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# Coarse Dead Wood Volume of Managed Oriental Beech (*Fagus orientalis* Lipsky) Stands in Turkey

E. Atici[1], A. H. Colak[2] and I. D. Rotherham[3]

[1] *Istanbul University, Faculty of Forestry, Department of Forest Growth Research, TR-34473 Bahceköy/Istanbul/Turkey.*
[2] *Istanbul University Faculty of Forestry Department of Silviculture, TR-34473 Bahceköy/Istanbul/Turkey.*
[3] *Sheffield Hallam University, Tourism and Environmental Change Research Unit, England.*

## Abstract

As a result of “clean management” systems in forests, many species are lost or reduced to the point of being endangered. This is a broad term which refers to the pursuit of a tidy, system of intensively productive forest in which dead and dying wood, standing and fallen, is rigorously removed or cleansed from the system. This is because foresters believed that such wood harboured diseases and pests. The consequence of such policies applied over decades or in some cases centuries has been a massive depletion of the resource and serious declines of removal of biodiversity. This study assesses the amount of coarse dead wood in oriental beech forests in Turkey. The total volume of dead wood was revealed as 22.87 ± 4.34 $m^3$/ha; made up of 3.37 ± 1.41 $m^3$/ha (15%) as $snag_1$ (standing dead wood with dried tips and intact top), 9.87 ± 2.2 $m^3$/ha (43%) as $snag_2$ (standing dead wood with bark loosened and broken top), 4.13 ± 1.9 $m^3$/ha (18%) as $log_1$ (newly fallen dead wood), and 5.51 ± 1.99 $m^3$/ha (24%) as $log_2$ (rotted fallen dead wood). From this research the managed oriental beech stands in Turkey can be described as relatively dead wood-rich. The proportion of the total dead wood volume (%) of oriental beech stands investigated 4.81 ± 4.72 percent of the total living wood volume.

There were significant differences ($F_{14;65}$= 4.109***, and SNK -Student-Newman-Keuls- = 3.99) in dead wood volume between the main study areas (min.: 4.46 $m^3$/ha; max.: 46.11 $m^3$/ha). This was due to the topography and particularly the steep slopes, and the road network infrastructure which influences the situation through local timber production. It is hoped that this study of oriental beech forests, may guide managers in considering dead wood and processes of decomposition in managing forests in Turkey, southeastern Europe, the northern Caucasus, northern Iran and Syria

**Key words**: Dead wood, *Fagus orientalis*, forest management, log, snag.

## Resumen

**Volumen de madera muerta en rodales gestionados de Haya Oriental (*Fagus orientalis* Lipsky) en Turquía**

Muchas especies forestales se pierden o ven reducida su distribución hasta el punto de estar amenazadas, como resultado de sistemas de “gestión limpia” de los sistemas forestales. Este es un término amplio que se refiere a conseguir un sistema de bosques productivos de forma intensiva en los que la madera muerta, tanto en pie como caída, se extrae del sistema. Esto es debido a que los forestales creen que esta madera alberga a plagas y enfermedades. La consecuencia de estas políticas, aplicadas durante décadas o siglos, ha sido una disminución de los recursos y la perdida de biodiversidad. Este estudio evalúa la cantidad de madera muerta en bosques de haya oriental en Turquía. El volumen total extraído fue de 22.87 ± 4.34 $m^3$/ha; siendo de 3.37 ± 1.41 $m^3$/ha (15%) la madera muerta en pie de árboles puntisecos, 9.87 ± 2.2 $m^3$/ha (43%) de madera muerta en pie con corteza desprendida y parte superior rota, , 4.13 ± 1.9 $m^3$/ha (18%) de madera muerta caída reciente, y 5.51 ± 1.99 $m^3$/ha (24%) de madera caída podrida. A partir de esta investigación, la gestión de los rodales de haya oriental en Turquía puede describirse como relativamente rico en madera muerta. La proporción del volumen total de madera muerta (%) de los rodales de haya oriental representan el 4.81 ± 4.72 % del volumen total de madera viva.

Existen diferencias significativas ($F_{14;65}$= 4.109***, y SNK -Student-Newman-Keuls- = 3.99) en el volumen de madera muerta entre las áreas principales de estudio (min.: 4.46 $m^3$/ha; max.: 46.11 $m^3$/ha). Esto se debe a la topografía y particularmente a las pendientes pronunciadas, y la red de caminos que influyen la situación de la producción local de madera. Se espera que este estudio sobre los bosques de haya oriental puedan servir de guía a los gestores para considerar la madera muerta y su proceso de descomposición en la gestión de los bosques de Turquía.

**Palabras clave:** Madera muerta, *Fagus orientalis*, gestión forestal, tronco.

* Corresponding author: eatici@istanbul.edu.tr
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## 1. Introduction

Dead wood, which consists of both standing dead wood (snags) and material that has fallen to the ground (logs) is a dynamic resource in forest ecosystems (Mark et al., 2006). It is recognized as having great importance for many wildlife species and ecological processes (Harmon et al., 1986; Hunter, 1990; Jonsson et al., 2005). Fallen dead wood and stumps provide nurse logs for regeneration in cool temperate, boreal and submontane-subalpine forest types (Christensen et al., 2005; Eichrodt, 1969; Ott et al., 1998). Dead wood is increasingly regarded as a major component of, and a useful indicator of, biodiversity in forests (Christensen et al., 2005; Colak, 2002; Hahn and Christensen, 2005; Marage and Lemperiere, 2005; Norden et al., 2004; Ratcliffe, 1994). For this reason it was adopted as an indicator for sustainable forest management by the Ministerial Conference (MCPFE, 2003) on the protection of forests in Europe (Butler and Schlaeper, 2004). The depauperate nature of the dead wood resource and the implications of this for nature conservation are well-established issues and concerns.

