Estimating occluded grape bunches using image analysis – case study with cv. ‘Arinto’

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Introduction

Grapevine yield estimation is an extremely important topic for the entire grape and wine sector. Conventional yield estimation methods are destructive, labor intensive and often provide inaccurate results.

Recent research aims at applying image analysis technologies for bunch and/or berry recognition in digital images. Image-based methods are strongly dependent on grape bunch visibility which is influenced by canopy density/porosity at fruiting zone and bunch number and morphology. Previous research overcame this problem using defoliation practices for full visibility of grape bunches.

In this work we present a methodology to estimate occluded bunch area without resorting to any invasive canopy management practices. The present work is an update on the models previously developed in Victorino et al. (2019).

Objective

To explore image traits such as canopy porosity and visible bunch pixels as explanatory variables of the portion of leaf-occluded bunches and surpass the need for defoliation on image-based yield estimation methods.

Materials & Methods

- Grapevines of cv. *Arinto* (portuguese white cv.) from season 2019;
- Data collected at veraison and ~~at~~ harvest;
- Canopy segments of 1 meter length; RGB images with a blue background;
- Canopy gaps (porosity) and visible bunch pixels obtained from the images;
- Stepwise defoliation (Fig. 1, steps A, B, C) to simulate different cases for modeling.

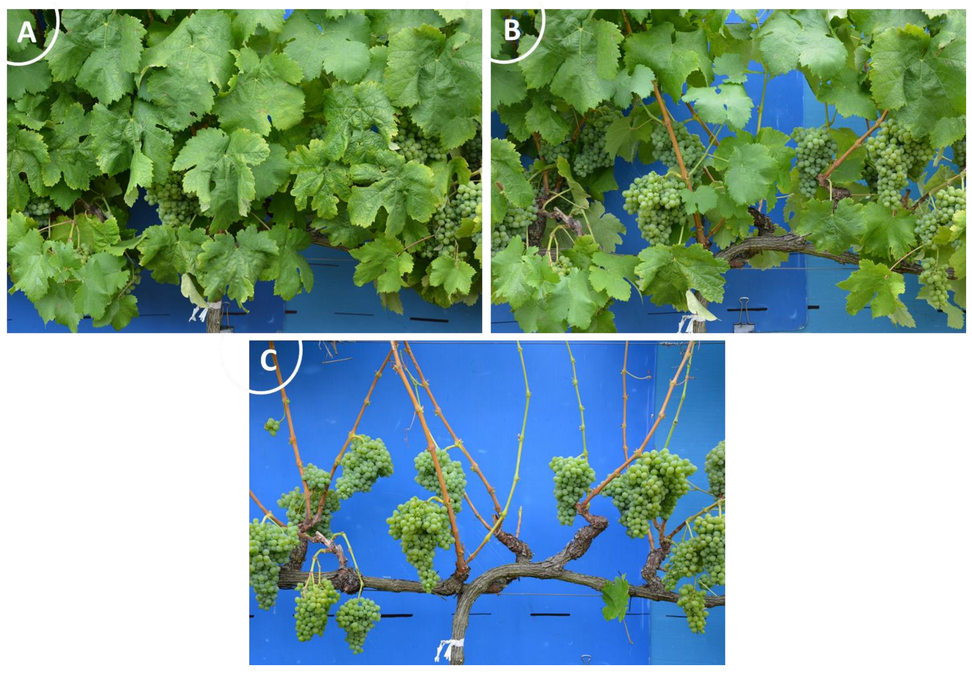

Figure 1. Images collected at different defoliation steps on a vine of the white variety *Arinto*. A) non-defoliated; B) half-defoliated; C) fully-defoliated vine.

Table 1. Variable list and description with respective acronyms and units.

Variable name	Acronym	Unit	Description
Visible bunch area	vBA	cm^2/m	Projected area of non-occluded bunches.
Total bunch area	tBA	cm^2/m	Projected area of occluded and non-occluded bunches, calculated after full defoliation.
% Visible bunch area	pvBA	%	Ratio between vBA and tBA.
Canopy porosity	POR	%	Percentage of canopy gaps at the fruiting zone.
Global porosity	GPOR	%	Percentage of canopy gaps plus segmented bunches (but not including shoots), at the fruiting zone.

