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Comparison of UAS LiDAR LAI Retrieval Methods for Vineyards

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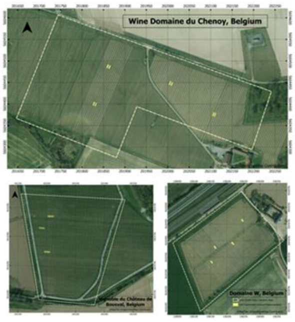
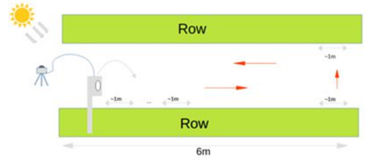
Abstract

Leaf area index (LAI) is a common crop parameter linked to biological and physical processes in plant transpiration, nutrients, and the carbon cycle often used to determine crop status to improve management practices. Ground collection methods of obtaining LAI can be time-consuming, restricted to spatially incomplete point data, and invasive to the crops. Satellite remote sensing-based data can be too coarse allowing for mixed information between the rows and inter-rows. Manned airborne methods can be cost-inefficient for the typical vineyard size. Unmanned aircraft systems (UAS), on the other hand, provide ultra-high-resolution remote sensing data that is now commonly accessible. Passive sensors such as RGB or multispectral are affected by issues in shadowing either from sun angles or clouds. Additionally, using RGB structure from motion (SfM) techniques often cannot offer a complete 3D render with areas of omission present and over-smoothing issues. Multispectral methods suffer from saturation issues at higher levels of LAI not allowing the true variability of LAI to be determined. However, UAS-mounted LiDAR sensors are becoming more common and have alleviated some of these issues. Regardless of lighting conditions, LiDAR with its active sensing nature can provide a more complete 3D depiction of the crop structure and canopy density. In order to determine canopy density, the rate of signal penetration can be observed using gap fraction (GF) techniques. Methods with 3D voxel hulls and 3D voxels can be used to determine vine volume. This study observes three different vineyard sites and compares the methods of GF, 3D voxel hulls, and 3D voxels in determining the best match with LAI variability as compared to ground ceptometer measurements taken at each vineyard site.

Study Area & Experimental Design

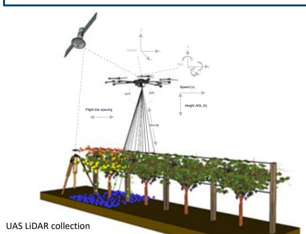




Measurements took place at three different vineyards including, Domaine de Chenoy, Domaine W, and Vignoble du Chateau de Bousval, Belgium. At each of these sites ground LAI measurements were taken using a Sunscan SS1 ceptometer. This device compares the total radiance to that intercepted by the canopy. Each site had three to four measurement locations distributed throughout the study areas. At each location, six measurements were taken per two rows, one meter apart for a six meter section each row. The averages of each row were taken and compared to six meter sections within the UAV data. In total there are 22 rows. measured.

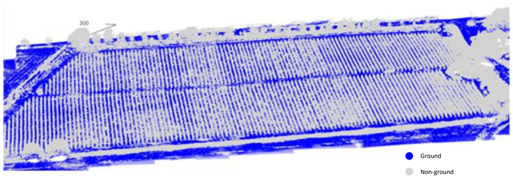
Methods

UAS LiDAR Collection

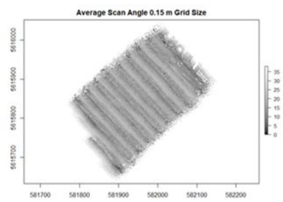


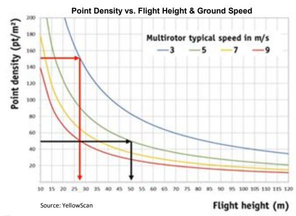
UAS LiDAR collection elements and parameters
*IMU: Inertial Measuring Unit
*DGPS: Differential Global Positioning System

