UDK: 630*851

Original scientific paper
Izvorni znanstveni članak

SOME QUALITY CHARACTERISTICS OF FIR TREES (*Abies alba* Mill.) IN THE EDUCATIONAL-EXPERIMENTAL FOREST SITE ZALESINA, MANAGEMENT UNIT "BELEVINE"

NEKE ZNAČAJKE KAKVOĆE STABALA OBIČNE JELE (*Abies alba* Mill.) U GOSPODARSKOJ JEDINICI "BELEVINE" NASTAVNO-POKUSNOG ŠUMSKOG OBJEKTA ZALESINA

MARIJAN ŠUŠNJAR

Department of Forest Harvesting, Faculty of Forestry, University of Zagreb,
Svetošimunska 25, HR – 10 000 Zagreb

Received – *Prispjelo*: 28. 9. 2002. Accepted – *Prihvaćeno*: 25. 9. 2003.

This paper presents research results of some quality characteristics of fir trees (*Abies alba* Mill.) in selection forests in "Belevine" management unit, EEFS Zalesina.

Research encompassed 1,404 fir trees with dbh from 20 cm to 85 cm and heights from 12 m to 40 m. After felling and debranching, the timber volume of trees up to 7 cm diameter under and over bark was determined with the sectioning method. Timber assortments were processed and measured according to the Croatian standards for roundwood.

Timber volume of trees to 7 cm diameter under and over bark, as well as the processed timber volume is shown in two-entry and one-entry tables.

Bark volume ranges from 12.45 % to 10.67 %. The proportion of bark decreases from 21.8 % at 20 cm diameter to 7.4 % at 84 cm diameter according to the diameter of roundwood.

The yield has values from 81.7 % to 83.0 %; it decreases with an increase in dbh and rises with an increase in tree height.

In the regressed assortment structure, sawlogs in quality class I have the highest values in the 42.5 cm diameter class (18.4 %), but sawlogs in quality class II have the highest value with the thinnest trees in the sample (36.2 %). The proportions of quality class III increase from 29.7 % to 42.4 % with a rise in dbh. The maximal proportion of mining timber is in the diameter class 22.5

cm (59.96 %), but it decreases to 0.51 % in the diameter class 77.5 cm. The proportions of pulpwood are under 8%.

The maximal value of wood is found in the 52.5 cm diameter class.

Key words: fir tree, quality characteristics, timber volume, timber assortment, quality class

INTRODUCTION
UVOD

Forests continuously produce wood - a living organic matter - by using natural factors of site and climate. The role of a forest is reflected in its direct (forest products) and indirect values (ecological, protective, social forest functions). Forest products, as direct forest values, are divided into main and secondary products. Main forest products are timber assortments, whereas secondary forest products include resin, edible forest fruit, medicinal herbs, mushrooms, leaf litter, forest grazing, forest litter, browse, duff, and products of forest soil (rocks, peat, clay).

Forest harvesting is a human activity dealing with the collection and purposeful utilisation of all existing renewable and non-renewable natural resources (products) of a forest.

Timber exploitation is a working process that entails a set of activities related to wood extraction. It includes felling trees, their conversion into forest products and removing trees or parts of trees from the forest to the user, sawmill processor or forest product market. Thus, timber exploitation relates only to felling and processing trees and their transport.

From the aspect of timber exploitation, stems are the most valuable parts of trees. Stem is a part of large timber used to estimate the value of a standing tree. When a tree is felled and processed, its branches are removed to obtain the stem, which is then cross cut into timber assortments.

Timber assortments depend on the properties of a given tree. Trees do not have uniform qualities. Knowing the structure and quality of trees allows us to determine which trees provide the most economical yields and helps in planning felling activities, rate and organisation of harvesting operations, costs, economic gain and marketing activities.

