figure 4. Meteogram of the 2015 vine growing season. Precipitation is expressed monthly, and resolution of temperature is not precise.

2.3. Statistical Analysis

Descriptive statistics for all measurements and Pearson's correlation tables for the two cultivars under investigation were calculated. Additionally, simple linear regression analysis was performed for the methods that presented the highest Pearson's correlations for assessing the optimal settings for laser scanner use on the estimation of the pruning wood parameters. The statistical software Statgraphics 19 (StatPoint Technologies Inc., Warrenton, VA, USA) was used for the statistical analysis.

3. Results

3.1. Sauvignon Blanc Vineyard

3.1.1. Descriptive Statistics

The descriptive statistics of the Sauvignon Blanc cultivar for the years 2014 and 2015 are presented in Table 2.

Table 2. Descriptive statistics of measurements of the Sauvignon Blanc cultivar.

Parameter	Minimum	Maximum	Mean	Standard Deviation	CV (%)
2014					
Method I	22	40	31	5	16.2
Method II	22	38	30	4	12.7
Method III	21	36	28	4	15.6
Method IV	23	40	31	4	13.5
Method V	39	83	62	12	18.7
Method VI	100	171	129	18	14.1
Pruning Wood Weight	0.46	1.43	0.90	0.240	26.8
Canes per vine	10	15	12	1	11.7
2015					
Method I	19	37	30	4	14.9
Method II	22	36	31	3	11.0
Method III	14	37	25	6	23.4
Method IV	23	44	32	4	14.1
Method V	42	87	62	11	18.4
Method VI	90	159	118	17	14.5
Pruning Wood Weight	0.63	1.93	1.18	0.369	31.2
Canes per vine	9	14	12	1	9.9
All years					
Method I	19	40	31	5	15.9
Method II	22	38	30	4	12.0
Method III	14	37	27	5	20.2
Method IV	23	44	31	4	14.0
Method V	39	87	62	11	18.4
Method VI	90	171	124	18	14.8
Pruning Wood Weight	0.46	1.93	1.04	0.339	32.6
Canes per vine	9	15	12	1	10.7

Methods are measured in impacts per vine; Pruning Wood Weight is measured in kg per vine.

According to the results, only laser scanner impacts per vine under Method VI settings (129 in 2014 and 118 in 2015) and pruning wood weight (0.90 kg in 2014 and 1.18 in 2015) presented a significant difference between 2014 and 2015. This finding indicated that the weather-induced variability in pruning wood weight can be better monitored through the use of a laser scanner with high angular resolution (0.25°). Additionally, the increased pruning wood weight of 2015 and the decreased number of impacts per vine of method VI indicated that during 2015, canes were generally of greater diameter. This could be related to the higher amount of precipitation that took place during the vegetative growth period (March–June) in 2015 (384 mm) compared to 2014 (320 mm).

Moreover, it is worth noticing that the coefficient of variation per method did not present significant differences between these years. This can be explained by the fact that the high number of canopy treatments weakened the impact of weather-induced cane variability.

3.1.2. Pearson's Correlation

Table 3 shows the Pearson's correlation of the laser scanner measurement methods with the weight of the pruned wood and the number of canes per vine for the Sauvignon Blanc cultivar.

Table 3. Pearson's correlation of the laser scanner measurements with the measured pruning wood parameters of the Sauvignon Blanc cultivar.

Measurement Method	2014		2015		All Years	
	Pruning Wood Weight	**Canes per Vine**	**Pruning Wood Weight**	**Canes per Vine**	**Pruning Wood Weight**	**Canes per Vine**
Method I	0.806 **	0.152	0.529 **	0.065	0.503 **	0.129
Method II	0.634 **	0.146	0.520 **	0.134	0.555 **	0.123
Method III	0.600 **	0.013	0.607 **	0.001	0.420 **	0.026
Method IV	0.624 **	−0.105	0.358	0.327	0.460 **	0.096
Method V	0.839 **	0.049	0.291	−0.093	0.448 **	−0.017
Method VI	0.664 **	0.098	0.374	0.206	0.292 *	0.160

** The correlation is significant at the 0.01 level. * The correlation is significant at the 0.05 level.

The laser scanner measurements presented a high correlation with the weight of the pruning wood in Sauvignon Blanc in 2014 in all methods (Table 3). The optimum method for measurement, according to Pearson's correlation, was Method V where the tractor speed was 2 km/h, the angular resolution was 0.5°, and the measurement included the entire pruning wood surface (r = 0.839, $p < 0.01$). In 2015, the maximum correlation was recorded with Method III where the tractor speed was 2 km/h, the angular resolution was 1°, and the measurement included the upper half of the pruning wood surface (r = 0.607, $p < 0.01$). However, in 2015, the laser scanner showed correlation only to the measurements with 1° angular resolution and tractor speed of 2 km/h. Finally, there was no correlation with the number of canes per vine for both years.

