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# Above-ground biomass and nutrients in a turkey oak (*Quercus cerris* L.) stand on Mount Etna

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**Abstract.** Above-ground biomass and nutrients were estimated in a turkey oak (*Quercus cerris* L.) stand on Mount Etna (Italy). The results indicated an above-ground biomass of 93.4 Mg ha$^{-1,}$ 91.4 Mg ha$^{-1}$ wood and 1.5 Mg ha$^{-1}$ leavels, with 3.7 Mg ha$^{-1}$ standing dead. The following nutrients were found to be immobilized in this biomass: 285.2 kg ha$^{-1}$ nitrogen, 198.6 kg ha$^{-1}$ calcium, 182.2 kg ha$^{-1}$ potassium, 34.2 kg ha$^{-1}$ magnesium and 26.2 kg ha$^{-1}$ phosphorus.

*Key-words: Quercus cerris* L., biomass, nutrients

## Introduction

Turkey oak (*Quercus cerris* L.) are found throughout Italy (Pignatti 1982), from the Alps to Sicily, growing on an area of more than 450000 ha, 59% of which are coppice stands under 20 years old (Amorini and Fabbio 1992).

In Sicily, this species is mainly found in the Nebrodi and Madonie mountains growing on the supramediterranean vegetation layer (Poli *et al*. 1981), located between 900 and 1,400 m above sea level. *Quercus pubescens* Wild. is also found in this layer, sensu lato, but its presencein Sicily is highly controversial (Brullo and Marceno 1984).

These oak stands currently have a small economic impact, i.e. limited to fuelwood production. Forestry management projects have changed some of these coppice stands into coppice with standards, which has many ecological advantages in terms of soil protection, water management and creation of recreational areas (Ciancio 1990).

The Etna volcano forest range extends along a 600-1900 m elevation gradient, with successively woodlands of *Quercus ilex* L., *Castanea sativa* Mill., *Betula aetnensis* Rafino, *Pinus laricio* Poir., in addition to the pioneer forest species *Genista aetnensis* (Biv.) DC., which colonizes areas with recent lava and new soils.

On the rainy eastern slopes of the volcano, *Castanea sativa* Mill. is sometimes replaced by *Quercus cerris* L., as this species has considerable water requirements (Pignatti 1982).

Very little information is available on ecological processes and population dynamics concerning all of these turkey oak stands, as well as coppices or forest stands. The present study focused on an *Quercus cerris* L. coppice stand in Etna Park, which is currently being transformed into a coppice with standards.

This study on above-ground biomass accumulation and immobilization of some nutrients should enhance the overall understanding of the ecology and productivity of turkey oak stands.

## Materials and methods

### *Coppice stand*

The study site (Cerrita) is located 1,300 m above sea level on the eastern slopes of Mount Etna. It covers an area of about 50 ha, and includes a relatively monospecific population of *Quercus cerris* (2,830 trees ha$^{-1}$), with a few *Pinus laricio* Poir. trees in the tree layer (29 ha$^{-1}$) and a few *Genista aetnensis* trees in the understorry (141 trees ha$^{-1}$), which are the last representatives of trees that colonized the initial lava layer.

All trees with a circumference at breast height of more than 20 cm, or DBH more than 6 cm, were more than 25 years old, whereas those with a DBH of 6 cm or less, or which were less than 3 m tall, were shoots under 12 years old. The *Quercus cerris* population and DBH class distribution are summarized in Figure 1.

The annual rainfall level at this site, as measured over a 30-year period at the closet meteorological station, was 1,306 mm year$^{-1}$, with 43% in winter, 33% in autumn, 20% in spring and 4% in summer (June, July and August). Maximum mean monthly temperatures ranged from 10 to 33 °C, minimum ones ranged between 4 to 20 °C.

The oak stand is growing on very old lava, which has been covered with more recent lava flows. This has given rise to an andosol, comprising a litter layer (1-2 cm), an $A_1$ layer (5 cm) with high organic matter content, and an $A_1B$ horizon (20-50 cm) colonized by *Quercus cerris* roots. The andosol is located over a sand and volcanic lapilli substrate.