Furthermore, silviculture and timber harvesting *per se*, other timber management such as mechanical site preparation, broadcast burning, and fire prevention/suppression can directly or indirectly affect the quantity, quality, and dynamics of dead wood resources (Müller-Using and Bartsch, 2003; Saniga and Schütz, 2001). The amount of dead wood, particularly as logs and snags, in forests is attracting attention from forest managers as part of their interest in increasing biodiversity within forests managed for timber (Kirby et al., 1998). Dead wood is often rare in managed forests because of silvicultural practice (Harmon et al., 1986). Its quantities are normally much lower in managed forests than in unmanaged old-growth forests, as most of the large-sized harvestable timber is extracted. In addition, dead wood in managed stands typically consists only of small twigs and branches and short stumps, with few large logs or snags to be found. In the interests of sustainable forestry and biodiversity conservation, efforts are being made to increase dead wood levels in managed forests (Christensen et al., 2005; Marage and Lemperiere, 2005). In Europe, the volume of standing and fallen dead wood is one of nine pan-European indicators for sustainable forest management (Criterion 4: maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems) (Christensen et al., 2005).

European beech forests (*Fagus sylvatica* L.) are the most important forest communities in terms of natural forested landscapes in Central Europe (Peterken, 1996). Because of this importance research on dead wood has been undertaken in stands of European beech coarse dead wood and forest reserves (Erdmann and Wilke, 1997; Heilmann-Clausen and Christensen, 2003; Müller-Using and Bartsch, 2003; Müller et al., 2007a, 2007b; Saniga and Schütz, 2001; von Obheim et al., 2005, 2007) However, in the wider area of managed oriental beech forests, such as in Turkey (Fig. 1), southeastern Europe, the northern Caucasus, northern Iran, and Syria, there has been no work on dead wood. Since native oriental beech forests are widespread, and they represent the potential natural vegetation of many areas of the lowlands and the mountains of northern Turkey (Atici, 1998; Colak, 2006; Colak and Rotherham, 2007), it is of interest to analyse and estimate the dead wood volumes in these forests. Forest management in the northern regions of Turkey is important, and the forests are very biodiverse. For a country such as Turkey, the recognition of the importance of management for dead wood is vital if its nature conservation objectives and obligations are to be met. The main aims of this research were therefore to establish an overview the coarse dead wood volume of managed native oriental beech forests across the country. Such information, may guide the formulation of management prescriptions to be adopted by future site managers, conservationists, forest managers and policymakers across the study area and the wider region in which these forests occur.

## 2. Material and methods

### 2.1. Study area

Oriental beech forests have a wide distribution in Turkey, extending in a broad band along the Black Sea coast, and around the Sea of Marmara in the north (Fig. 1). There are outlying areas of oriental beech forest in the southeastern Mediterranean region in the Amanos Mountains in the Adana region. On the north-facing slopes of the eastern Black Sea region, oriental beech occurs from the humid zone to the steppe transition zone. The study was conducted in oriental beech forests on the North Turkey (latitude between 42º 0’ - 39º 30’, longitude between 27º 15’ - 42º 45’), dominated by naturally regenerated, with the highest degree of naturalness in Turkey (Colak et al., 2003). It lies within the central broad-leaved region of the northern deciduous forest.

Despite centuries of human impact and forest destruction over much of Turkey, the natural likeness classes for most of the high forests of oriental beech are near-natural and semi-natural and these are defined by hemeroby classes (Brentrup, 2002; Hill et. al., 2002; Ziarnek, 2007) oligohemerobe and mesohemerobe (Colak et al., 2003; Colak and Rotherham, 2006). Forest management practices based on age classes have clearly taken place in Turkish silviculture since 1963, and have been applied extensively in uneven-aged oriental beech forests. As a result of these applications, uneven-aged oriental beech forests have started to convert into even-aged forest stands (Atici, 1998a).

Oriental beech forests typically occur on acid clay soils (Colak and Rotherham, 2006) in areas with cool winters, and humid to sub-humid summers. The best sites, along most of northern Anatolia and a narrow strip of the Black Sea coast in European Turkey, are characterized by a wet climate, particularly in the east where there is heavy precipitation throughout the year and mists are frequent. Mean annual precipitation in oriental beech forests ranges from 700 mm to 2300 mm (Atici, 1998a). They are mainly found in sites up to 500-1200 m altitude, but a few were as high as 1560 m (Tab. 1).

## 2.2. Selection of sample plots

Sample plots were chosen from the fifteen main discontinuous distribution areas (covering all the range of Turkish beech forests) (Atici, 1998a) making up the main areas of this broken distribution across the range of oriental beech forests in Turkey (see Fig. 1 and Tab. 1). Although beech forests occur across the Black Sea Region, pure beech forests are present only in the areas selected.

Sample plots were chosen from managed stands with no gaps. These were stands, which according to stand maps in forest management plans had relatively pure beech (shelterwood). They were sampled with a simple random sampling method. (For a more detailed method-description see Atici, 1998a). The sample plots were in pure oriental beech forests but in a small number of cases some other species were mixed (*Quercus, Pinus, etc.*) in at very low levels. So in seventy-nine sample plots, oriental beech occurred with a frequency of 97%.

Sample plots (squares) of between 50 m x 50 m and 100 m x 100 m were used (Atici, 1998; Kalipsiz, 1962; Saracoglu, 1988), with some plots of 50 m x 50 m used where the slope was particularly steep. Sampling intensity varied between sites, but in most cases, corresponded well with the area of study (Christensen et al., 2005). So large areas (Tab. 1. e.g. Ayancik *etc.*) were typically sampled less intensively than small areas (Christensen et al., 2005; Tab. 1: Coruh and Ordu *etc.*). Efforts were made to maximize the number of sample plots, with a total of seventy-nine sample squares.

For orientation, the locations and living wood volumes ($m^3$/ha) of the sample plots are given in Tab. 1. For each sample, information on living wood, snag and log volume was compiled. Data on the living wood volume of trees based on diameter and height measurements were similarly collected for all sites (Christensen et al., 2005). Data and detailed method for sampling and describing living wood volumes were taken from Atici (1998a). The total living wood volume of sample plots ranged between 206 $m^3$/ha (sample plot 77) and 1440 $m^3$/ha (sample plot 45) in pure stands, giving a mean volume for all stands of 500 $m^3$/ha (Tab. 1).