When using data from both years for Pearson's correlation, the different laser scanner methods presented low to moderate correlations (r = 0.292 – 0.555) for pruning wood weight and negligible correlations for the canes per vine. Based on the aforementioned, Method II, which showed maximum correlation for both years, is the most preferable method for estimating pruning wood weight.

3.1.3. Linear Regression Models

The best fitted models for estimating pruning wood weight are presented below.

According to the results of Table 4, all models presented low to high coefficients of determination ($R^2 = 0.31 - 0.71$), with the best fitted model being developed with the 2014 data and the least fitted model with the data from both years. This indicates that the degree of accuracy is highly affected by the annual variability of weather conditions, with the highest being met during dry weather conditions (320 mm in 2014) and the lowest during wet weather conditions (384 mm in 2015) during the cane development period.

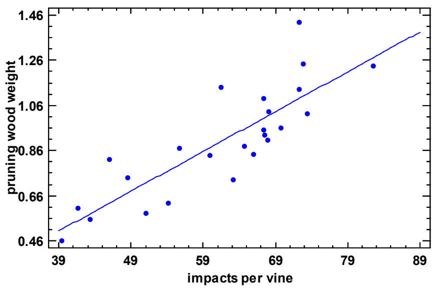
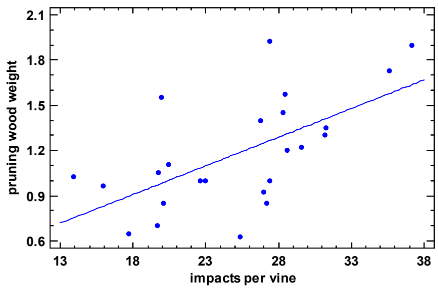
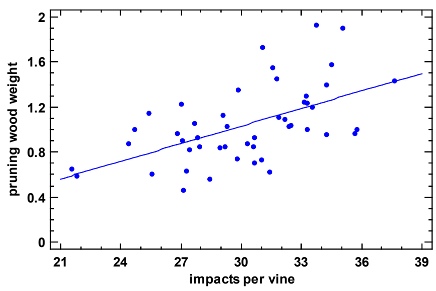
3.2. Syrah Vineyard

3.2.1. Descriptive Statistics

The descriptive statistics of the Syrah cultivar for the years 2014 and 2015, respectively, are presented in Table 5.

According to Table 5, there were no significant differences in the pruning wood parameters and the different methods that were used in the experiment on the Syrah cultivar for both years, although the annual weather conditions were different between them, especially in terms of water availability. This can be explained by the limited number of interventions that do not permit the management of spatial variability and is also exhibited in the high values of coefficients of variance of all parameters on this cultivar. Additionally, it is worth noticing that the coefficient of variance of the pruning wood weight presented an almost two-fold difference between the two years due to the different weather conditions.

Table 4. Best fitted models for the estimation of pruning wood weight using a laser scanner on Sauvignon Blanc.

Year	Plot of Fitted Model	Model Parameters	Results
2014		Equation	Pruning wood weight = 0.018 × Method V − 0.183
		R^2	0.71
		Mean Absolute Error	0.104 kg/vine
2015		Equation	Pruning wood weight = 0.038 × Method III + 0.227
		R^2	0.37
		Mean Absolute Error	0.234 kg/vine
All years		Equation	Pruning wood weight = 0.052 × Method II − 0.530
		R^2	0.31
		Mean Absolute Error	0.220 kg/vine

Pruning wood weight is measured in kg per vine, while Method II, Method III, and Method VI refer to the impacts per vine, which are measured by the laser scanner.

3.2.2. Pearson's Correlation

Table 6 shows the Pearson's correlations of the laser scanner measurement methods with the weight of the pruning wood and the number of vines per root for the Syrah cultivar.

