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Digital mapping of pruning weight in vineyards in the framework of precision viticulture

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Abstract: This study showcases the potential of utilizing LiDAR sensing technologies as an automated, efficient, and rapid method for mapping winter pruning wood across vineyards. It was conducted in 2024 in a commercial vineyard in the region of Attica in Greece in the framework of "AGROSYS" project. The experimental area was 3.5 ha grown with Savvatiano variety. Cane weight data were collected manually at pruning, while soil spatial variability, and canopy properties were mapped and analyzed. The regression analysis of the three-dimensional point clouds and the manual measurements of pruning weight revealed a strong relationship. This signifies the high potential of accurate mapping of dormant pruning canes across vineyards using rapid and time-efficient digital methods. The analysis also revealed strong relationships with the NDRE and canopy temperature at harvest.

Keywords: Precision Viticullture; LiDAR; spatial variability; vine vigour; pruning wood mapping

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1. Introduction

Assessing vine vigour is a key focus in Precision Viticulture (PV), aimed at identifying zones of common characteristics with consistent vine performance within vineyards. Traditionally, one of the most informative indicators of vine balance has been the counting and weighing of dormant canes during winter [1]. This method, although widely used by grape growers for vineyard management, is labor-intensive, time-consuming, and limits the scope of detailed sampling.

In recent decades Precision Viticulture (PV) has attracted considerable interest from both growers and researchers. This growing attention has been fueled by the development and accessibility of digital technologies tailored to agricultural use. Among the various tools used in PV, the most commonly employed sensors include RGB, multispectral, hyperspectral, thermal, and LiDAR sensors [2]. With the new advanced Simultaneous Localization and Mapping (SLAM) LiDAR sensors, data acquisition has become simpler and more efficient providing high quality and high-resolution point cloud datasets. This makes the utilization of LiDAR sensors a viable solution for mapping and preparing three-dimensional models of agricultural environments. Analysis of the produced point clouds provide a reliable representation of the structural parameters of the crops, adequately describing their shape and volume [3].

Another important layer of information utilized in PV is the soil electrical conductivity (EC) which, with the currently available sensing and mapping systems, can provide estimation of the soil spatial variability in high resolution. Managing vineyard variability has been the key goal in numerous studies and may be the key for maximizing grape and wine quality [4-5].

In this work, the utilization of SLAM LiDAR scanner to map and quantify the dormant pruning canes in orchards was investigated in the framework of "AGROSYS" project. The relationship between dormant pruning and canopy parameters at veraison and harvest was investigated.

2. Materials and Methods

The study was conducted during summer in 2024 in a commercial vineyard located in Attica region in Greece (23.9059097°E 37.9872950°N). The experimental area was 3.5 ha, a subsection of a 26 ha vineyard grown with the traditional Greek variety Savvatiano (Vitis vinifera L.). The EM38-MK2 electromagnetic probe (Geonics LTD, Ontario, Canada) was utilized to map the apparent soil electrical conductivity (ECa). The sensor was positioned in a wheeled cart towed by a vehicle following parallel transects between the vine rows 12m apart.

The analysis of the soil ECa spatial variability resulted in the delineation of soil zones based on which 26 vines were selected. For the sake of simplifying the measurement acquisition process the sample vines were selected in four paths to be followed during each measurement, selecting vines from both consecutive rows adjacent to each path. The selection of the sampling points was done as such to make sure that zones of Low, Medium and High ECa were equally represented in the dataset.

The hypothesis was based on the fact that soil variability has a significant effect on vine development, thus, expecting to produce spatial variability on the latter. The sample vines were measured for their physiological status utilizing proximal sensing. Vine canopy reflectance was measured during two stages, Veraison and Harvest, using the CropCircle (Holland ScientificInc., Lincoln, NE, USA) multispectral sensor. The sensor was mounted on Thorvald Unmanned Ground Vehicle (UGV) (SAGA Robotics SA, Oslo, NorwaySAGA robotics) pointing towards the side of the sample vines' canopy with the sensor beam at vertical setup. Additionally, a handheld (IR) thermal camera (FLIR Systems, Inc.) was utilized to measure canopy temperature as an assessor of the vines' reaction to water scarcity and heat stress.

The pruning canes scanning process occurred in February 2025 at dormancy stage using a 3D SLAM LiDAR scanner (FJD, FJDYNAMICS PTE.LTD.) for the construction of the three-dimensional model of the vine rows. The point cloud was analyzed with the FJD Trion Model processing software (FJD, FJDYNAMICS PTE.LTD.). The sample vines were marked within the 3D model using their coordinates and were isolated by masking the rest of the items in the vineyard.

Linear regression analysis was performed to reveal the relationship between the measured parameters.

3. Results and Discussion

As described above, the sample vines were isolated from the 3D point cloud of the experimental area and the count of the total points in each vine was estimated as the metric of growth (Figure 1).

Figure 1. Three-dimensional representation of the point cloud acquired from the experimental vineyard. Sample vines were annotated.

The initial hypothesis that soil variability produces spatial variability on vine development was confirmed by the results of the analysis; the descriptive statistics of the point cloud measurements of the sample vines showed considerably high coefficient of variation (CV=37%).

The count of the total points per vine was used as dependent variable in the regression analysis with the rest of the measured parameters. The results revealed a strong positive relationship between the points count and the pruning canes weight (Figure 1; R2=0.65). This is consistent with the results presented in [6] where a 2D LiDAR scanner was proved as a viable tool for mapping pruning canes in vineyards.