MAIN ISSUES
PROBLEMATIKA

The basic question that forestry specialists are faced with is how to decipher natural rules and understand the biological production of a forest in given site and climatic conditions, as well as how to identify the type of factors and the extent to which they affect a forest. Extensive past research has revealed certain differences in the characteristics of trees of the same species and identified some of these characteristics. Determining tree characteristics and their dependence on certain conditions, apart from broadening forestry knowledge, has also substantially influenced the forestry practice in the sense of planning and organising work, intensifying forest operations and increasing timber volume yield.

Timber volume tables have been drawn up for individual tree species, in which timber volume is expressed as a function of easily measurable tree functions - breast diameter and height. Timber volume tables are based on the fundamental truth that trees of the same species, of identical breast diameters and heights and grown under very similar ecological conditions, as a rule have identical volumes. The accuracy of tables increases with the number of sample trees. Timber volume in a table can be expressed as the total volume or the volume of limited diameters, over or under bark. In timber exploitation, tables of timber volume up to 7 cm in diameter are more important because they represent the volume of large timber used for timber assortments.

The number of independent variables in a regression table model determines table types: there are one-entry tables (tariffs), two-entry (volume) tables and multi-entry tables. One-entry tables express the volume of mean tree of a diameter class as a function of one parameter - usually breast diameter. In two-entry tables, volume is the function of breast diameter and tree height.

The first timber volume tables were made for birch by Cotta in 1804 (Pranjić & Lukić 1997).

In 1891, Schuberg constructed volume tables for main tree species using sample trees measured in even-aged forests. Timber volume tables were based on a large number of trees in the thinner diameter class. Since Schuberg's tables for trees with breast diameters exceeding 50 cm were obtained with extrapolation, their application yields too low volume values of thicker trees.

In his search for the most suitable form of a regression function in drawing up two-entry volume tables, Emrović (1960b) concludes that data regression will be achieved with the lowest possible standard deviation around the regression range using the highest possible number of parameters. However, since it is neither practical nor economical to have a large number of function parameters, he recommends the Schumacher-Hall function.

Špiranec (1976) made timber volume tables for fir and spruce by sectioning 3,844 fir trees and 750 spruces tree from 43 management units in the area of 6 forest-management classes. He used Schumacher-Hall's equation to regress tree volumes.

Schmid-Haas & Winzeler (1981) devised more accurate method of calculating timber volume with a three-parameter function (breast diameter, tree height and diameter at 7 m from the ground or 30% of the tree height) rather than with two-parameter functions. Kružić (1993) found the Schumacher-Hall's function for volume table regression unsuitable, especially for thin trees.

While studying the applicability of Algan's and Schaeffer's tariffs for the calculation of fir wood volume, Rebula (1996) found that these tariffs yielded 3- 7 % higher values of timber volume.

In fir forest management, tariffs by Šurić, Šurić - Pranjić and Špiranec have been used to calculate growing stocks since 1945. However, when growing stocks calculated with local tariffs and with the tariffs mentioned above were compared, deviations were detected in growing stocks (Božić 2000).

Although in felling and processing operations efforts are made to utilise as much timber volume as possible, losses are inevitable. The volume of timber assortments represents the processed volume. The non-processed product of felling and processing consists of bark, waste related to large timber which has not been used for a variety of reasons, and waste incurred by the prescribed method of assortment measuring. Volume losses at felling and processing occur in measuring processed assortments due to rounding down diameters and lengths, making undercuts, butt shaping, cross cutting, as well as to length allowance and errors in Huber's formula.

Since the bark of technical timber assortments represents waste, it is necessary to determine the proportion of bark in the total timber volume. The proportion of bark is usually expressed for the tree as a whole. However, bark thicknesses and percentages change along the stem at different heights from the ground or at different diameters. Accordingly, bark thickness and percentage is not the same for all timber assortments obtained from felling and processing one tree.