## 2.3. Field procedures and calculations/equations

There is no accepted standard for definitions and inventory format for dead wood (e.g. decay classification, minimum diameter, volume functions, and sampling methods) (Fridman and Walheim, 2000). In practice, dead wood (coarse woody debris) is generally classified as snags and logs (von Oheimb et al., 2005; Mark et al., 2006) rather than at a more detailed level of classification. Two types of dead wood were recorded in this work, as defined Fridman and Walheim, (2000), Mark et al. (2006), McComb and Lindenmayer (1999), Wanderwel et al., (2006) and shown in Fig. 2. Both logs and snags were identified to one of two hardwood logs or snags decay classes, as $log_1$, $log_2$, $snag_1$, and $snag_2$ (Fig. 2).

Dead wood with diameter of more than 6-7 cm (von Oheimb et al., 2005) is generally accepted as "dead wood" in the context of forest management. Smaller material has a role but is of less importance (Colak, 2002). The coarse dead wood volumes have been standardised where the minimum diameter used to measure dead wood that was over 10 cm (Colak, 2002; Fridman and Walheim, 2000; Norden et al., 2004). According to Colak, (2002), Fridman and Walheim, (2000), Koch, (1998), Norden et al., (2004) and Swanson et al., (1976) the minimum and critical diameter limit between coarse

**Table 1.** Details of locations and living wood volume (m³/ha) of 79 sample plots

| Enterprise of forest (Number of sample plots) | Area (ha) | Elevation (m) | Aspect | Number of trees (N/ha) | Basal area ($m^2$/ha) | Living wood volume ($m^3$/ha) |
|---|---|---|---|---|---|---|
| Yenice (1-5) | 0.25 | 950 | E | 1092 | 46.9 | 702.56 |
| | 0.25 | 1000 | NE | 728 | 42.4 | 675.98 |
| | 0.25 | 850 | NE | 1916 | 54.0 | 700.90 |
| | 0.25 | 750 | E | 1420 | 42.4 | 540.03 |
| | 0.25 | 650 | S | 616 | 44.0 | 707.00 |
| Bartin (6-9) | 0.25 | 1010 | SE | 1240 | 44.9 | 503.42 |
| | 0.25 | 1150 | S | 1680 | 65.2 | 910.28 |
| | 0.25 | 1300 | NW | 2024 | 68.5 | 869.94 |
| | 0.25 | 1250 | NW | 2064 | 64.7 | 849.49 |
| Zonguldak (10-12) | 0.25 | 590 | E | 1572 | 53.9 | 713.22 |
| | 0.25 | 550 | E | 1436 | 50.5 | 655.49 |
| | 0.25 | 500 | NW | 1580 | 55.8 | 718.38 |
| Düzce (13-19) | 0.25 | 800 | E | 2576 | 49.8 | 462.53 |
| | 0.25 | 800 | E | 1548 | 46.5 | 559.99 |
| | 0.25 | 1200 | NW | 3076 | 41.9 | 372.47 |
| | 0.25 | 1200 | SE | 2536 | 42.6 | 387.28 |
| | 0.25 | 1200 | SW | 1696 | 46.8 | 497.66 |
| | 0.25 | 1350 | S | 2692 | 61.9 | 617,57 |
| | 0.25 | 1000 | SW | 1060 | 37.2 | 406.21 |
| Akyazi (20-25) | 0.25 | 1150 | E | 1300 | 33.3 | 285.51 |
| | 0.25 | 1250 | W | 1404 | 35.2 | 343.95 |
| | 0.25 | 1350 | SW | 1504 | 43.0 | 387.47 |
| | 0.25 | 1250 | N | 1176 | 29.8 | 287.97 |
| | 0.25 | 820 | E | 1552 | 53.5 | 720.28 |
| | 0.25 | 850 | SE | 1196 | 45.0 | 560.25 |
| Inegöl (26-37) | 0.25 | 1500 | N | 856 | 37.7 | 481.42 |
| | 0.25 | 1100 | E | 2992 | 55.6 | 512.48 |
| | 0.25 | 1060 | NE | 3140 | 47.6 | 430.55 |
| | 0.25 | 1520 | SW | 748 | 47.6 | 536.38 |
| | 0.25 | 1000 | NE | 2200 | 51.9 | 576.91 |
| | 0.25 | 940 | E | 2252 | 45.0 | 426.49 |
| | 0.25 | 1250 | E | 1500 | 52.2 | 651.06 |
| | 0.25 | 1200 | SE | 1572 | 37.3 | 413.89 |
| | 0.25 | 1150 | W | 1776 | 40.4 | 362.92 |
| | 0.25 | 1200 | NW | 2192 | 51.4 | 582.54 |
| | 1.00 | 1000 | N | 576 | 36.7 | 339.88 |
| | 0.25 | 1300 | NE | 2348 | 52.4 | 601.14 |
| Demirköy (38-43) | 0.25 | 800 | SW | 2500 | 52.9 | 493.54 |
| | 0.25 | 500 | W | 972 | 45.5 | 564.16 |
| | 0.25 | 680 | W | 1612 | 58.2 | 629.06 |
| | 0.25 | 600 | NE | 976 | 38.0 | 441.04 |
| | 0.25 | 350 | N | 820 | 51.0 | 662.74 |
| | 0.25 | 300 | N | 1024 | 44.9 | 506.92 |