### *Above-ground biomass*

In the "Cerrita" stand, a one hectare area was marked out and subdivided into five 2,000 m$^2$

 

plots. On the initial area, trees were counted and classified according to tree- and understory-layers as follows for each 2,000 $m^2$ plot:

| Plot | *Quercus cerris* trees | *Quercus cerris* understorry |
|---|---|---|
| 1 | 92 | 84 |
| 2 | 221 | 188 |
| 3 | 313 | 253 |
| 4 | 292 | 264 |
| 5 | 389 | 264 |
| hectare | 1307 | 1051 |

On the basis of this chart, plot number 3 was selected as the representative plot of the stand. All trees on this plot were measured and classified according to DBH (Fig. 1).

Ten trees representative of the main DBH classes were then felled and the trunks, living branches and dead branches (standing dead), leaves and other fractions were separated and weighed in the field. Subsamples were taken to the laboratory, dried at 85˚C to constant weight in order to determine their water contents, and then grinded for chemical analysis.

Trunk slices were also cut at different heights, the wood and bark were separated and weighed, and the respective percentages of these two tissue fractions were calculated.

Using the separate biomass measurements obtained for each of these 10 felled trees, we calculated regressions, with DBH or circumference and weights of the different organs or total tree biomass as variables, based on the following equation: $\mathbf{y = a \times X^b}$.
Total and partial biomass was estimated for the entire station by calculating the amounts of biomass for each circumference class and multiplying it by the number of trees in each class.

*Immobilized nutrients*

The different collected and grinded plant samples were analysed to determine their nitrogen, phosphorus, potassium, calcium and magnesium contents. Potassium, calcium and magnesium were determined by atomic absorption spectrometry after wet mineralization using nitric and perchloric acid. In the same solution, phosphorus was measured by calorimetry in the presence of ammonium nitrovanadomolybdate. Nitrogen content was separately determined by Kjeldahl´s method.

Based on these determinations, mineral contents (i.e. each of the five elements determined above) were then calculated for the biomass of each tree organ and tissue and for the standing dead. This provided an estimate of nutrients immobilized in the above-ground phytomass in the studied stand.

## Results and Discussion

The weighted results obtained for the 10 felled representative trees are summarized in Table 1. Yearly growth rings at the base of the same trees were also counted, indicating an age range of 12-59 years. Age was correlated with the circumference at breast height by the following linear regression equation:

$$\text{age} = \mathbf{9.7 + 1.7 \times (Circ._{1.30});\ r = 0.94.}$$

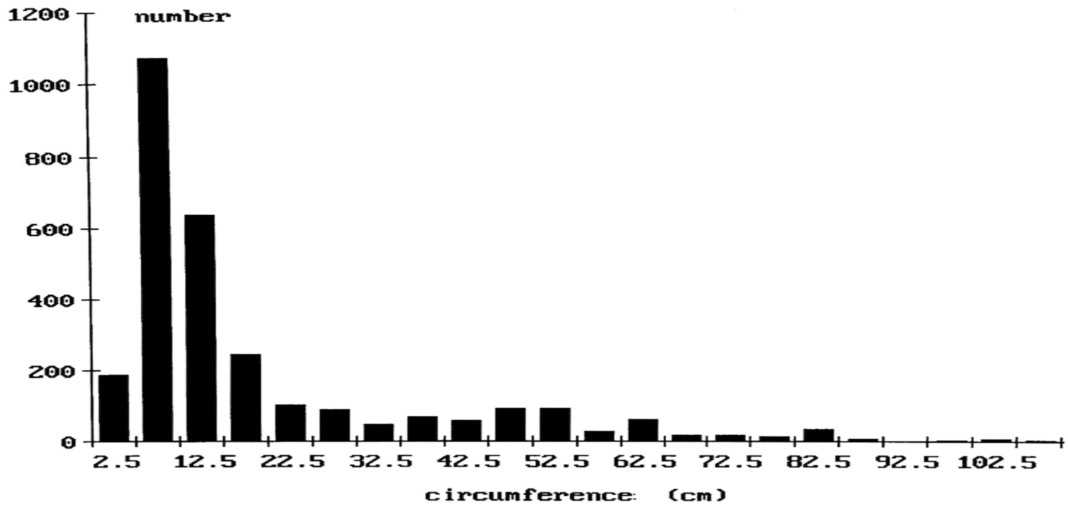


**Fig.1.** DBH class distributions of the *Quercus cerris* population at the Mount Etna study site.

That regression equation, obtained for the 10 trees was applicable for trees than 10 cm diameter or 33 cm circumference at breast height.