Results

- In natural conditions, leaves occluded an average of 67.2% of the total bunch projected area.
- A high percentage of pvBA can be explained by POR, especially when visible bunch pixels are added to create the GPOR (Fig. 2).

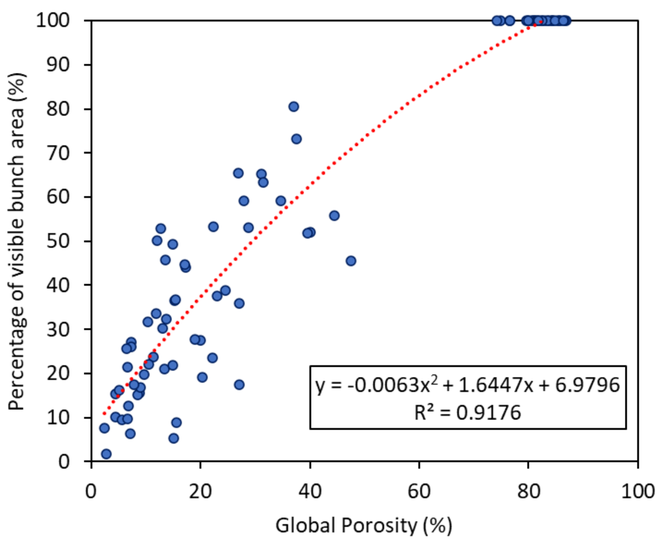

Table 1. Validation

bias	-1.0
MAE	5.9
MA%E	0.2
RMSE	8.3
RRMSE	0.2

Figure 2. Polynomial regression of pvBA over GPOR, with respective equation and resulting R^2, fitted with the training set (n = 86) [left]. Table 1: statistical metrics for model validation (calculated on an independent validation set, n = 34). Metrics calculated according to Wallach et al. (2006) [right].

- Total estimated bunch area, including occluded bunches, was calculated using estimated pvBA and visible bunch area (Fig. 3). The actual accumulated tBA of the 34 vines was 29.9 m^2, while the estimated one was 31.3 m^2, resulting in a final relative error of 4.7%, 7% lower than when using POR exclusively.

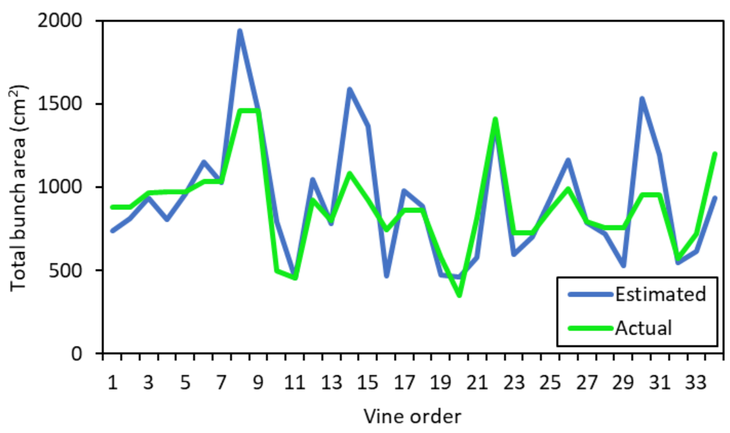

Figure 3. Comparison between estimated and actual tBA on the validation set.

Conclusions

- Canopy gap pixels and visible bunch pixels added together are shown to be an effective estimator of pvBA.
- By knowing pvBA, tBA can be estimated with an error below 5%.
- This approach is significantly better than using only POR for the same purpose.
- Research is ongoing to increase the number of seasons, sites and vines analyzed and to convert tBA into mass ~~with accuracy~~.

References:

Victorino, G., Maia, G., Queiroz, J., Braga, R., Marques, J., Santos-Victor, J., & Lopes, C. (2019). Grapevine yield prediction using image analysis - improving the estimation of non-visible bunches. Digitizing Agriculture.

Wallach, D., Makowski, D., Jones, J. W., & Brun, F. (2006). Working with dynamic crop models: evaluation, analysis, parameterization, and applications. Elsevier.

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