| Enterprise of forest (Number of sample plots) | Area (ha) | Elevation (m) | Aspect | Number of trees (N/ha) | Basal area ($m^2$/ha) | Living wood volume ($m^3$/ha) |
|---|---|---|---|---|---|---|
| Bolu (44-47) | 0.25 | 1000 | NE | 720 | 40.8 | 602.31 |
| | 0.25 | 1230 | E | 1272 | 91.6 | 1440.3 |
| | 0.25 | 1150 | W | 1632 | 50.1 | 448.65 |
| | 0.25 | 1030 | W | 944 | 43.6 | 607.93 |
| Inebolu (48-53) | 0.25 | 700 | NE | 1872 | 48.4 | 656.92 |
| | 0.25 | 750 | NE | 2980 | 44.3 | 428.89 |
| | 0.25 | 860 | NW | 1980 | 46.4 | 536.48 |
| | 0.25 | 700 | NW | 1808 | 52.2 | 646.75 |
| | 0.25 | 720 | NW | 1228 | 49.9 | 664.52 |
| | 0.50 | 1270 | NE | 666 | 45.26 | 595.44 |
| Ayancik (54-65) | 1.00 | 610 | NE | 572 | 31.7 | 460.58 |
| | 1.00 | 960 | NE | 1118 | 31.4 | 352.69 |
| | 1.00 | 500 | N | 177 | 25.0 | 390.85 |
| | 1.00 | 1270 | NW | 329 | 32.9 | 449.40 |
| | 1.00 | 1340 | NW | 2880 | 28.9 | 408.96 |
| | 1.00 | 1010 | NE | 613 | 31.8 | 485.36 |
| | 1.00 | 930 | N | 311 | 34.7 | 578.76 |
| | 1.00 | 1000 | NW | 407 | 39.0 | 424.72 |
| | 0.25 | 930 | SW | 2724 | 35.9 | 327.49 |
| | 0.25 | 850 | N | 668 | 47.6 | 776.05 |
| | 0.25 | 1000 | N | 1920 | 44.6 | 533.68 |
| | 0.25 | 740 | N | 2196 | 51.9 | 621.07 |
| Coruh (66-68) | 1.00 | 600 | N | 574 | 28.3 | 379.85 |
| | 1.00 | 1100 | NW | 473 | 27.3 | 331.77 |
| | 1.00 | 1560 | N | 267 | 39.9 | 499.44 |
| Ordu (69-70) | 1.00 | 1190 | N | 345 | 29.2 | 403.02 |
| | 1.00 | 1300 | N | 319 | 44.4 | 683.13 |
| Tokat (71-74) | 1.00 | 1180 | N | 505 | 37.2 | 507.34 |
| | 0.50 | 1260 | NW | 450 | 34.9 | 405.90 |
| | 1.00 | 1500 | NW | 412 | 36.7 | 367.80 |
| | 0.50 | 1280 | E | 388 | 31.3 | 322.84 |
| Karabük (75-77) | 0.50 | 570 | NE | 840 | 17.4 | 148.90 |
| | 0.50 | 850 | N | 512 | 30.5 | 446.77 |
| | 0.35 | 240 | N | 326 | 21.7 | 206.61 |
| Adapazarı (78-79) | 0.25 | 400 | NE | 464 | 28.7 | 419.85 |
| | 0.50 | 820 | NW | 1114 | 42.2 | 461.22 |

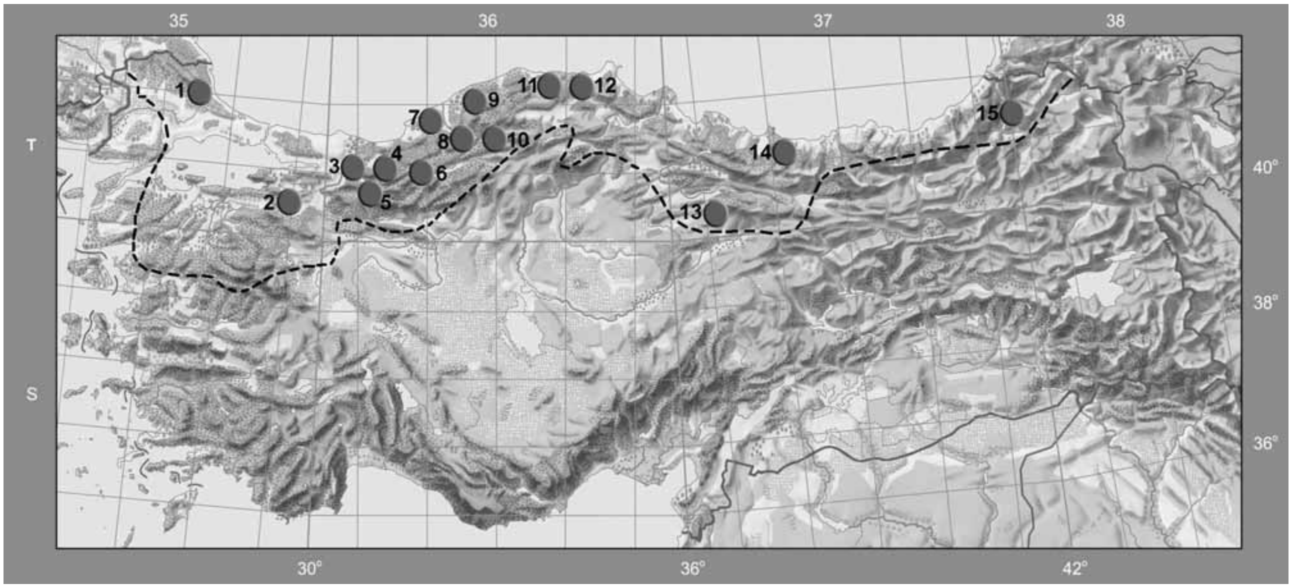


**Figure 1.** Natural range of oriental beech (*Fagus orientalis*) forests in Turkey (----), and fifteen main sampling locations (Map after UTM system): 1-Demirköy, 2-Inegöl, 3-Adapazarı 4-Düzce, 5-Akyazi, 6-Bolu, 7-Zonguldak, 8-Yenice, 9-Bartin, 10-Karabük, 11-Inebolu, 12-Ayancik, 13-Tokat, 14-Ordu and 15-Coruh.

and fine dead wood is 10 cm. For this study coarse dead wood (snags and logs) were those with a diameter over 10 cm. Fine dead wood may also be defined as wood with a diameter of 1-10 cm (Norden et al., 2004). For dead wood volume estimation, the height and dbh of all snags and the length of logs were measured (von Oheimb et al., 2005). Since the diameter at breast height ($d_{1.30}$) cannot be measured because of the steam deformation, the statistical relationship between the diameter at stump height ($d_{0.3}$) and diameter at breast height ($d_{1.30}$) is used in the following Eq. 1 (Atici, 1998a, b):