In the Syrah cultivar, laser scanner measurement settings showed a correlation not only with the pruning wood weight, but also with the number of canes per vine (Table 6). Only two methods did not present any correlation with the number of canes per vine on the Syrah cultivar according to Pearson's correlation for 2015 (Method II and Method III). Laser scanner measurement methods presented the maximum correlation on Syrah with the pruning wood weight using Method VI, where the tractor speed was 2 km/h, the angular resolution was 0.25°, and when the measurement included the entire pruning wood surface (r = 0.966, $p < 0.01$) in 2014, while the highest correlation in 2015 was presented with Method IV, where the tractor speed was 2 km/h, the angular resolution was 1°, and when only the upper half of the pruning wood surface was measured (r = 0.806, $p < 0.01$). It should be noted that Method VI provided a very slightly lower correlation than Method IV (0.803 vs. 0.806, $p < 0.01$), showing that these two methods provided similar correlation results for both years. Lastly, laser scanner measurements showed the maximum correlation on Syrah with the number of canes per vine using Method I, where the tractor speed was

2 km/h, the angular resolution was 1° and having included the entire pruning wood surface (r = 0.683, $p < 0.01$) in 2014, and Method VI, where the tractor speed was 2 km/h, the angular analysis was 0.25° and again having included the entire pruning wood surface (r = 0.768, $p < 0.01$) in 2015 (Table 6). The pruning wood weight showed twice the variability rate in 2015 (53.7%) in comparison to 2014 (26.4%), which was obviously bigger than the Sauvignon Blanc cultivar. Respectively, the number of impacts per vine showed higher variability rates during 2015 when compared to 2014.

Table 5. Descriptive statistics of measurements for the Syrah cultivar.

Parameter	Minimum	Maximum	Mean	Standard Deviation	CV (%)
2014					
Method I	10	31	21	6	26.1
Method II	11	29	21	5	24.9
Method III	7	28	18	6	32.4
Method IV	8	32	21	6	30.6
Method V	16	61	41	13	32.8
Method VI	34	120	79	23	28.7
Pruning Wood Weight	0.070	0.610	0.327	0.039	28.7
Canes per vine	7	16	11	2	21.2
2015					
Method I	8	33	21	6	30.6
Method II	13	32	23	6	27.5
Method III	5	27	15	7	43.8
Method IV	9	32	21	7	34.3
Method V	20	59	41	13	31.1
Method VI	39	120	83	25	29.8
Pruning Wood Weight	0.110	0.700	0.359	0.191	53.1
Canes per vine	6	15	11	3	26.4
All years					
Method I	8	33	21	6	28.4
Method II	11	32	22	6	26.1
Method III	5	28	17	6	38.1
Method IV	8	32	21	7	32.0
Method V	16	61	41	13	31.4
Method VI	34	120	81	24	28.9
Pruning Wood Weight	0.070	0.700	0.342	0.174	51.0
Canes per vine	6	16	11	3	23.6

Methods are measured in impacts per vine; Pruning Wood Weight is measured in kg per vine.

Table 6. Pearson's correlation of the laser scanner measurements with the measured pruning wood parameters of Syrah cultivar.

Measurement Method	2014		2015		All Years	
	Pruning Wood Weight	Canes per Vine	Pruning Wood Weight	Canes per Vine	Pruning Wood Weight	Canes per Vine
Method I	0.918 **	0.683 **	0.614 **	0.679 **	0.737 **	0.686 **
Method II	0.871 **	0.398	0.660 **	0.532 *	0.749 **	0.462 **
Method III	0.912 **	0.468	0.734 **	0.567 *	0.762 **	0.522 **
Method IV	0.940 **	0.527 *	0.806 **	0.685 **	0.861 **	0.604 **
Method V	0.710 **	0.611 **	0.784 **	0.639 **	0.741 **	0.619 **
Method VI	0.966 **	0.660 **	0.803 **	0.768 **	0.872 **	0.707 **

** The correlation is significant at the 0.01 level. * The correlation is significant at the 0.05 level.

When combining data from both years for Pearson's correlation, the different laser scanner methods presented high correlations (r = 0.737 – 0.872) for pruning wood weight and low to high correlations for the canes per vine (r = 0.462 – 0.707). Based on the aforementioned, Method VI, which showed maximum correlation for both years, is the most preferable method for estimating pruning wood weight and number of canes per vine when weather conditions are unknown.

