40 (1), 2016: 104-107

http://ojs-cra.cilea.it/index.php/asr

Technical note

Volume function for the tree farming English oak plantations of the Valdarno (Tuscany, Italy)

Maurizio Marchi[1*], Serena Ravagni[1], Francesco Pelleri[1]

Received 01/05/2015 - Accepted 25/02/2016 - Published online 19/07/2016

Abstract - In the past centuries, a notable reduction of lowland forests in Italy was detected as a result of the expansion of intensive agriculture and deforestation activities. According to the National Forest Inventory (INFC 2005), the English oak (*Quercus robur* L.) is mainly a scattered species distributed across 146,000 hectares of mixed forests. This species has been used in many national programs to recreate woods in the lowlands as well as tree in farming plantations. In the 1980s, within the restoration program of the Santa Barbara mining area in the Municipality of Cavriglia (Valdarno, Tuscany), about 172 hectares of tree farming plantations were created with English oak. Due to the shortage of specific volume equations for Italian plantations, a sampling campaign was carried out. The volume of 299 sample trees was measured using the Heyer formula and a volume equation was studied as a polynomial function of DBH and total height of trees. The final equation demonstrated to be quite robust with a RMSE of 0.0176 m3 corresponding to a relative RMSE of 10%.

Keywords - volume equation, tree farming plantation, English oak, Valdarno

Introduction

The English oak (*Quercus robur* L.) together with Sessile oak (*Quercus petraea* (Matt.) Liebl.), Common walnut (*Juglans regia* L. 1753) and Wild cherry (*Prunus avium* (L.) L. 1755) is one of the most commonly and widely used tree species in planting forestry for valuable timber production (Kenk 1993; Kerr 1996, Loginov 2012, Saha et al. 2012). These species were used across the whole Europe according to climatic conditions and managed by a specific silvicultural model (Lamaire 2010, Nubout 2006, Perin and Claessens 2009).

The distribution of the English oak in Italy is nowadays strictly connected to tree farming systems and mixed forests. In fact, its spatial distribution has been gradually reduced due to the intense land uses and the socio-economical changes occurred over the past centuries. The deforestation activities, due to the expansion of intensive agricultural crops, have caused a heavy reduction of the forests dominated by this oak species (Pividori et al. 2015). According to the last National Forest Inventory (Tabacchi et al. 2007), English oak is mainly a scattered species distributed across 146,000 hectares of mixed forest. On the opposite, it has been used for timber production because of reforestation programs financed by the EU since the 1980s, and many plantations were created in the floodplains. As a consequence, the species was reintroduced in the Italian framework in many lowland forests and in almost all the Italian Regions, even if mainly as tree farming plantation. These typical tree farming plantations have been managed with periodical geometrical or selective thinning (Ravagni et al. 2015) and a rotation age of 40 years was commonly adopted. Unfortunately, specific volume equations for English oak growing into tree farming plantations are missing in Italy, the only volume table for this species regarding natural forests (Castellani 1970, Castellani 1972, Castellani 1980, Castellani et al. 1984).

Aim of the paper is to set up a specific volume equation for pure plantations with English oak. At this purpose, a sample of trees felled in the course of thinning operations conducted between 1996 and 2014 was measured and analyzed.

Materials and Methods

The restoration program of Santa Barbara's mining area (Valdarno - Arezzo Province) represents first examples of English oak tree farming plantations in Italy. It was established in the '70s and '80s of 1900 reforesting 172 hectares with English oak seedlings (Buresti 1984, Ravagni et al. 2015). During thinning operation, undertaken in different plantations of

[1] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Forestry Research Centre (CREA-SEL), Arezzo, Italy
[*] maurizio.marchi@crea.gov.it

http://dx.doi.org/10.12899/ASR-1079

the Santa Barbara area (43.5737 N, 11.4912 E), 299 trees were cut and fully measured to determine the volume. For each sampled tree, the following parameters were measured:

- diameter at breast height (DBH) above bark;
- stem circumference at intervals of one meter from 0.5 meters up to the top diameter of 3 centimeters;
- total height of the tree.