$$d_{0.3}=0.783696*d_{1.3}-1.027547 \qquad (1)$$

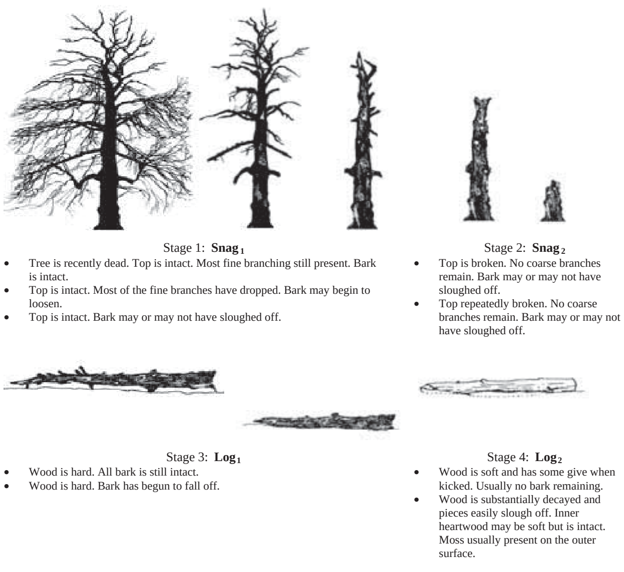


**Figure 2.** Decay stage (modified after McComb and Lindenmayer, 1999) and class descriptions (modified after Mark et al., 2006) of snags (standing dead wood) and logs (fallen dead wood).

The dead wood volume was estimated using the function by Atici (1998b) for *Fagus orientalis* following Eq. 2 and the volume-diameter tables used from Atici (1998a) like the work from Reid et al. (1996).

$$\ln(V) = (-9.559 + 1.885 * \ln(d) + 0.013 * \ln(d)^2 + 0.675 * \ln(h) + 0.058 * \ln(h)^2)*1.007 \qquad (2)$$

V: Dead wood (snags and logs) volume ($m^3$)
$d_{1,30}$: Diameter at breast height (cm)
h: Dead wood height or length (m)

## 2.4. Data analysis

Statistical evaluations including t-tests, Z-tests, one-way variance analyses (ANOVA), Student-Newman-Keuls (SNK) test, correlation and regression analyses, were applied to the data collected. These used SPSS 5.01 software for Windows.

Equation (Eq. 3) was used to calculate the proportion of the total dead wood volume of population of snags and logs as a percentage (Kalipsiz, 1994; Sachs, 1972):

$$P = p' \pm z\,(p'q'/n)^{1/2} \qquad (3)$$

z: z coefficient (P=0.05, $z_{0,05}$ =1.96)
*p'*: The existence rate of dead wood in sample plots.
*q'*: The absence rate of dead wood in sample plots.
*n*: Sample size.

The relationship between living and dead wood volume was calculated using equation 4 with data from 78 sample plots:

$$f(x) = 52.832682 - 0.160247x + 0.0001183x^2 \qquad (4)$$

*f* (*x*): Dead wood volume ($m^3$/ha)
*x*: Living wood volume ($m^3$/ha)

## 3. Results

Data analysis of the field results on snags (standing dead wood) and logs (fallen dead wood) are presented in Tables 1-5. These derive from seventy-nine sample plots selected from the fifteen individual areas from the main but discontinuous distribution of oriental beech forest in Turkey.

The total volume of dead wood of natural oriental beech stands (Tab. 2 and 3) had Student's t-test applied and gave the results as follows ($t_{0,05;79}$= 1.99; Eq. 3): 22.87 ± 4.34 $m^3$/ha. The proportion of the total dead wood volume (%) of oriental beech stands was assessed by z-test and gave result as ($z_{0,05}$ =1.96; Eq. 4) 4.81 ± 4.72 percent of the total trees volume. The results are presented with 95% confidence intervals in Tab. 3.

Oriental beech stands have a large total volume of dead wood composed mostly of snags. The component of logs is lower (Tab. 2 and 3). Mean total volume (%) of each dead wood category (Tab. 2 and 3) was: 58% snags: a) 15% as $snag_1$, b) 43% as $snag_2$; 42% logs: a) 18% as $log_1$ and, b) 24% as $log_2$. These are (Tab. 3): 3.37 ± 1.41 $m^3$/ha as $snag_1$ (standing dead wood with dried tips and intact top), 9.87 ± 2.2 $m^3$/ha as $snag_2$ (standing dead wood with bark loosened and broken top), 4.13 ± 1.9 $m^3$/ha as $log_1$ (newly fallen dead wood) and 5.51 ± 1.99 $m^3$/ha as $log_2$ (rotted fallen dead wood).

One-way variance analyses (ANOVA) were carried out to test difference in dead wood volume between main discontinuous distribution areas and established a significant difference ($F_{14;65}$= 4.109***; Tab. 4). Student-Newman-Keuls (SNK) test was applied to the difference and three separate groups were determined as a result (SNK= 3.99; Tab. 4).

Fig. 3 is proposed to help the examination of the relationships between living and dead wood volume from seventy-nine sample plots in fifteen main discontinuous distribution areas. Living and dead wood volume differed between certain plots and this was significant at a 95% confidence level ($_{upper}$-$_{lower}$) (Tab. 5; $_{upper}$: 567, 9, $_{lower}$: 486, 4); the particular sample is circled in Fig. 3). There was a weak relationship between living and dead wood volume determined with equation 4 ($R^2$=0.159; Fig. 3).

## 4. Discussion and conclusion

Existing levels of dead wood in managed oriental beech forests were assessed to provide a basis for what might be considered as high or low amounts of dead wood under present conditions. The results of this study are discussed mostly in the context of a comparison between European beech (*Fagus sylvatica* L.) and Oriental beech. This is because there has been no work on dead wood in the wider area of managed oriental beech forests as found in Turkey, south-eastern Europe, the northern Caucasus, northern Iran, and Syria. However, there has been a substantial amount of research on dead wood in stands of European beech, particularly in relation to coarse dead wood and forest reserves.