Klepac (1972) studied the bark of fir in different plant communities. According to Klepac, bark thickness and percentage share in the total timber volume depend on a range of factors, such as tree thickness, stand structure, stand density (basal area), management method, site class, phytocoenological community and others. The average volume of bark of 11% for all observed phytocoenological communities falls within the limits of fir bark percentage according to Flury (8.3 - 12.3 %). He finds the thinnest fir bark in the phytocoenosis of fir and hard fern (10.1 % of the total wood volume), and the thickest in the phytocoenosis of fir with small-reed (14.4 %). His research shows that bark is thicker in stands with a low basal area where trees are exposed to external influences and thinner in better-quality sites.

Bark thicknesses along the stem and its proportion in the volume of timber and sawlogs with regard to tree thickness, sawlog origin and thickness and tree heights was studied by Bojanin (1960, 1966a, 1966b). The share of bark volume in his research ranges from 10.7 % to 12.6 % (11.05 % on average).

Macek & Korinek (1972) and by Kirschner (1976) studied double bark thickness in dependence on the diameter of fir roundwood.

From an economic standpoint, timber assortments are the main forest products. As the demand for wood is constantly growing, forestry is faced with the challenge of providing increasing quantities and qualities of wood assortments. Adequate stem processing yields timber assortments with properties, qualities and dimensions that enable further conversion and utilisation and ensure the best use of timber volume at the lowest production costs and the highest value of processed timber assortments. Timber assortments on the market are classified into quality classes according to a given standard system. In order to determine annual harvesting volume, plan the operations and keep the records more easily, it is important to know the quantity and quality of timber assortments. These tasks can be done properly if sufficiently accurate data are available about the structure of timber assortments (assortment tables). Therefore, advance knowledge of the participation of timber assortments by quality classes in dependence on forest communities is very important forest-management, marketing and organisational information.

Bojanin (1960) studies the share of assortments and the amount of losses incurred by felling and processing fir trees in the phytocoenosis of fir with hard fern, while Plavišić & Golubović (1963) investigate the percentage ratio of fir assortments and identify the highest quantity of sawlogs in the III quality class (65 % of the total processed volume). According to research by Plavšić (1967) in the forest of fir with hard fern, the highest quantity of fir timber assortments in the highest quality class is found in the diameter class 62.5 cm in site class I and in the diameter class 57.5 cm in site class II.

The quality of fir timber assortments has been studied by a number of scientists who have endeavoured to find an answer as to what the quality of assortments depends on and which breast diameter of fir trees yields the economically highest values. Rebula (1998a) defines the highest value of fir stems at 50 cm dbh, while the value of trees with dbh less than 27 cm is lower than felling and processing costs. Knoke (1997) studies the economic value of logs and finds that the relative value of logs with large mean diameters compared to those with smaller mean diameters decreases with an increase in breast diameter.

There are numerous different tables worldwide showing the kind and quantity of timber assortments made from stems of different dimensions. Most of these tables are based on breast diameters, tree heights and stem forms (form factor). The quality of wood assortments is evaluated and sorted on the basis of assortment dimensions while the presence of defects is evaluated using the norms that prescribe product characteristics. With regard to past application of the Croatian system of norms, it was shown that wood defects play an important role in placing timber assortments into quality classes, while the dimension of assortments is decisive only as a minimal measure (Rebula 1994).

The following authors constructed assortment tables for main tree species: Hubač (1973) in the Chech Republic, Mikhov (1980) in Bulgaria, Schopfer & Dauber (1989) in the area of West Germany, Sterba et al. (1986) in Austria and Petraš & Nociar (1991) in Slovakia.

RESEARCH GOAL
CILJ ISTRAŽIVANJA

Research aimed at defining the quality characteristics of fir trees in "Belevine" management unit was intended to achieve applicable results in future management with fir stands in the studied area.

The following tasks have been set to achieve research goals:

- construct two-entry tables and one-entry tables of fir tree timber volume in "Belevine" management unit,
- construct two-entry tables of fir tree timber volume under bark in "Belevine" management unit and use the differences in the tables of fir tree timber volume over and under bark to determine the volume and percentage of bark with regard to breast diameter and tree height,
- construct two-entry tables of processed fir tree volume and use two-entry tables of fir tree volume to study yield and loss percentages of felling and processing with regard to breast diameter and tree height,
- construct one-entry tables of fir timber volume under bark and processed timber volume of trees,
- determine yield of felling and processing fir trees and the quantity of waste in absolute and relative values according to breast diameters,
- determine bark thickness and percentage according to varying diameters of roundwood,
- study the structure of timber assortments by quality classes in the processed fir tree volume, construct assortment tables by diameter classes,
- make value analysis of timber assortment structure by tables and determine a diameter class with the economically highest value of timber volume.

