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VALIDATION OF AN EMPIRICAL MODEL FOR GRAPEVINE LEAF AREA ESTIMATION WITH DATA FROM SIMPLIFIED PRUNING SYSTEMS

VALIDATION D'UN MODÈLE STATISTIQUE POUR ESTIMER LA SURFACE FOLIAIRE PRINCIPALE D'UN RAMEAU DE VIGNE AVEC DES DONNEÉS DE SISTÈMES DE TAILLE SIMPLIFIÉS

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Abstract: The performance of a mathematical model developed for non-destructive estimation of primary leaf area per shoot of Tempranillo grapevines, was tested using independent datasets from two vineyards with simplified pruning techniques. The first dataset was collected in Portugal on Cabernet Sauvignon grapevines subjected to mechanical hedge pruning and the second one in Germany on minimal pruned Riesling grapevines. For both datasets the model presented a very good fit between observed and estimated values with the error increasing with the increase in leaf area per shoot. The mean absolute percent error for all systems was lower or equal to 10% with lower absolute values (7.7%) for the Riesling dataset. Both linear regression between observed (dependent variable) and estimated (independent variable) leaf area had high and significant R^2 with an intercept not significantly different from zero. Fitted lines were not significantly different from 1 for Cabernet Sauvignon, but slightly yet significantly different from 1 for Riesling fitted line (1.03), indicating that the model underestimated the leaf area per shoot. The good results obtained with this validation test show that the model can be used to accurately predict primary leaf area per shoot independent of variety, training system and climatic conditions.

Key words: grapevine, leaf area, statistical model, Tempranillo, Cabernet Sauvignon, Riesling, validation.

Résumé: Avec l'objectif de tester un modèle statistique développé pour estimer de façon non destructive la surface foliaire principale d'un rameau de vigne du cépage Tempranillo, un test de validation a été fait avec des donnés indépendants obtenus en deux différents vignobles. Un échantillon a été prélevé dans un vignoble au Portugal du cépage Cabernet Sauvignon taillée en haie fixe rectangulaire et l'autre dans un vignoble Allemande du cépage Riesling conduite en taille minimale sur cordon. Les valeurs de la surface foliaire estimées par le modèle présentent un très bon accord avec les valeurs mesurées toutefois les résidus augmentent avec l'augmentation de la surface foliaire par rameau. L'erreur moyenne absolue en pourcentage a été inférieur ou égal a 10% avec la valeur plus bas (7.8 %) présenté par les données du Riesling. Les régressions linéaires entre valeurs mesurées (variable dépendante) et simulées (variable indépendante) ont présenté un R^2 élevé et significatif et des droites de régressions avec une constante pas significativement différent de zéro. La droite de régression du Cabernet Sauvignon a présente un pente pas significativement différent de 1, mais les donnés du Riesling ont présenté une droite de régression avec un pente significativement supérieur a 1 ce qui montre que le modèle surestime la surface foliaire principal par sarment par un facteur multiplicative. Le modèle a présenté aussi une très élevée efficience de modélisation pour les deux groupes de donnés avec la valeur plus haut présenté par le Riesling (0.98). Les bons résultats obtenus avec ce test de validation montre que, avec ce modèle, ont peut estimer de façon non destructive, rapidement et avec une bonne précision, la surface foliaire d'un rameau de vigne independenment du cépage, système de conduite et terroir.

***Mots clés*:** vigne, surface foliaire, modèle statistique, Tempranillo, Cabernet Sauvignon, Riesling, validation.

1. INTRODUCTION

In viticulture research the measurement of leaf area is fundamental to understand the responses of grapevines to environment, training systems and canopy management strategies (Smart, 1995; Murisier, 1996). Yet, the monitoring of grapevine leaf area is tedious and time consuming. Leaf area can be measured or estimated by a variety of techniques, which can be divided in destructive and non-destructive methods (Mabrouk e Carbonneau, 1996). Within the non-destructive methods the use of empirical models for the estimation of the leaf area per shoot have been developed in recent years (Barbagallo *et al*, 1996; Mabrouk and Carbonneau, 1996; Lopes and Pinto, 2000, 2005). The simplicity and accuracy of those models makes them appropriate for common use since no special equipment is needed. However, in order to test their potential applicability it's necessary to validate the models with independent datasets from other varieties, regions and training systems.

The aim of this paper was to test the performance of a mathematical model proposed by Lopes and Pinto (2005) for non-destructive estimation of primary leaf area per shoot of Tempranillo grapevines using independent datasets from two vineyards and varieties, one in Portugal and another in Germany, were simplified pruning techniques had been applied.