The amount of dead wood quantity in the less intensively and more natural forests of Middle and Eastern Europe is generally from 40 to 220 $m^3$/ha (Hahn and Christensen, 2005; Vallauri et al., 2003), with a maximum of 400 $m^3$/ha (Colak, 2002). Neumann (1978) found the highest levels of dead wood to be about half that in the declining stages of the more natural forests of Rothwald in Austria. Dead wood at this level is considered important in the forest ecosystem for soil improvement, water economy, micro-climate, nutrient cycling, and energy flow. However, in managed forests it may be reduced to only 1-5 $m^3$/ha (Albrecht, 1991) with an average for example, of only 2.2 $m^3$/ha in France (Vallauri et al., 2003). Utschik (1991) states that it is important for levels to be at least 3 $m^3$/ha in managed forest. According to Scherzinger (1996), very low values (for instance 1 $m^3$/ha) are probably too low to have any nature conservation value. Results from the present study concur with this. This study established that oriental

**Table 2.** The data on snags and logs from seventy-nine sample plots selected in the fifteen different main discontinuous distribution areas

| Enterprise of forest (Number of sample plots) | Snags | | Logs | | Total dead wood volume (%) | Total dead wood volume ($m^3$/ha) |
|---|---|---|---|---|---|---|
| | Snag$_1$ ($m^3$/ha) | Snag$_2$ ($m^3$/ha) | Log$_1$ ($m^3$/ha) | Log$_2$ ($m^3$/ha) | | |
| Yenice (1-5) | 1.40 | 10.81 | 22.82 | 2.26 | 5.31 | 37.29 |
| | 2.61 | 10.55 | 8.33 | 6.10 | 4.08 | 27.60 |
| | 3.45 | 22.82 | 32.20 | 6.57 | 9.28 | 65.05 |
| | 1.93 | 22.82 | 8.88 | 0.00 | 6.23 | 33.64 |
| | 1.01 | 7.32 | 1.66 | 0.00 | 1.41 | 9.99 |
| Bartin (6-9) | 2.09 | 3.12 | 1.38 | 0.87 | 1.48 | 7.46 |
| | 8.11 | 25.46 | 6.85 | 0.25 | 4.47 | 40.68 |
| | 3.51 | 27.49 | 5.30 | 0.00 | 4.17 | 36.31 |
| | 9.81 | 49.59 | 20.11 | 0.76 | 9.45 | 80.27 |
| Zonguldak (10-12) | 16.42 | 8.93 | 0.00 | 0.00 | 3.55 | 25.35 |
| | 2.34 | 5.16 | 47.63 | 0.00 | 8.41 | 55.13 |
| | 0.80 | 4.45 | 5.06 | 0.00 | 1.44 | 10.31 |
| Düzce (13-19) | 0.75 | 9.47 | 10.73 | 29.36 | 10.88 | 50.31 |
| | 13.87 | 19.01 | 0.13 | 39.93 | 13.02 | 72.93 |
| | 3.22 | 10.37 | 1.51 | 2.26 | 4.66 | 17.37 |
| | 0.56 | 15.21 | 0.00 | 26.88 | 11.01 | 42.65 |
| | 0.66 | 26.96 | 0.00 | 18.67 | 9.30 | 46.30 |
| | 1.89 | 20.76 | 0.40 | 3.34 | 4.27 | 26.39 |
| | 1.01 | 10.86 | 0.00 | 10.12 | 5.41 | 21.99 |
| Akyazi (20-25) | 0.19 | 2.34 | 0.00 | 8.77 | 3.96 | 11.31 |
| | 0.26 | 1.54 | 0.00 | 31.36 | 9.64 | 33.15 |
| | 0.19 | 3.43 | 0.00 | 5.68 | 2.40 | 9.30 |
| | 0.28 | 2.49 | 0.23 | 0.85 | 1.34 | 3.86 |
| | 3.79 | 22.87 | 1.26 | 0.81 | 3.99 | 28.74 |
| | 1.19 | 20.77 | 5.52 | 7.88 | 6.31 | 35.36 |
| Inegöl (26-37) | 0.67 | 4.28 | 0.71 | 16.80 | 4.67 | 22.46 |
| | 2.96 | 9.48 | 1.61 | 2.50 | 3.23 | 16.54 |
| | 3.93 | 8.58 | 0.00 | 3.43 | 3.70 | 15.94 |
| | 0.04 | 0.07 | 0.00 | 4.49 | 0.86 | 4.60 |
| | 4.75 | 7.86 | 0.31 | 1.42 | 2.49 | 14.34 |
| | 2.80 | 4.20 | 0.16 | 0.42 | 1.78 | 7.58 |
| | 0.95 | 8.50 | 6.51 | 18.16 | 5.24 | 34.12 |
| | 0.29 | 6.43 | 6.87 | 17.93 | 7.61 | 31.51 |
| | 0.16 | 1.47 | 0.38 | 0.25 | 0.62 | 2.27 |
| | 2.22 | 9.92 | 0.00 | 2.18 | 2.46 | 14.32 |
| | 0.27 | 10.67 | 0.89 | 0.00 | 3.48 | 11.83 |
| | 5.35 | 2.49 | 0.00 | 0.89 | 1.45 | 8.73 |
| Demirköy (38-43) | 0.28 | 8.80 | 0.00 | 0.00 | 1.84 | 9.08 |
| | 0.21 | 5.87 | 0.00 | 0.16 | 1.10 | 6.23 |
| | 0.20 | 37.19 | 11.19 | 0.64 | 7.72 | 49.22 |
| | 0.62 | 5.20 | 0.00 | 5.80 | 2.64 | 11.63 |
| | 1.00 | 4.17 | 2.31 | 0.00 | 1.13 | 7.48 |
| | 0.05 | 2.78 | 0.00 | 0.00 | 0.56 | 2.83 |
| | 4.30 | 2.92 | 22.28 | 2.95 | 5.39 | 32.45 |
| Bolu (44-47) | 0.02 | 0.80 | 0.00 | 14.10 | 1.04 | 14.92 |
| | 1.82 | 8.19 | 0.32 | 3.31 | 3.04 | 13.64 |
| | 2.62 | 6.96 | 0.43 | 0.00 | 1.65 | 10.01 |
| | 2.94 | 15.11 | 5.74 | 3.00 | 4.08 | 26.80 |
| | 1.81 | 11.63 | 1.37 | 8.97 | 5.55 | 23.78 |
| Inebolu (48-53) | 0.69 | 11.89 | 3.40 | 7.15 | 4.31 | 23.12 |
| | 3.65 | 33.69 | 15.33 | 7.55 | 9.31 | 60.21 |
| | 1.53 | 18.74 | 27.85 | 12.42 | 9.11 | 60.55 |
| | 0.47 | 21.1 | 0.00 | 29.02 | 8.50 | 50.59 |
| | 0.57 | 0.36 | 0.00 | 0.00 | 0.20 | 0.93 |
| | 0.68 | 0.85 | 0.00 | 0.00 | 0.44 | 1.54 |
| | 1.02 | 0.46 | 0.00 | 0.00 | 0.38 | 1.48 |
| | 0.59 | 1.03 | 0.00 | 0.00 | 0.36 | 1.62 |
| Ayancik (54-65) | 0.66 | 0.57 | 0.00 | 0.00 | 0.30 | 1.23 |
| | 1.03 | 0.53 | 0.00 | 0.00 | 0.32 | 1.56 |
| | 0.14 | 1.05 | 0.13 | 1.45 | 0.48 | 2.77 |
| | 11.51 | 0.85 | 0.00 | 0.00 | 2.91 | 12.35 |
| | 5.16 | 2.94 | 0.00 | 0.00 | 2.47 | 8.11 |
| | 0.08 | 0.41 | 0.00 | 2.35 | 0.37 | 2.84 |
| | 7.20 | 4.32 | 0.00 | 4.59 | 3.02 | 16.10 |
| | 2.01 | 0.99 | 0.00 | 0.00 | 0.48 | 3.00 |
| Coruh (66-68) | 0.00 | 6.17 | 0.00 | 0.00 | 1.63 | 6.17 |
| | 0.00 | 0.38 | 0.00 | 0.23 | 0.19 | 0.62 |
| | 0.00 | 13.05 | 0.00 | 0.00 | 2.61 | 13.05 |
| Ordu (69-70) | 10.49 | 0.10 | 0.00 | 7.09 | 4.39 | 17.68 |
| | 0.53 | 10.69 | 0.00 | 16.38 | 4.04 | 27.60 |
| | 7.77 | 11.17 | 0.00 | 0.00 | 3.73 | 18.94 |
| Tokat (71-74) | 1.80 | 0.76 | 16.52 | 1.96 | 5.19 | 21.05 |
| | 1.59 | 7.53 | 1.77 | 1.36 | 3.33 | 12.25 |
| | 9.08 | 25.39 | 0.00 | 0.00 | 10.68 | 34.47 |
| | 41.41 | 22.70 | 0.00 | 0.00 | 43.05 | 64.11 |
| Karabük (75-77) | 0.09 | 9.81 | 17.72 | 0.00 | 6.18 | 27.62 |
| | 30.36 | 13.36 | 0.00 | 2.89 | 22.56 | 46.61 |
| Adapazarı (78-79) | 0.55 | 0.31 | 0.00 | 0.00 | 0.20 | 0.86 |
| | 3.87 | 10.10 | 2.59 | 30.32 | 10.16 | 46.88 |