3.2.3. Linear Regression Models

The best fitted models for estimating pruning wood weight and number of canes per vine are presented in Table 7.

Table 7. Best fitted models for the estimation of pruning wood weight and canes per vine using a laser scanner on Syrah.

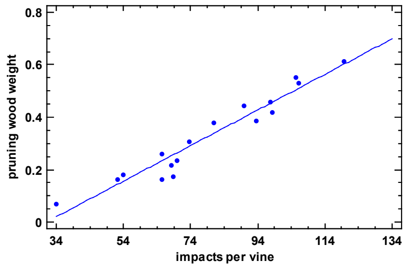
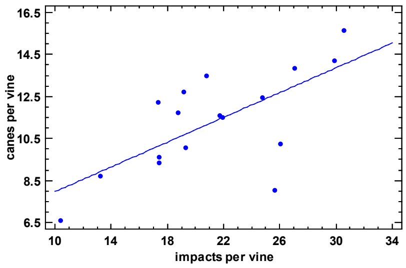
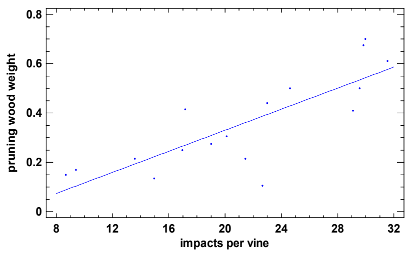
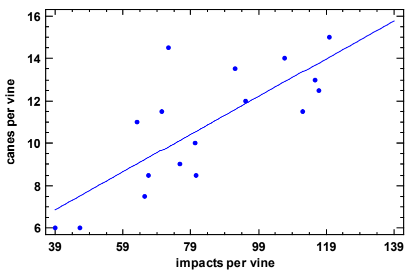
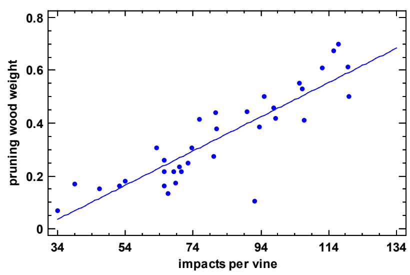
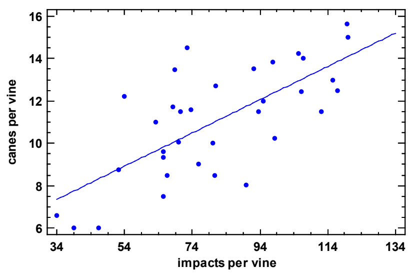
Year	Plot of Fitted Model	ModelParameters	Results
2014		Equation	Pruning wood weight = 0.007 × Method VI − 0.209
		R^2	0.93
		MeanAbsolute Error	0.035 kg/vine
		Equation	Canes per vine = 0.295 × Method I + 5.025
		R^2	0.47
		MeanAbsolute Error	1.26 canes/vine
2015		Equation	Pruning wood weight = 0.021 × Method IV − 0.097
		R^2	0.65
		MeanAbsolute Error	0.087 kg/vine
		Equation	Canes per vine = 0.089 × Method VI + 3.402
		R^2	0.60
		MeanAbsolute Error	1.47 canes/vine

Table 7. *Cont.*

Year	Plot of Fitted Model	ModelParameters	Results
All years		Equation	Pruning wood weight = 0.006 × Method VI − 0.184
		R^2	0.76
		MeanAbsolute Error	0.064 kg/vine
		Equation	Canes per vine = 0.078 × Method VI + 4.686
		R^2	0.50
		MeanAbsolute Error	1.51 canes/vine

Pruning wood weight is measured in kg per vine, while Method I, Method IV, and Method VI refer to the impacts per vine, which are measured by the laser scanner.

As it is presented in Table 7, the models that estimate pruning wood weight presented a moderate to very high coefficient of determination (R^2 = 0.65 − 0.93) if compared with the canes per vine models that presented a low to moderate (R^2 = 0.47 − 0.60). It is worth noticing that the models' accuracy is also affected by weather conditions and more specifically precipitated water, as in the case of Sauvignon Blanc. Moreover, the estimation of canes per vine was more accurate during wet weather conditions, which is in contradiction to the case of pruning wood estimation, which had the highest accuracy in dry weather conditions.