OBJECT OF THE RESEARCH
PREDMET ISTRAŽIVANJA

EUROPEAN SILVER FIR (*Abies alba* Mill.)
OBIČNA JELA (*Abies alba* Mill.)

Silver fir (*Abies alba* Mill.) is a tree attaining 40 m in height and 1.5 m in breast diameter. The stem is cylindrical and straight. The bark is light grey and relatively smooth, whereas at an older age it becomes broken and darker. In youth, the crown is conical, at an older age it is cylindrical, while when old, the crown tops assume plate-like forms. The branches are laid horizontally and are placed into whorls around the stem, forming more or less regularly arranged branch layers at right angles to the stem axis. The branch whorl is a point on the stem where several branches or nodules grow at approximately the same height. Fir trees are capable of self-cleaning. The shoots are grey-brown and slightly hairy. The needles are tufted, 1-5 - 3 cm long and 2 - 2.5 mm wide, notched at the tip or blunt, grooved on the upper side, dark green and glossy, while on the underside there are 2 white strips of stomata. At the tips of branches and on the main shoot the needles point at all sides and are spiky at the top. The root system of silver fir has a typical taproot that grows about 1 m deep on average. The roots of adjacent trees are frequently fused.

Silver fir is a sciophytic species. At a young age it grows very slowly and may tolerate shade for a long time. Šafar (1981) found that firs 1.5 - 2 m tall were aged between 20 to 120 years. When stunted firs gain space, they start growing faster and are normally fertilised and propagated with seeds.

Silver fir grows on limestone and on silicates. It favours fresh, cooler, humus-rich soils. In the summer it prefers warm weather and in the winter moderately colder climate with abundant air humidity. It is sensitive to early and late frosts and does not tolerate polluted air. It grows best in areas with mean annual air temperatures of 9°C and mean annual precipitation quantity of about 1,500 mm. It forms pure or mixed stands with beech and spruce, which ensures natural regeneration and sustainability.

Fir is naturally distributed in mountainous districts of central, southern and partly Western Europe. In the north, it starts from Poland to extend westwards up to northern Spain and eastwards to the east of Romania and Bulgaria, while southwards it reaches the northern boundaries of Greece. In Croatia, silver fir has a widespread distribution: from Gorski Kotar over Velebit it extends across the whole Dinaric mountain chain, and can also be found in mountainous areas between the rivers Sava and Drava (Vidaković 1993). The upper boundary of the altitudinal distribution of silver fir is in the Alps from 1,200 to 1,700 m above the sea, with optimal heights ranging between 400 and 1,500 m.

SELECTION FIR FORESTS
PREBORNE ŠUME JELE

Silver fir (*Abies alba* Mill.) is one of the most important and the most valuable tree species in Croatian forestry. It participates with 9.4 % or 30,374 million m^3 in the total growing stock of the Republic of Croatia. In state-owned forests managed by the company "Hrvatske šume" d.o.o., Zagreb, fir accounts for about 28.133 million m^3 or 10.1 % of the growing stock. In other state-owned forests fir participates with 20.2 % (1,594 million m^3), while in private forests its share is only 1.7 % of the growing stock (648,000 m^3).

The company "Hrvatske šume" d.o.o., Zagreb produces about 3 million m^3 timber assortments annually. Of this amount, roundwood accounts for about 50 %, while the rest relates to stacked wood (for fuelwood and industrial processing). The annual net prescribed yield of fir is about 350,000 m^3, or about 12 % of the total production of timber assortments (www.hrsume.hr).