**Table 3.** Statistical analysis of data on snags and logs of oriental beech. This was confirmed by Z-test (P= 0.05; n= 79, z =1.96) and Student's t-test (P=0.05, n= 79, v =78, t= 1.99). μ (Eq.3): Arithmetic mean of 95% confidence interval of total population

| Parameters | Snags | | Logs | | Total dead wood (Snags + Logs) volume ($m^3$/ha) | Ratio of total dead wood volume to living wood volume (%) |
|---|---|---|---|---|---|---|
| | Snag $_1$ volume ($m^3$/ha) | Snag $_2$ volume ($m^3$/ha) | Log $_1$ volume ($m^3$/ha) | Log $_2$ volume ($m^3$/ha) | | |
| $\overline{X}$ | 3.3690519 | 9.867288 | 4.13149 | 5.505126 | 22.87296 | 4.807675 |
| $S^2$ | 39.554162 | 95.58522 | 72.56147 | 79.50867 | 375.6405 | 33.63336 |
| $s$ | 6.28921 | 9.77677 | 8.518302 | 8.916763 | 19.38145 | 5.799428 |
| $S_{\overline{x}}$ | 0.7075914 | 1.099973 | 0.958384 | 1.003214 | 2.180583 | 0.652487 |
| $n$ | 79 | 79 | 79 | 79 | 79 | 79 |
| μ | **3.3690 ± 1.4079** | **9.8672 ± 2.1888** | **4.1314 ± 1.9070** | **5.5051 ± 1.9963** | **22.8729 ± 4.3391** | **4.8076 ± 4.7174** |

**Table 4.** Statistical analysis of difference in dead wood volume between main discontinuous distribution areas. This was confirmed by oneway variance analyses (ANOVA) and Student-Newman-Keuls (SNK)

| ANOVA | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 13868.500 | 14 | 990.607 | 4.109 | 0.000 |
| Within Groups | 15430.829 | 64 | 241.107 | | |
| Total | 29299.328 | 78 | | | |

**Student-Newman-Keuls Test (SNK)**

| Main disconti-nuous distribution areas | N (Number of sample plots) | Subset for alpha = 0.05 | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Ayancik | 12 | 4.4608 | | |
| Coruh | 3 | 6.6133 | | |
| Demirköy | 6 | | 14.4117 | |
| Inegöl | 12 | | 15.3533 | |
| Bolu | 4 | | 17.7550 | |
| Akyazi | 6 | | 20.2867 | |
| Tokat | 4 | | 21.6775 | |
| Ordu | 2 | | 22.6400 | |
| Adapazari | 2 | | 23.8700 | |
| Zonguldak | 3 | | 30.2633 | |
| Yenice | 5 | | 34.7140 | |
| Düzce | 7 | | 39.7057 | |
| Inebolu | 6 | | 40.8417 | |
| Bartin | 4 | | 41.1800 | |
| Karabük | 3 | | | 46.1133 |
| Sig. | | 0.073 | 0.192 | |

beech stands in northern Turkey have 22.87 ± 4.34 $m^3$/ha coarse dead wood. In demonstrating total dead wood volumes at this level, the research indicates that this resource is above the critical desired levels. Schmitt (1992) compared the dead wood in European beech forest reserves and managed forests and found 104.7 $m^3$ and 4.2 $m^3$ per hectare, respectively. Interestingly, according to research in samples of managed forests in Europe, 5 $m^3$ dead wood per hectare can be easily achieved. Indeed, yields of dead wood in a recently managed forest might have conservation targets of over 15-30 $m^3$ per hectare (Butler and Schlaeper, 2004; Colak, 2002).