2. MATERIAL AND METHODS

The two datasets used in the validation tests where obtained in two different vineyards. The first dataset was collected in 1997 in a commercial vineyard located at Cartaxo, center Portugal, within the Ribatejo wine region (39º 10` N; 8º 45` W). The thirteen-year-old 'Cabernet Sauvignon' vines, grafted on SO4 rootstock, were spaced 2.8 m between and 1.3 m within rows on a vertical trellis and vines were trained to a bilateral cordon at a height of 0.6 m and mechanical hedge pruned (rectangular hedge of about 35 cm width and 20 cm height). Periodically, from April 14 (4 weeks after bud burst) to the beginning of September (6 sampling dates), a sample of 10 (22 at the last sampling date) fruiting shoots was randomly collected from the exterior and interior of the canopy, inserted in plastic bags and transported to the laboratory. From each shoot, primary leaves were separated and numbered according to node insertion and the leaf area was measured by a leaf area meter (Delta T area meter, Delta-T Devices, England).

The second data set was collected in Germany, in a commercial 25-year-old 'White Riesling' (*Vitis vinifera* L.) (clone 239 Gm) vineyard, grafted on 5 C rootstocks (*Vitis berlandieri* Planchon x *Vitis riparia* Michaux) at the Johannisberger Schloβberg, Geisenheim, (50`N; 8°E), during 2001. Plants were spaced 3.0 m between and 1.3 m within the rows and minimally pruned. The length of the main vein of every single leaf on all shoots of two vines were measured between the 29th and 31st of May 2001 and individual leaf area calculated according to Schultz (1992).

Data were treated separately per variety and all small shoots with less than 3 leaves were excluded. As only very few shoots carried laterals, lateral leaf area was not considered for this validation. For each shoot we computed the variables needed for the model (Lopes and Pinto, 2005): sum of primary leaf area (LA_1), number of primary leaves (NL_1), area of the largest primary leaf (L_1), area of the smallest primary leaf (S_1). From these variables two new variables were calculated:

- the mean primary leaf area: $M_1 = (L_1 + S_1)/2$ (1)
- the mean primary leaf area per shoot: $MLA_1 = M_1 * NL_1$ (2)

The mathematical model used for primary leaf area estimation was developed by Lopes and Pinto (2005) for Tempranillo grapevines and is represent by the following equation (Eq. 3):

$$LA_1 = EXP[(0.0835 + 0.992 * \ln(MLA_1)] \quad (3)$$

In order to evaluate the goodness of fit to the observed data, the following deviance measures were used (Schaeffer 1980):

- mean absolute error: $MAE = (\Sigma \mid y_i - \hat{y}_i \mid)/n$ (4)

- mean absolute percent error: $MA\%E = 100\ [\Sigma\ (\mid y_i - \hat{y}_i \mid / \mid y_i \mid)]/n$ (5)

where y_i represents the observed values, $\hat{y}_i$ the simulated values and n the number of pairs.

The modeling efficiency (EF), a dimensionless statistical parameter that relates model predictions to observed data was determined (Loague and Green, 1991) and a linear regression analysis of observed *vs*. predicted was performed. For the regression analysis the observations were taken as independent Y-variable (Mayer and Butler, 1993) and F-tests were conducted for slope=1 and for intercept=0 using SAS®.

3. RESULTS

3.1. Cabernet Sauvignon from Portugal

Figure 1 presents the relationship between observed and estimated values of Cabernet Sauvignon primary shoot leaf area using equation 3. Visual observation showed good agreement between observed and estimated values and also showed an increase in bias with the increase in shoot leaf area. This is corroborated by the applied statistics (Table 1). The deviance measures show a mean absolute error of 110.8 cm and a mean absolute percent error (MA%E) around 10. The linear regression between observed (dependent variable) and estimated (independent variable) data showed a high and significant R^2 and the fitted line had a slope and an intercept not significantly different from one and zero, respectively. The modeling efficiency was 0.92.

3.2. Riesling from Germany

The relationship between observed and estimated values of Riesling primary shoot leaf area is presented in figure 2. As for Cabernet Sauvignon, there was very good agreement between observed and estimated values. The mean absolute percent error was lower and the modeling efficiency higher than the values presented by the Cabernet Sauvignon dataset. The linear regression between observed and estimated values had a very high R^2 and the fitted line presented an intercept not significantly different from zero but a slope significantly different from 1 (Table 1).

