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Research Note

Determination of shadow as a simple way for biomass estimation of *Vitis vinifera*

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Introduction: Estimation of aboveground vegetation biomass often consists of a relationship between the biomass and one or more dendrometric parameters such as height, basal diameter, diameter at breast height (dbh) or crown projection area. Current techniques for estimation of the biomass of woody plants are based on a complete harvest of randomly selected plots (Ranger *et al.* 1992; Usoltsevt and Hoffmann 1997; Ingerslev 1999) or on non-destructive methods (Uso *et al.* 1997; Fang *et al.* 1998; Vann *et al.* 1998; Montès *et al.* 2000). All these methods are well adapted to agroforestry and for natural ecosystems where the annual increase of biomass for the different compartments (foliage and woody parts) is related to an increase of dendrometric parameters (height and diameter). In vineyards, the annual productivity represents a large amount of the total biomass. Indeed, in addition to litterfall, canes are heavily pruned after harvest, usually in winter. In these annually perturbed agrosystems, the annual production of biomass is therefore periodically removed and no relationship could be found between biomass and dendrometric data. In vineyards, the above-ground biomass and foliage surface are of importance as the sun exposure of leaves and grapes controls the quantity of sugar and pigments in berries and the reserves of starch (May *et al*. 1969; Hummel and Ferree 1998; Kliewer 1977; Diofasi 1969; Kliewer and Weaver 1971). To provide biomass data for an easy and accurate estimation of vegetative biomass production and of the importance of grape shade, a fast photographic method is proposed.

Material and Methods: Study sites: The research was initiated in a commercial vineyard of "Côtes de Provence" in southeastern France. The vineyard was planted in 1992 with a monoclonal strain of Grenache noir (*Vitis vinifera* L.), spaced 1.0 m x 2.5 m (4000 vines/ha) and managed on a trellis system. Vines were regularly trimmed to maintain a maximum height of 150 cm and a width of 50 cm to allow mechanical management.

Photography: This method was based on the hypothesis that in these agrosystems there is a relationship between pruning weight, biomass of the foliage and surface area of the shadow of foliage. We assumed that by estimating the surface area of the shadow (which is related to light interception), we could deduce the pruning weight.

Eleven plots (80 m^2) with differences in vegetative biomass production due to soil fertility, were randomly sampled. To determine the surface area of the shadow, each plot was photographed vertically from 4 m above ground using a telescopic tripod and a digital camera with a remote control (Fig. 1). Each picture was taken at the same distance from the center of the row.

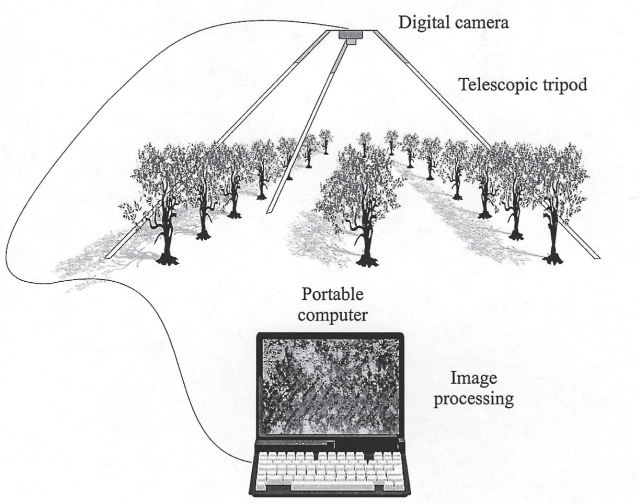

Fig. 1: Photographic sampling procedure.

To take into account the moving sun during the sampling procedure and therefore the elongation of shadows, a gauge was photographed before each sampling in the same way. It consisted of a vertical stick on a plank with graduations. The shadow on the plank was used to establish a correction factor.

The pictures were then analyzed with Adobe Photoshop 6.0 software (Adobe system Inc. Pantone®, USA): each picture was treated using specialized filters to discriminate shadow and lightened pixels. The strong albedo of the cultivated soils (no litter and no humus) and the structural homogeneity of the ground (no stones and no vegetation layer) enabled an easy identification of pixels. Picture interpretation resulted in a black and white picture. The surface of the shadow was then given by the number of black pixels. From the surface area of the shadow its relative surface area (percentage of shadow on the picture) was calculated, using the correction factor:

$$S_{\%} = [(S_s / S_t) / L_s] \, x100 \, ,$$

where $S_{\%}$ is the relative surface area of the shadow, S_s is the surface area of the shadow, S_t is the total surface area of the picture and L_s is the length of the shadow on the gauge.

In each plot, all canes were harvested and weighed to determine their biomass. The relative surface area of the

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shadow was then related to this pruning weight to obtain regression equations between these two parameters.

Results and Discussion: Polynomial, exponential and linear regression equations were tested. Of these, the linear model was the best to explain the relationship between the surface of the shadow and the pruning weight (Fig. 2). This result shows that the method is reliable to estimate the biomass data ($R^2 = 0.82$, $p = 0.001$) from the surface area of the shadow.

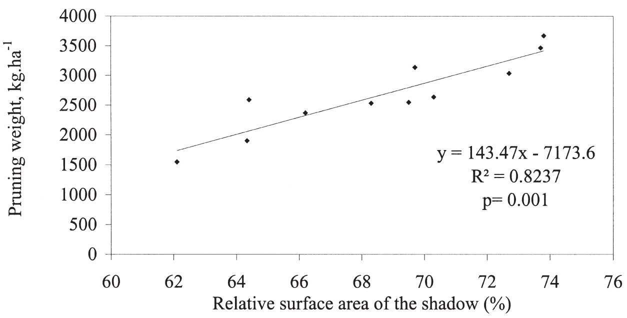

Fig. 2: Regression analysis between relative surface area of the shadow ($S_{\%}$) and biomass.

Since this agrosystem is periodically perturbed from a biomass point of view due to wood and foliage removals, no significative relationship could be found between biomass and dendrometric parameters. Consequently, all methods based on measurements of dendrometric parameters (height, diameter or cover) are not suitable for an accurate biomass estimation. The same holds for non-destructive methods which often depend on a biovolume determination. Indeed mechanical trimming leads to a homogenization of shoot length and thus of the plant biovolume.

The method presented in this paper gives a reliable relationship between biomass of the plots and the measured parameter because the surface area of shadow is related to foliage density even though there are wood and foliage removals. This method could be used for two main purposes:

1) To compare vine vigour of different plots in the same vineyard or of different vineyards. In this case, the method is very simple because only measurements of the shadow are necessary and the estimation of biomass is not necessary. Therefore, direct comparisons with the surface area of the shadow ($S_{\%}$) are possible without calculating regression equations.

2) To estimate biomass. A regression equation between biomass and the $S_{\%}$ should be obtained, but only once. When the relationship between these two parameters is established, plant growth can be compared from year to year. In addition, if nutrient concentrations of plants are known, effects of nutrient uptake by plants on soil composition and nutrient fluxes in the agrosystem can be studied.

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