This present investigation found that oriental beech forests in Turkey already exceed this target for coarse dead wood volume. It is anticipated that associated biodiversity levels will be higher in forests with higher dead wood. Other studies have shown for example, that associated with higher dead wood levels, the populations of saproxylic beetles associated with 'near-naturalness' condition was significantly higher for dead wood volumes above 100 $m^3$/ha. This was for a beech forest in Northern Bavaria. Ammer (1991) claimed that the volume of dead wood to be around 1-2% of the whole forest yield. More than 50% of dead wood occurs as thick diameter dead wood, and 50% of as snags (Erdmann and Wilke, 1997). Möller (1994) advocates 5% of the yield in managed forests should be kept to generate dead wood, and Jedicke (1995) proposes 5-10% dead wood per compartment. Butler and Schlaeper (2004) and Leibundgut (1978) also proposed an optimal value of 10% dead wood. The consideration threshold values for deadwood from the literature shows that critical threshold values lie mainly within a spectrum between 40 and 60 $m^3$/ha (Müller et al., 2007b). In this context

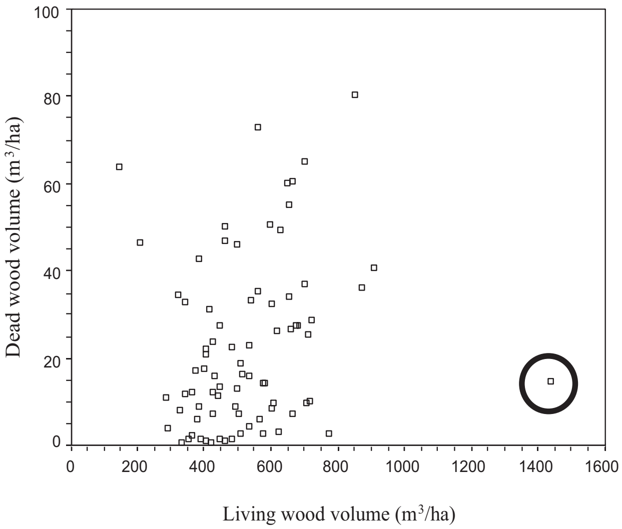


**Figure 3.** Relation between total dead wood volume and living wood volume of oriental beech forests at stand level (Point distribution of sample plots).

the main factors which appear to influence dead wood volumes are site productivity, decomposition rate, and disturbance regime. These are all factors that are included in concepts and definitions of forest types (e.g. Hahn and Christensen, 2005). In managed European beech forests dead wood in occurs mainly as logging waste and stumps, but large logs and snags are rare. Surveys in Finland, Sweden, Germany, France, Belgium, and Switzerland show that the average dead wood volume in present-day production forests is less than 10 m$^3$/ha (Christensen et al., 2005). Encouragingly from a conservation perspective the results of this study indicate that dead wood volume is much higher in Turkish managed beech forests than in those across Europe. This may be due to the prevalence of steep slopes and also to local timber production policy. Although the 'naturalness' of the dead wood levels recorded in the database of European beech forest reserves is open to debate, it nevertheless indicates that the amount of dead wood is in the order of 10-20 times higher in unmanaged than in intensively managed production forests (Christensen et al., 2005). This research found that the total dead wood volume of oriental beech stands was 4.8% of the total tree volume (within in 95% confidence limits), and it is therefore suggested that this is close to the total dead wood volumes advocated.

In considering the benefits for nature conservation, Ammer (1991) also found 5-10 m$^3$ per hectare dead wood, with at least 50% as snags was of benefit to both birds and insects. This current study established that oriental beech stands have total snag volume component of 58% (snag dead wood category 15% as snag$_1$, 43% as snag$_{2)}$, and therefore sufficient to benefit birds and insects. However, the literature also suggests that logs are an important and manageable habitat component for the promotion of biological diversity (Colak, 2002). To conserve the biodiversity connected to dead wood of European beech forests it is also important to balance the proportions of logs and snags (Hunter, 1990; Christensen et al., 2005). In this study a volume of 9.6 m$^3$/ha was found as log$_1$ (4.13 ± 1.91 m$^3$/ha), and log$_2$ (5.51 ± 2.00 m$^3$/ha).

To promote more active retention and generation of dead wood it is important to ask how forest management might affect the resource. Live trees that might otherwise be removed by foresters may be retained to use as future replacement snags and logs. Similarly, during thinning operations, large snags and logs can be protected. Fallen wood can be added by piling or windrowing slash, or by felling trees (Chambers, 2002). Modern forestry of the twentieth century has caused many species to be lost in the pursuit of "clean management", or to be reduced to the point of being endangered. Referen-

**Table 5.** Statistical analysis of living dead wood volume of sample plots

| | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|
| Living wood volume (m$^3$/ha) | 79 | 527.2146 | 181.97210 | 20.47346 |

| | t | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference | |
|---|---|---|---|---|---|---|
| | | | | | Lower | Upper |
| Living wood volume (m$^3$/ha) | 25.751 | 78 | .000 | 527.21456 | 486.4550 | 567.9741 |

ce to relevant red data books listing endangered species confirms this trend (Eckloff and Ziegler, 1991).

From these findings and with reference to McCommb and Lindenmayer (1999), there are four key steps suggested to managing more effectively the habitat for species that depend on cavities, snags, or logs in Turkey. These are:

1. Goals for stand or forest prescriptions must be developed.
2. Logs and/or snags need to be identified for retention during harvesting.
3. Cavity and dead wood availability should be estimated over time with losses and gains predicted.
4. Finally, because of uncertainty in the relationships between the quantity of dead wood and ecosystem functions, managers need to monitor the effectiveness of their management plans. They can then adjust prescriptions using a responsive management approach.

The results presented here are important in helping to inform the future debate and any management work concerning coarse dead wood in oriental beech forests in the study regions. Further work is needed on the assessment of the dead wood resource in unmanaged and managed beech forests in the present study region. It would also be informative to then undertake detailed assessments of critical indicators of dead wood and its quality from key faunal and floral taxonomic groups. This paper represents a start in this process.

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