***Table 1** – Statistical data for the validation of the mathematical model (equation 3) for the estimation of grapevine primary leaf area per shoot.*

***Tableau 1** – Mesures statistiques de la validation du modèle représenté dans l'équation 3 pour l'estimation de la surface foliaire principale d'un sarment de vigne.*

Data set	nº shoots	Deviance measures		Linear regression				Modeling efficiency
		MAE	MA%E	R^2	Intercept(1)	Slope(2)	RMSE	
Cabernet S.	72	110.8	10.2	0.93	35.7 ns	1.02 ns	132.8	0.92
Riesling	488	21.7	7.7	0.97	-3.44 ns	1.03***	30.4	0.98

*(1) t-test for intercept = 0; (2) t-test for slope = 1; ns - not significant; *** P < 0.001.*

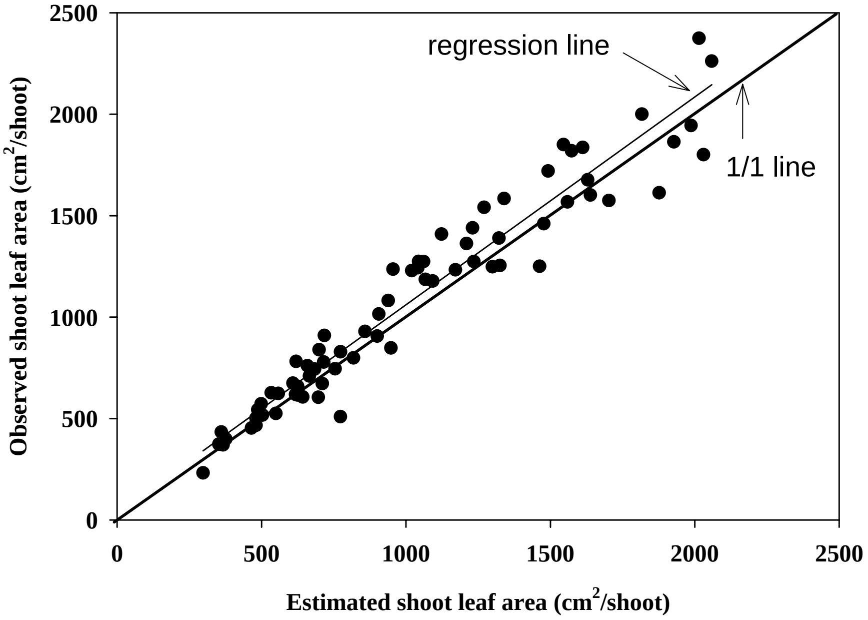

Figure 1

Relationship between observed and estimated values of Cabernet Sauvignon primary shoot leaf area. Cartaxo, Portugal, n= 72.

Figure 1

Relation entre valeurs mesurées et estimées de la surface foliaire par rameau du cépage Cabernet Sauvignon. Cartaxo, Portugal, n= 72.

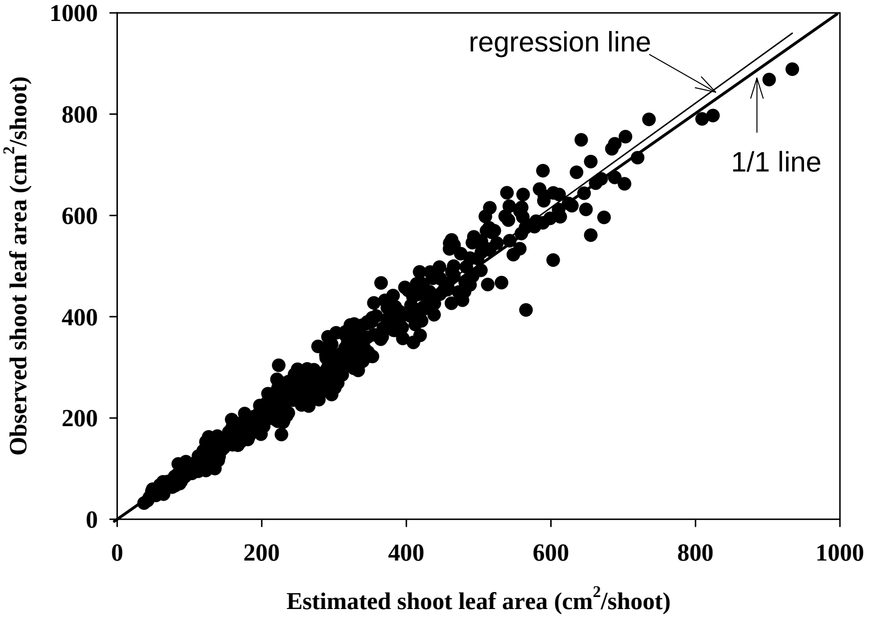

Figure 2

Relationship between observed and estimated values of Riesling primary shoot leaf area. Geisenheim, Germany, n= 488.