4. Discussion

As it was presented in this study, there were significant differences in the accuracy of estimation of pruning wood parameters through the use of a laser scanner between cultivars and years. Specifically, there was higher accuracy on estimating vine pruning wood parameters in Syrah compared to Sauvignon Blanc cultivar. This can be explained by the number of interventions (higher for Sauvignon Blanc) that occurred during the vine growing season for managing the canopy as well as yield components, which reduced or eliminated the variability induced by soil and topographic conditions [16,17]. Additionally, the wet weather conditions during 2015 led to reduced accuracy of the pruning wood parameters estimation in both cultivars compared to 2014. This can be explained as a result of increased water supply in 2015, similar to irrigation [20–23]. However, in wet weather conditions and/or under increased irrigation, shoot growth is limited only in terms of length due to the cultivation practices like trimming, which is compensated by increased cane diameter. This result is in accordance with the findings of Anderson and Schultz, who found that cane diameter is larger in well-watered vines [24].

Weather conditions, and more specifically precipitated water, greatly affected the accuracy of pruning wood parameters estimations using the laser scanner sensor. In particular, the models' accuracy decreased significantly during the wet weather conditions that occurred in 2015. This can be explained by the fact that there was no water deficit in the vineyards due to the high rainfall [25], leading to a more homogenized canopy and therefore pruning wood parameters, especially in the case of the Sauvignon Blanc cultivar, which received more cultivation practices than the Syrah cultivar.

The optimal sensor settings were different among the cultivars, but also in the attempt to estimate pruning wood parameters. For the Sauvignon Blanc cultivar, the optimal tractor speed was 2 km/h in all years, while the angular resolution and placement of the laser scanner sensor differed. The optimal angular resolution in 2014 was 0.5° and the sensor placement allowed measurement of all the pruning wood surface, while in 2015 the settings were 1° and scanning of the upper half of the pruning wood surface, respectively. The overall optimal sensor setting when including measurements from both years was achieved by placing the sensor for scanning the lower half of the pruning wood surface at 1° angular resolution. Accordingly, the optimal sensor placement allowed the scanning of all the pruning wood surface in Syrah in all cases. Additionally, the optimal tractor speed for measurement was 2 km/h in all cases, except in the case of measuring pruning wood weight in 2015, which was 4 km/h. The optimal angular resolution was 0.25° in most cases, except when measuring the number of canes per vine in 2014 and pruning wood weight in 2015, which was 1°. The difference in optimal angular resolution in each year can be explained by the fact that during the wet year of 2015, the vines had developed canes of larger diameter and therefore could be easily detected by the laser scanner. This is also justified by the fact that the optimal angular resolution was lower in the Sauvignon Blanc cultivar than in Syrah since it had larger canes due to the higher amount of applied water. This is in accordance with other studies that referred to estimation errors due to sensor placement and the small size of the measured object [26–29]. Accordingly, the higher scanning speed can be effective only on larger objects since smaller objects such as very thin canes tend not to reflect back all the total amount of light used for the measurement [30]. Based on the aforementioned, cane diameter measurement was proven to be a limited factor for further insights on the efficiency of laser scanners in vineyards. Therefore, it is suggested that cane diameter measurements should also be included in this type of study, along with other pruning wood parameters such as pruning wood weight and number of canes per vine.

5. Conclusions

The laser scanner measurements presented the highest correlation rates for Syrah compared to Sauvignon Blanc for both years. This can be justified by the different management of the two vine cultivars during the growing season, resulting in the partial elimination of the initial spatial variability of the pruning wood parameters, induced by soil and topographic parameters. Thus, the laser scanner should be placed in order to measure the lower half, at 1° angular resolution and at 2 km/h speed, when the vineyards are well irrigated, as in the case of the Sauvignon Blanc cultivar. In the case of vineyards with limited irrigation, such as in the case of the Syrah cultivar, the laser scanner should measure the whole vine canopy surface at 0.25° angular resolution and at 2 km/h measurement speed. However, these settings should change in the case of wet weather conditions due to changes in pruning wood parameters. It can be concluded that the laser scanner has turned out to be a promising technology for the non-destructive evaluation of the spatial variability of vigor within precision viticulture and thus can be used as an alternative method for this purpose.

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