Table 1 indicated that the trees in the study stand are ranged between 2.5-32.5 cm trunk circumference. As circumference classes from 2.5 to 7.5 cm represent trees under 20 years old, the current mean age of the main population could be estimated at 40 years old, but a few older trees that were not cut during the previous clearcutting operations are also present.

Table 2 presents regression equations used for calculating total biomass and biomass of the different fractions as a function of the DBH of each tree. Power regressions: $\mathbf{Y = a \times X^b}$ were used because they gave the best determination coefficient.

| circumference(cm) | height (m) | wood | trunk bark | total | branches | Total wood | leaves | fruit | Biomass | standing dead |
|---|---|---|---|---|---|---|---|---|---|---|
| **10** | 3.10 | 861 | 394 | 1255 | 379 | 1634 | 88 | | **1722** | 37 |
| **15** | 5.80 | 2723 | 1038 | 3761 | 1245 | 5006 | 290 | | **5296** | |
| **15** | 6.30 | 2996 | 751 | 3747 | 1340 | 5087 | 310 | | **5397** | 180 |
| **20** | 6.20 | 4549 | 1518 | 6067 | 1153 | 7220 | 242 | | **7462** | 137 |
| **25** | 7.90 | 8301 | 3800 | 12101 | 2166 | 14267 | 643 | | **14910** | |
| **30** | 10.60 | 18989 | 6221 | 25210 | 3927 | 29137 | 585 | | **29722** | 1211 |
| **40** | 9.10 | 28063 | 10794 | 38857 | 3727 | 42584 | 228 | | **42812** | |
| **50** | 14.00 | 67484 | 22750 | 90234 | 13750 | 103984 | 1521 | | **105505** | 1718 |
| **62** | 15.90 | 135492 | 17478 | 152970 | 69868 | 222838 | 2510 | 11 | **225359** | 9735 |
| **82** | 13.40 | 199714 | 47503 | 247217 | 85877 | 333094 | 6787 | 61 | **339942** | 19684 |

**Table 1.** Circumference, height biomass (total, partial, per-tissue) and standing dead measurement for the 10 representative turkey oaks (*Quercus cerris*) studied. The results are shown in gms.

| | equation | r | n |
|---|---|---|---|
| Biomass | | | |
| -leaves | $0.0026x(Circ._{1.30})^{1.628}$ | 0.881 | 10 |
| -branches | $0.0010x(Circ._{1.30})^{2.507}$ | 0.899 | 10 |
| -trunk | $0.0033x(Circ._{1.30})^{2.575}$ | 0.966 | 10 |
| -above ground | $0.0047x(Circ._{1.30})^{2.547}$ | 0.935 | 10 |
| Standing dead | $0.000045x(Circ._{1.30})^{2.889}$ | 0.903 | 7 |

**Table 2**. $Y=ax(Circ._{1.30})^b$ type regresion equations, with trunk circumference at breast height given in cm and biomass(Y) in g.

| | Small trees DBH<10 cm | Large trees DBH>10 cm | **Above ground biomass** |
|---|---|---|---|
| Number trees | 1265 | 1565 | 2830 |
| Trunk | | | |
| -wood | 439.0 | 56857.8 | 57296.8 |
| -bark | 201.0 | 17272.3 | 17473.3 |
| -total | 640.0 | 74130.1 | 74770.1 |
| Branches | 169.6 | 17007.6 | 17177.2 |
| Total wood | 809.6 | 91137.7 | 91947.3 |
| Leaves | 76.3 | 1336.7 | 1413.0 |
| **Total above ground** | | | **93360.3** |
| Standing dead | 101.9 | 3607.5 | 3709.4 |

**Table 3.** Total above-ground living and standing dead biomass. Biomass per tree class (<or>17.5 cm DBH) in kg $ha^{-1}$ at the studied *Quercus cerris* stand.

The various biomass levels for the entire station were then calculated from these equations.