Figure 2

Relation entre valeurs mesurées et estimées de la surface foliaire par rameau du cépage Riesling. Geisenheim, Germany, n= 488.

4. DISCUSSION

Validation of the model showed a very good fit for both the Cabernet Sauvignon dataset from Portugal and the Riesling dataset from Germany. The modeling efficiency, an overall measure of goodness of fit, was always ≥0.90 indicating a high level of accuracy (Mayer and Butler, 1993). The MA%E values were also within the limits of acceptability (≤ 10%) (Kleijnen 1987). The higher modeling efficiency and lower deviance measures of the Riesling dataset indicated a better fit than for Cabernet Sauvignon despite the fact that the slope of the fitted line between observed *vs* estimated leaf area was significantly different from 1 indicating that the model underestimated the leaf area per shoot. This underestimation should be confirmed with more data from other growing stages as the Riesling shoots were measured only at one growth stage.

This positive validation with data from simplified pruning systems is an important feature for the model because shoot growth is very different from those shoots used to build the model. On simplified pruning systems, like hedge pruning or minimal pruning, an excess of buds is left on the vine, inducing a strong competition between shoots and, consequently, a reduction in shoot growth and vigor when compared to the traditional hand pruning (Clingeleffer, 1988; Lopes *et al*, 2000).

These good validation results, combined with the results of other validations made by Lopes and Pinto (2005) with 4 independent data sets periodically sampled during several seasons from different vineyards and varieties showed that this model can be used to accurately predict primary leaf area per shoot independently of the ecological conditions, variety, year, growth stage and training system. The small underestimation of leaf area shown for Riesling may be avoided if the model would be build on Riesling data. The possibility of a generalized use of this type of model represent a powerful tool for grapevine research, and even for consultants and advanced growers allowing them to evaluate vine leaf area more frequently.

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REFERENCES

BARBAGALLO M.G., LORENZO R.I., MOTISI A., SOTTILE I., 1996. Estimation of leaf area changes along the primary shoot in grapevine. *Compte Rendu 9^{émes} Journées GESCO*, Univ. Horticulture & Food Industries (ed.), Budapest, 245-250.

CLINGELEFFER P.P., 1988. Minimal Pruning of cordon trained vines (MPCT). *Proc. 2nd Int. Sem. Mechanical Pruning of Vineyards, Riv. Ing. Agraria*, **9**, 112-120.

KLEIJNEN J.P.C., 1987. Statistical tools for simulation modeling and analysis. McGraw-Hill (ed.), New York.

LOAGUE K., GREEN R.E., 1991. Statistical and Graphical methods for evaluating solute transport models: overview and application. *J. Contam. Hydrol.* **7**, 51-73.

LOPES C.M., MELÍCIAS J., ALEIXO A., LAUREANO O., CASTRO R., 2000. Conséquences de la taille mécanique en haie fixe sur la vigueur, rendement et qualité du cépage 'Cabernet Sauvignon'. *Acta Horticulturae,* **526**: 261-268.

LOPES C.M., PINTO P.A., 2000. Estimation de la surface foliaire principale et secondaire d'un sarment de vigne. *Prog. Agricole et Viticole*, **117**, 160-166.

LOPES C.M., PINTO P.A., 2005. Easy and accurate estimation of grapevine leaf area with simple mathematical models. *Vitis* **44**: 55-61.

MABROUK H., CARBONNEAU A., 1996. Une méthode simple de détermination de la surface foliaire de la vigne (V*itis vinifera* L.). *Prog. Agricole et Viticole*, **113(18),** 392-398.

MAYER D.G., BUTLER D.G., 1993. Statistical validation. *Ecol. Model.* **68**, 21-32.

MURISIER F.M., 1996. Optimisation du rapport feuille-fruit de la vigne pour favoriser la qualité du raisin et l'accumulation des glucides de réserve. *Thèse Doctorat,* Ecole Pol. Fédérale de Zurich, Zurich, 132 pp.

SCHAEFFER D.L., 1980. A model evaluation methodology applicable to environmental assessment models. *Ecol. Model.* **8**, 275-295.

SCHULTZ H.R., 1992. An empirical model for the simulation of leaf appearance and leaf development of primary shoots of several grapevine (*Vitis vinifera* L.). *Scientia Hortic*. **52**, 179-200.

SMART R.E., 1985. Principles of grapevine canopy microclimate manipulation with implications for yield and quality. A review. *Am. J. Enol. Vitic.,* **36**, 230-239.