Domain W, Belgium - 3D POint Cloud w/ Ground Segmentation

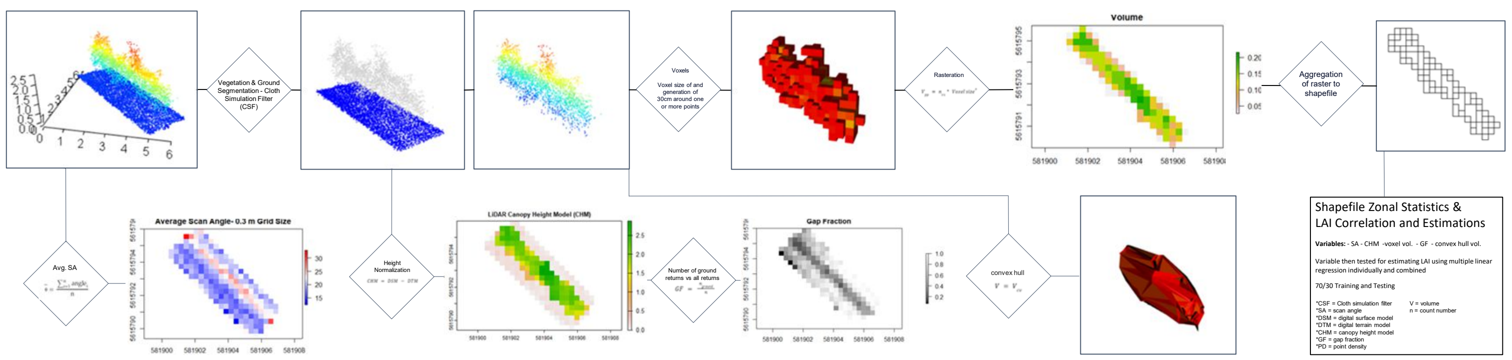


LiDAR Data Considerations

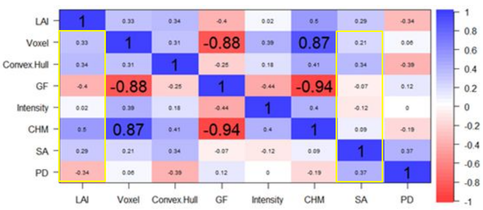




Vineyard 3D Point Cloud LAI Workflows



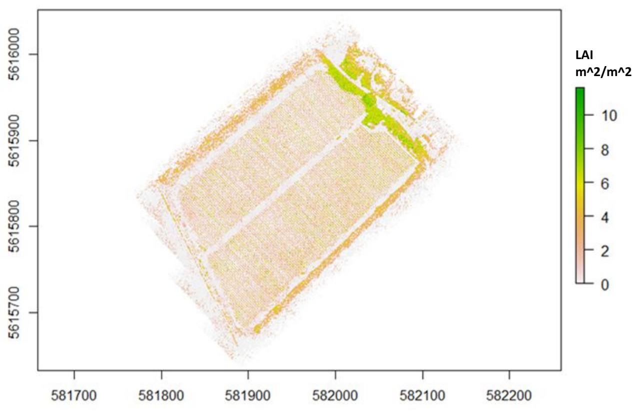
Results



	LAI	Voxel	Convex.Hull	GF	Intensity	CHM	SA	PD
LAI	1	0.33	0.34	-0.4	0.02	0.5	0.29	-0.34
Voxel	0.33	1	0.31	-0.88	0.39	0.87	0.21	0.06
Convex.Hull	0.34	0.31	1	-0.25	0.18	0.41	0.34	-0.39
GF	-0.4	-0.88	-0.25	1	-0.44	-0.94	-0.07	0.12
Intensity	0.02	0.39	0.18	-0.44	1	0.4	-0.12	0
CHM	0.5	0.87	0.41	-0.94	0.4	1	0.09	-0.19
SA	0.29	0.21	0.34	-0.07	-0.12	0.09	1	0.37
PD	-0.34	0.06	-0.39	0.12	0	-0.19	0.37	1

Variables	RMSE (m^2/M^2)	R2
GF	0.322	0.153
Voxel	0.461	0.126
CHM	0.416	0.291
Convex Hull	0.558	0.117
GF, SA	0.307	0.152
Voxel, SA	0.441	0.127
GF, CHM	0.546	0.389
Voxel, GF	0.402	0.144
Voxel, GF, SA	0.322	0.153
Voxel, GF, CHM	0.561	0.408
Voxel, GF, CHM, SA	0.555	0.422

Domain W, Belgium - LAI - September 7, 2022



Conclusion

This study provides insights on various potential avenues to estimate LAI for vineyard type plant structures using the advantages of UAS LiDAR. Thus far, it shows that when using a single type of LiDAR derived parameter to estimate LAI, GF performs the best in means of RMSE and CHM performs best in means of R2. However, any single variable alone does not achieve an R2 as high as the combination of GF, voxels, height, and scan angle with multi linear regression. The correlations indicate that the scan angle of the observed area affects attributes such as GF and voxel volume's ability to accurately estimate LAI. These correlations were lower with GF. Each time that the scan angle was included in the multiple linear regression the RMSE improved. This concludes that it is important to consider the scan angle when making estimations. Overall, the results prove that UAS LiDAR can be a viable option for measuring LAI for an entire vineyard with several means to do so.

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