Above-ground biomass for the stand was found to be 93.4 Mg $ha^{-1}$, including 1.4 Mg $ha^{-1}$ leaves and 92.0 Mg $ha^{-1}$ wood (trunks and branches). The 74.8 Mg $ha^{-1}$ trunk wood comprised 77% wood and 23% bark (Table3). Cutini (1992) reported 181 Mg $ha^{-1}$ biomass for a 40 year old *Quercus cerris* L. stand which had not been altered by silvucultural operations. This level is much higher than that calculated in the present study, but the stand is being transformed into a coppice with standards. Cutini also reported a biomass level of 111 Mg $ha^{-1}$ for a plot similar to that of the Etna station where trees were being managed and pruned, which is much closer to the biomass level noted in the present study.

At the Etna stand, foliar biomass was low in comparison to wood biomass (i.e. 1.5 %), which could be explained by the age of the stand. Amorini & Fabbio (1989) pointed out that the increments sharply declined after 30-35 years. Moreover,as the study was carried out in September-October, there could havebeen a loss of foliar biomass after the begining of litterfall. This trend was also highlighted in the study of Cutini (1992), where leaf litterfall amounted successively 2.6 and 2.8 Mg $ha^{-1}$ $year^{-1}$ in a 40 year old stand. Based on a biomass loss of 15 % between green leaves and litter leaves, foliar biomass could be estimated at 3.0 and 3.2 Mg $ha^{-1}$ at the station studied by Cutini.

Dyankova (1989) reported an above-ground biomass of 132 Mg $ha^{-1}$ for a 40 year old stand in Bulgaria. In the same stand, net primary production was estimated at 8.1 Mg $ha^{-1}$ $year^{-1}$, including perennial above-ground biomass increments of 5.5 Mg $ha^{-1}$ $year^{-1}$ and 2.6 Mg $ha^{-1}$ $year^{-1}$ litterfall. This litterfall represented 2 % of the total above-ground biomass. According

| | Nitrogen | Phosphorus | Potassium | Calcium | Magnesium |
|---|---|---|---|---|---|
| Leaves | 1.99 | 0.200 | 0.89 | 0.92 | 0.21 |
| Fruit | | | | | |
| -acorns | 0.69 | 0.096 | 0.86 | 0.12 | 0.075 |
| -cups | 0.54 | 0.051 | 0.94 | 0.25 | 0.070 |
| Trunk | | | | | |
| -small trees | 0.21 | 0.022 | 0.19 | 0.13 | 0.026 |
| -large trees | 0.16 | 0.016 | 0.16 | 0.14 | 0.020 |
| Bark | | | | | |
| -small trees | 0.61 | 0.033 | 0.27 | 0.23 | 0.089 |
| -large trees | 0.47 | 0.020 | 0.15 | 0.21 | 0.043 |
| Branches | | | | | |
| -living | 0.47 | 0.061 | 0.29 | 0.40 | 0.068 |
| -dead | 0.56 | 0.024 | 0.03 | 1.05 | 0.052 |

**Table 4.** Chemical composition (%) of the different *Quercus cerris* tree organs.

| | Nitrogen | Phosphorus | Potassium | Calcium | Magnesium |
|---|---|---|---|---|---|
| Trunk | | | | | |
| -woods | 92.85 | 9.31 | 92.36 | 79.92 | 11.6 |
| -bark | 83.52 | 3.62 | 27.31 | 36.94 | 7.93 |
| -total trunk | 176.37 | 12.93 | 119.67 | 116.86 | 19.53 |
| Branches | 80.73 | 10.45 | 50.01 | 68.71 | 11.68 |
| Total wood | 257.10 | 23.41 | 169.68 | 185.57 | 31.21 |
| Leaves | 28.12 | 2.82 | 12.57 | 12.99 | 2.96 |
| Total nutrients | **285.22** | **26.23** | **182.25** | **198.56** | **34.17** |
| Standing dead | 20.77 | 0.89 | 1.11 | 38.95 | 1.93 |

**Table 5**. Above-ground nutrient accumulation within living and standing dead biomass of the studied *Quercus cerris* study stand. Results in kg $ha^{-1}$.

that leaves accounted for two-thirds of this litter, and they had lost 10-20 % of their weight during senescence, it could be considered that the leaf mass in this Bulgarian stand was similar to that in the Etna stand studied here. The trees were also about the same ages, thus also confirming the relation between tree age and production in *Quercus cerris* stands reported by Amoni and Fabbio (1989).