Silver fir in Croatia constitutes selection forests of a high silvicultural form, which cover 29 % of the total forest area or 540,641 ha. The growing stock of these forests is about 102 million m^3, of which silver fir accounts for about 30 %. The remaining 70 % in the mixture proportion largely relates to common beech, and less to common spruce and other broadleaves (Matić et al. 1996).

A selection forest is any high forest with a permanently non-uniform structure. It constantly regenerates with selection management (Križanec 1987). This form of management, important for sciophytic tree species, relates primarily to fir because the selection structure and selection management suit the ecological requirements and biological properties of this tree species. Fir is capable of tolerating shade for a very long period. When it acquires living space, it grows into a tree of good quality both in pure stands and in mixed stands in combination with spruce or beech.

"Selection management can only be applied to forests in which silver fir is a structural element, because silver fir is the basic species of selection forests and selection management. Fir may be accompanied by beech and spruce (Matić et al. 1996)".

A selection forest consists of trees of differing heights, differing diameters and differing ages over a surface unit. The selection structure presupposes the classification of trees into diameter classes according to Liocourt's rule of gradual and regular decrease in the number of trees with a growing diameter class. Liocourt established a ratio between the number of trees in one diameter class and that in the immediately higher diameter class. This ratio is constant for a given site quality and ranges from 1.3 to 1.5 (Božić 1999). In a graph, Liocourt's curve or the curve of a normal tree series has the shape of a hyperbolic curve, which is determined with maturity dimension and geometric progression coefficient.

$$k^n, k^{n-1}, k^{n-2}, \ldots k^3, k^2, k^1, k^0, \text{ where:}$$

k - geometric progression coefficient,

n - number of diameter classes from maturity dimension to taxation limit of 10 cm.

When trees distributed by diameter classes form Liocourt's curve in a graph, the forest is said to have an optimal structure in terms of tree number. An optimal structure may be achieved with a different arrangement of trees over an area.

In selection management, trees may be arranged over an area in two ways; for this reason, we speak about single tree management and group management. The spatial arrangement of trees in selection management is estimated in the following way:

- single tree management - trees of differing heights and different diameters are scattered over an area,
- group management - trees of similar diameters and heights, or similar tree species are distributed over an area larger than 10 ares and smaller than 1 ha.

The single tree management method is applied to stands on karst terrain with shallow soils, where soil should be permanently protected from unfavourable abiotic factors. The group management method is applied to stands on mildly sloping terrains with deep, nutritious and humid soils, since on good soils fir regenerates naturally in groups.

Until the Forest Management Act of 1994 came to force, selection forests were also managed with the cluster management method. The diameter of a cluster is larger than two heights of the tallest trees. The application of the cluster management method in the range of beech-fir forests disrupts the selection structure, which is out of line with the natural management method and is mistaken from an ecological and biological standpoint and consequently from an economic standpoint (Prpić & Seletković 1996). The Forest Management of 1996 banned the cluster management method.

Normal or optimal growing stock in a selection forest is that growing stock which gives the best yield and enables permanent natural regeneration of the forest. This means that normal growing stock in a selection forest should not be either too high or too low, but just sufficient for the best production and permanent natural regeneration.

The ideal selection forest structure is composed of trees of differing heights and diameters over a unit area. Such a forest contains normal growing stock, distributed in the selection structure, which ensures maximal increment, optimal natural regeneration and stability (Matić et al. 1996).

The goal of selection felling is to form and maintain the selection structure of a stand. Selection felling is characterised by a synchronous use of all stages of silvicultural treatments in the same area, ranging from tending seedlings and young forests to thinning and tree exploitation.

Felling intensity depends on the quality and structure of a stand, the total growing stock, increment, and management intensity. Management intensity depends on the length of the felling cycle, which is the period between two felling operations over the same area in a selection forest.

Selection single or group felling is performed in ten-year felling cycles. Trees above the defined diameter of felling maturity are marked and cut in regular cutting operations.