The collected data were first scanned to evaluate the quality of the dataset. Stem volume was calculated by the Heyer formula determining the volume of each section (La Marca 1999). The regression model was calculated using a stepwise analysis based on the Akaike's information criterion (AIC, Akaike 1974) of backward type starting from the "maximum model" [1] (Del Favero 1978, Del Favero and Hellrigl 1978, Mancino and Verrastro 2002, Nosenzo 2008). Following this procedure, the stem volume (expressed in m^3) was calculated as a function of a polynomial equation using the DBH (expressed in centimeters) and the total height of the tree (expressed in meters).

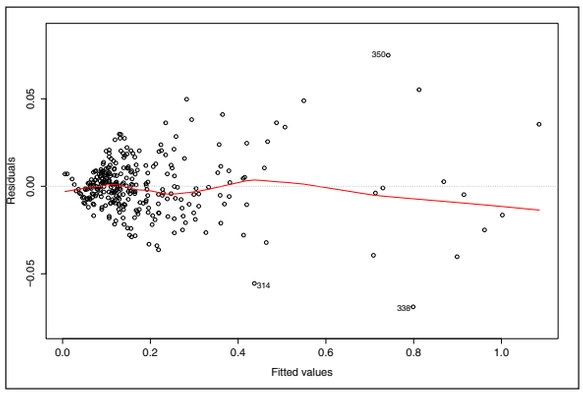

Figure 1 - Distribution of regression's residuals.

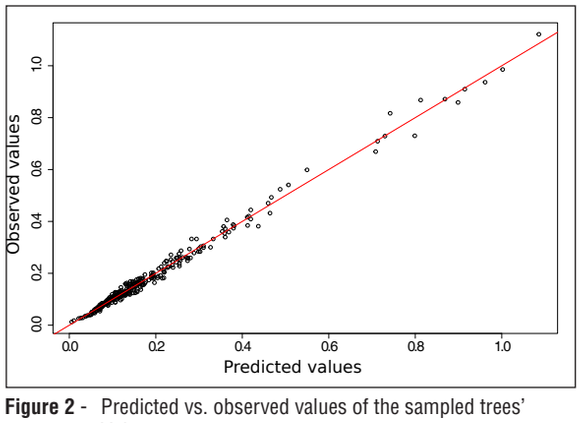

Figure 2 - Predicted vs. observed values of the sampled trees' Volumes.

$$V = a+b\,D+c\,D^2+d\,D^3+eH+f\,H^2+g\,D\,H+h\,D\,H^2+i\,D^2H+l\,D^2\,H^2+m\,B^3\,H+n\,D^3\,H^2$$

The Durbin-Watson test (Durbin and Watson 1971) was used to test the autocorrelation of disturbances of the regressive model. Root Mean Squared Error (RMSE) and relative RMSE (rRMSE) were calculated using a cross-validation procedure with the leave-one-out approach. All the calculations and statistical analyses were conducted on R software (R CoreTeam, 2015) using the *stats* and the *ipred* (Peters and Hothorn 2015) packages.

The tree sampling was limited only to same plantations without following complex schemes and was configured as not probabilistic but according a reasoned choice type (Mancino and Verrastro 2002).

Results

The main statistics of the 299 sampled trees are reported in Table 1, while the regression coefficients of the final equation with the statistical significance of coefficients are shown in Table 2. The Residual Standard Error was 0.01631 with an adjusted R^2 of 0.9907. The Durbin-Watson test showed a p-value of 0.2785 highlighting an absence of autocorrelation of residuals. These values are plotted Fig. 1, while predicted values versus observed values are reported in Fig. 2. The cross-validation procedure calculated a very low RMSE of 0.0176 m^3 and the rRMSE was lower than 10% (9.33%).

Table 1 - Main statistics of all the collected mensurational variables.

		n.observ.	minimum	maximum	average	st. dev.
d	cm	299	4.5	41.0	17.9	0.155
H	m	299	4.9	24.0	13.2	0.166
V	m3	299	0.006	1.121	0.174	0.177

Table 2 - Regression coefficients and their significance for the two-entry stem volume table. Significance of parameters is reported with the following legend: p<0.1 (.), p<0.05 (*), p<0.01 (**), p<0.001 (***).