Dyankova (1989) also calculated a root biomass of 47.4 Mg $ha^{-1}$, i.e. 35.9 % of the above-ground. Based on this percentage, below-ground biomass in the Cerrita stand could be estimated at 33.5 Mg $ha^{-1}$, with 126.9 Mg $ha^{-1}$ total biomass.

Cutini (1992) estimated net above -ground primary productivity to be 7.7-10.0 Mg $ha^{-1}$ $year^{-1}$, while Dyankova calculated a level of 8.1 Mg $ha^{-1}$ $year^{-1}$. At Etna, we calculated 2.3 Mg $ha^{-1}$ $year^{-1}$ increment of perennial biomass, 2.0 Mg $ha^{-1}$ $year^{-1}$ leaf-litterfall and an undetermined amount of the litter (wood, flowers, fruit, etc.). Net above-ground primary production would thus be 5.0-5.5 Mg $ha^{-1}$ $year^{-1}$, which is much lower than primary productivity calculated for the two other reported stands. The long summer drought period in Sicily and volcanic soil features (i.e. highly permeable, with little water retention) could explain this low primary productivity at Etna. However, Pignatti (1982) pointed out that Turkey oaks require a regular water supply from a substantial underground water table.

There was also 3.7 Mg $ha^{-1}$ standing dead, i.e. mainly dead branches on standing trees.

Note also that, despite the fact that there was a similar number of large trees: 1,265, compared to the 1,585 small trees (less than 3-4 m tall and 10 cm circumference), the weighted proportion of the last ones was less than 1 % of the perennial biomass and less than 5 % of the foliar biomass. As this fraction is very low, total biomass evaluations will therefore not be altered by thinning operations that are conducted regularly by foresters every 10 to 20 years.

Table 4 shows the chemical composition of the different tree tissues and organs : *Quercus cerris* trunk wood, trunk bark, branches, leaves, dead branches and fruit. Trunk wood and bark were separated into two groups according to tree ages.

Leaves were found to contain the highest levels (concentrations) of the five nutrient elements studied, followed by fruit, living branches, bark and trunk wood. Trunk wood tissues of young trees always had higher nutrient contents than older trees, but calcium levels were slightly higher in trunk wood tissues of older trees.

In comparison to results obtained by Kutbay and Kilinc (1994), *Quercus cerris* leaves in the Etna stand contained higher levels of nitrogen and phosphorus, but the same potassium contents.

Dead branches were found to contain calcium and slightly less nitrogen, but levels of potassium, phosphorus and magnesium

*Above-ground biomass and nutrients*

were very low.

The amounts of above-ground nutrient sinclude in the biomass of the Etna stand (Table 5) were estimated on the basis of the nutrient concentrations relative to the biomass amounts given in Table 3. These nutrient levels were as follows: 285 kg $ha^{-1}$ nitrogen, 199 kg $ha^{-1}$ calcium, 182 kg $ha^{-1}$ potassium, 34 kg $ha^{-1}$ magnesium and 27 kg $ha^{-1}$ phosphorus.

Most of these bioelements (ranging from 49 % phosphorus to 66 % potassium), were immobilized in the trunks. Leaves, although they only represented 1.4 % of the total above-ground biomass, were found to contain 11 % phosphorus, 10 % nitrogen, 9 % magnesium, 8 % potassium and 7.5 % calcium.

Despite the fact that much higher levels were often noted, trunk bark only contained 42 % of all nutrient elements accumulated in the trunks, with respectively 47 % nitrogen, 41 % magnesium, 32 % calcium, 28 % phosphorus and 23 % potassium.

## Conclusions

A 40 year old turkey oak (*Quercus cerris* L.) coppice stand, in the process of being transformed into a coppice with standards, was found to have an above-ground biomass of 92 Mg $ha^{-1}$.

Above-ground productivity in this stand was around 5.0-5.5 Mg $ha^{-1}$ $year^{-1}$, which was lower than levels reported for other turkey oak stands. This low productivity could be explained by the water deficit at the Etna site (despite the fact that conditions in volcanic zones can be quite suitable for productivity) and, moreover, Quercus cerris has substantial warer needs.

This biomass included 285 kg $ha^{-1}$ nitrogen, 199 kg $ha^{-1}$ calcium, 182 kg $ha^{-1}$ potassium, 34 kg $ha^{-1}$ magnesium and 24 kg $ha^{-1}$ phosphorus.

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