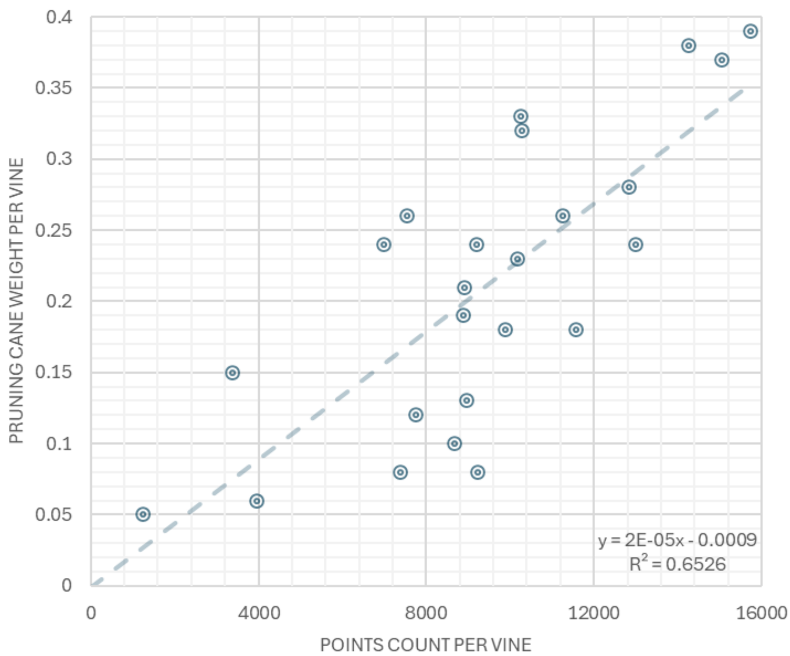

Figure 2. Regression between point cloud counts and measured weight of pruning canes per sampling vine.

A strong relationship was also observed among the LiDAR scans and the leaf temperature measured using a thermal camera during harvest (Table1; R2=0.64). Weaker relationship between the same parameters, yet significant (R2=0.41), was also observed with the canopy temperature measured at veraison. The weaker relationship is attributed to the water status in July when due to precipitation events, the vines were less stressed and, thus, the range of the temperature measurements was shorter, and the variability was low. The negative relationship indicates that the more vigorous vines had better reaction to heat and water scarcity stress.

Table 1. Regression analysis between pruning canes estimation from 3D model and other measured parameters

Measurement	Relationship	Coefficient of Determination (R2)
NDVI at harvest	positive	0.19
NDRE at harvest	positive	0.56
Thermal at harvest	negative	0.64
Thermal at veraison	negative	0.41

Furthermore, NDRE vegetation index measured at harvest had a stronger relationship with pruning measurements (R2=0.56) as compared to the NDVI (R2=0.19) supported by the fact that the NDVI is saturated at dense canopies making NDRE more appropriate indicator of canopy variability at such conditions.

4. Conclusions

Mapping the soil ECa, confirmed the hypothesis that soil spatial variability is a reliable factor that determines the spatial variability of grapevines' growth and physiology throughout vineyards.

The method described in this study provides rapid mapping of the 3D representation of vines. The analysis of the 3D point clouds of the sample vines provided an accurate estimation of the dormant canes which is a reliable indicator of within season vine vigour. This highlights the potential of 3D mapping to accurately assess spatial variability of vine status, making the LiDAR 3D scanners a valuable tool for characterizing within-vineyard variability.

On the other hand, this technology shows limitations that are related to the complexity of data acquisition and analysis and the large volume of data that need to be stored and processed.

Further studies are required to enrich the dataset and improve the efficacy of the proposed methodology. The relationship between LiDAR sensor data and thermal measurements should be further investigated under different climatic conditions through multiple site-years.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Figure S1: title; Table S1: title.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

LiDAR	Light Detection and Ranging
SLAM	Simultaneous Localization and Mapping
NDVI	Normalised Difference Vegetation Index
NDER	Linear dichroism
PV	Precision Viticulture
ECa	Apparent Electrical Conductivity
UGV	Unmanned Ground Vehicle
IR	Infra-Red

References

1. Smart, R.; Robinson, M. Sunlight into wine: A handbook for winegrape and canopy management. Winetitles, Adelaide. 1991.
2. Ferro, M.V.; Catania, P. Technologies and Innovative Methods for Precision Viticulture: A Comprehensive Review. *Horticulturae* **2023**, 9, 399. https://doi.org/10.3390/horticulturae9030399.
3. Tagarakis, A.C.; Filippou, E.; Kalaitzidis, D.; Benos, L.; Busato, P.; Bochtis, D. Proposing UGV and UAV Systems for 3D Mapping of Orchard Environments. *Sensors* **2022**, 22, 1571. https://doi.org/10.3390/s22041571.
4. Tagarakis, A; Liakos, V.; Fountas, S.; Koundouras, S.; Gemtos, T. Management zones delineation using fuzzy clustering techniques in grapevines. *Precision Agriculture* **2013**, 14(1), 18-39. DOI 10.1007/s11119-012-9275-4.
5. Bramley, R.G.V. Precision Viticulture: Managing vineyard variability for improved quality outcomes. In *Managing Wine Quality*, 2nd ed.; Reynolds, A.G., Ed.; Woodhead Publishing, 2022; pp. 541-586). ISBN 9780081020678, https://doi.org/10.1016/B978-0-08-102067-8.00002-6.
6. Tagarakis, A.; Koundouras, S.; Fountas, S.; Gemtos, T. Evaluation of the use of LIDAR laser scanner to map pruning wood in vineyards and its potential for management zones delineation. *Precision Agriculture* **2018**, 19(2), 334–347. DOI 10.1007/s11119-017-9519-4.