Coefficients	Estimate	Std.	Error	t value	Pr(>|t|)
(Intercept)	-0.3641	0.0980	-3.716	0.0002	***
D	0.0504	0.0146	3.456	0.0006	***
I(D^2)	-0.0011	0.0006	-2.178	0.0302	*
H	0.0535	0.0154	3.469	0.0006	***
I(H^2)	-0.0018	0.0008	-2.334	0.0202	*
I(D*H)	-0.0076	0.0016	-4.714	0.0000	***
I(D*H^2)	0.0003	0.0001	5.700	2.95E-008	***
I(D^2*H)	0.0002	0.0001	3.936	0.0001	***
I(D^2*H^2)	-0.0001	0.0001	-5.169	0.0000	***

In Table 3 the trend of stem form factor per DBH and tree height classes are reported. A part for the DBH 5 class, in all the other DBH classes the form factor increase with the tree height.

Discussion and conclusions

The use of trees collected from thinning activi-

Table 3 - Expected value of stem form factor per dbh and tree height classes.

dbh 10		dbh 15		dbh 20		dbh 25		dbh 30		dbh 35		dbh 40	
H (m)	f	H (m)	f	H (m)	f	H (m)	f	H (m)	f	H (m)	f	H (m)	f
8	0.492	8	0.537	9	0.450	12	0.391	20	0.429	20	0.399	20	0.376
9	0.493	9	0.487	10	0.425	13	0.393	21	0.438	21	0.402	21	0.374
10	0.503	10	0.457	11	0.411	14	0.398	22	0.447	22	0.404	22	0.371
11	0.520	11	0.443	12	0.407	15	0.406	23	0.456			23	0.368
12	0.541	12	0.441	13	0.409	16	0.416						
13	0.566	13	0.447	14	0.417	17	0.428						
		14	0.460	15	0.429	18	0.441						
		15	0.479	16	0.444	19	0.455						
				17	0.463	20	0.471						
				18	0.483								

ties demonstrated to be a fair choice, not limiting the calculation neither the growth of the species (Kerr 1996, Jobling and Pearce 1977). The study produced a local volume equation ready to use after a preliminary analysis of DBH distribution and DBH-tree height relationship. The physical attributes of sampling area (Valdarno), even if localized as compared to the overall distribution of the species, makes the area a good "reference site" because of the mild climate, the average rate of precipitations during summer and an average temperature of 11°C, all of this representing fair conditions for the species autoecology .

The database was highly representative of the full life-span of a typical English oak plantation and the volume function demonstrated a close fit with a low RMSE.

According to the literature, this equation represents the first calculated for English oak tree farming plantations in Italy and is an useful tool to evaluate the oak stem volume growing in tree farming plantations undergoing a regular thinning regime. An adequate analysis of ranges (diameter and tree height) is anyway needed prior to using this function in other geographical locations.

References

Akaike H., 1974 - *A new look at the statistical model identification.* IEEE Transactions on Automatic Control 19(6): 716–723. DOI:10.1109/TAC.1974.1100705

Buresti E., 1984 - *Il restauro forestale delle discariche minerarie dell'ENEL. Miniera di S.Barbara nel Valdarno [The forest restoration of ENEL mining dumps of Santa Barbara in Valdarno]* Ann. Ist. Sper. Selv. XV: 157-171. [In Italian]

Castellani C., 1970 - *Tavole stereometriche ed alsometriche costruite per i boschi italiani [Volume and yeld tables for Italian forests]* Ann. Ist. Sperim. Assestamento Forestale e Apicoltura Vol 1, 418 pp. [In Italian]

Castellani C., 1972 - *Tavole stereometriche ed alsometriche costruite per i boschi italiani [Volume and yeld tables for Italian forests]* Ann. Ist. Sperim. Assestamento Forestale e Apicoltura Vol 2, 149 pp. [In Italian]

Castellani C., 1980 - *Tavole stereometriche ed alsometriche costruite per i boschi italiani [Volume and yeld tables for Italian forests]*. Ann. Ist. Sperim. Assestamento Forestale e Apicoltura Vol. 6, 265 pp. [In Italian]

Castellani C., Scrinzi G., Tabacchi G., Tosi V., 1984 - *Inventario forestale nazionale italiano. Tavole di cubatura a doppia entrata [National Forest Inventory. Volume tables]* Ministero dell'Agricoltura e delle Foreste, Istituto Sperimentale per l'Assestamento Forestale e per l'Alpicoltura, Trento. :1-114 [In Italian]

Del Favero R., 1978 - *Sulla scelta del miglior modello perequativo nell'interpretazione delle correlazioni d'interesse dendrometrico [About the best equation model for mensurational correlations]* - Università degli Studi di Padova. [In Italian]

Del Favero R., Hellrigl B., 1978 - *Indagine sulla capacità interpretativa delle funzioni stereometriche impiegabili nella costruzione delle tavole di cubatura a doppia entrata [A screening on volume functions for the construction of volume tables]*. Ann. Ist. Sperim. Assest. For. e Alpic, Vol. 5: 3-32 [In Italian]

Durbin J., Watson G.S., 1971 - *Testing for Serial Correlation in Least Squares Regression III.* Biometrika 58: 1–19

Kenk G. K. , 1993 - *New perspectives in German oak silviculture.* Annales Des Sciences Forestieres, 50(6): 563-570.

Kerr G., 1996 - *The effect of heavy or 'free growth' thinning on oak (Quercus petraea and Q. robur).* Forestry, vol. 69, n. 4: 303-316

Jobling J., Pearce M.L., 1977 - *Free growth of oak.* Forestry Commission Forest Record No 113. HMSO, London: 16 pp.

La Marca O., 1999 - *Elementi di dendrometria [Mensurational elements].* Patron Editor: 512 pp. [In Italian]

Lemaire J., 2010 - *Le chêne autrement. Produire du chêne de qualité en moins de 100 ans en futaie reguiliere [Oaks as alternatives: high quality oak's wood production in less than 100 years in regual high forests.].* Guide tecniche IDF: 176 pp.

Loginov, D. (2012). *Oak in mixtures and monocultures.* SLU University Library, 60 pp. Retrieved from http://stud.epsilon.slu.se/3971/

Mancino G., Verrastro F. 2002 - *Modelli di stima del volume per i polloni di faggio dell'Appennino Lucano settentrionale [Volume estimation models for beech coppices ain Northern Lucan Appennines].* L'It. For. e Mont. 57 (2): 163-176. [In Italian]

Nebout J.P., 2006 - *Des chênes en croissance libre: bilan et perspectives [Free growth of oaks: reulst and prespectives].* Bollettin 3 Set. 2006, LII, Société Forestière de Franche-Comtê: 103-135.

Nosenzo A., 2008 - *Tavola di cubatura a doppia entrata per i cedui di faggio del Piemonte [A double-entry tree volume table for beech (Fagus sylvaticaL.) coppices in Piedmont].* Forest@ 5: 227-232 [online: 2008-09-02] URL: http://www.sisef.it/forest@/. [In Italian, Abstract in English]

Perin J., Claessens H., 2009 - *Considerations sur la designation et le detourage en chênes et hetre.* Foret wallonne n. 98: 39-52

Peters A., Hothorn T., 2015 - *ipred: Improved Predictors.* R package version 0.9-4. http://CRAN.R-project.org/package=ipred

Pividori M., Marcolin E., Marcon A., Piccinin N., 2015 - *Prove di diradamento in impianti di bosco planiziale della Pianura veneta orientale [Thinning trials in foodplains forests of Veneto oriental plain].* Annals of Silvicultural Research, 39 (1): 46–54. DOI: 10.12899/ASR-777. [In Italian, abstract in English]

R CoreTeam., 2015 - *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria: https://www.R-project.org/.

Ravagni S., Bidini C., Bianchetto E., Vitone A., Pelleri F., 2015 - *Cultivation techniques in a 34 years old farming oak.* Annals of Silvicultural Research, 39(2): 111–117.

Saha S., Kuehne C., Kohnle U., Brang P., Ehring A., Geisel J., Leder B., Muth M., Petersen R., Peter J., Ruhm W., Bauhus, J., 2012 - *Growth and quality of young oaks (Quercus robur and Quercus petraea) grown in cluster plantings in central Europe: A weighted meta-analysis.* Forest Ecology and Management, 283, 106–118. http://doi.org/10.1016/j.foreco.2012.07.021

Tabacchi G., De Natale F., Di Cosmo L., Floris A., Gagliano C., Gasparini P., Genchi L. et al., 2007 - *Le stime di superficie 2005. Inventario Nazionale delle Foreste e dei Serbatoi Forestali di Carbonio [Estimation of forest areas 2005. National forest Inventory].* Trento, Italy: CRA-ISAFA, 653 pp. [In Italian].