Klepac (1997) cites the conditions for successful selection management:

- selection felling should be performed frequently (in 5 to 10-year intervals) with the most favourable selection felling intensity of 15 to 25 % (based on 10 years),
- a selection forest should contain a dense network of communications and skid roads so that frequent felling operations are economically viable,
- a selection forest should permanently undergo natural regeneration.

In the last several decades, the selection of trees to be cut was influenced by physiological weakening and dieback of fir. In some years the entire annual harvesting volume from the forest of Gorski Kotar was derived from dead trees. Research by Krpan et al. (1995) showed that trees with damage degrees between zero and three did not suffer any change in physical-mechanical properties and neither did the usable value of fir. However, changes in dead trees, especially if they were left standing for longer periods, affected their quality and considerably lessened the exploitable and market value of fir roundwood.

RESEARCH SITE
MJESTO ISTRAŽIVANJA

FOREST MANAGEMENT UNIT "BELEVINE"
GOSPODARSKA JEDINICA "BELEVINE"

The management unit "Belevine", part of the educational-experimental forest site Zalesina, Faculty of Forestry in Zagreb, is located in the area of selection forests in Gorski Kotar.

The mildly undulating relief furrowing fan-like in the northeast - southwest direction extends from the east towards the northwest. The relief is marked by two hills (two knolls), three smaller plateaux, and one narrow valley stretched along the part in the northeast. The remaining part covers the more or less mild slopes interspersed with numerous beds of mountain streams.

The management unit "Belevine" lies at an altitude of 720-870 m. The altitudinal difference between the highest and the lowest point of the terrain is only 150 m, resulting in the entire management unit being in the same site class. Almost the whole management unit has a sunny exposition, except for 10 - 15 % of the area with a shaded exposition. The slopes are largely mild to moderately steep (inclination up to 20 °). The mild to moderate inclination has influenced the formation of deep soils.

The geological substrate in the management unit "Belevine" is made up of silicate rocks. The parent material has diverse composition. The prevalent parent substrate is made up of Permo-Carbonate (Palaeozoic) layers of black slates, orange-reddish schists, sandstones and conglomerates. The stands in the management unit "Belevine" are supported by podzols, acid brown soils and brown podzol soils. From the aspect of forest management, the soils on Palaeozoic sediments are considered better than the soils on Mesozoic limestones, because the diverse composition, soil depth, terrain form and hydrographic features provide favourable conditions for the development of vegetation. This is confirmed by the high site class (site class II for fir according to tariffs by Šurić-Pranjić).

In Köppen's classification of climatic regions in Croatia, "Belevine" management unit is located in the climatic zone of C-climate or warm-temperate rainy climate and belongs to the "Cfsbx" climate type. The features of this climate type are as follows: the mean monthly temperature of the coldest month ranges from -3 °C to + 18 °C; summers are fresh with the mean monthly temperature in the warmest month below 22 °C; precipitation is relatively uniformly distributed over the whole year, but the driest part of the year occurs in the warm season. The secondary precipitation maximum occurring at the beginning of the warm part of the year is followed by the principal maximum in the autumn, which is higher than the former.

The climate is characterised by low monthly mean air temperatures, which is reflected in the low annual mean air temperature of 6.7 °C. One of the climatic particularities is the occurrence of late spring frosts in April, May and even June. Relative air humidity is high over the whole year and varies from 76 % to 86 %. The distribution of the total annual precipitation quantity (1,982 mm) is characterised by two minimums: at the end of winter and in summer. During the vegetation period (which coincides with the length of the warm part of the year), there is about 1,000 mm precipitation or about 50 % of the total annual precipitation quantity. In this locality, the growth period lasts for 146 days on average (from 116 - 195 days) or about 5 months. The snow period lasts for 188 days and inevitably affects the length of the growth period.

With regard to the geographical position and altitude and to horizontal vegetation distribution, "Belevine" management unit belongs to the zone of deciduous and mixed forests of moderately humid, cold sites of the alliance *Fagion illyricum.*

In vertical sense, "Belevine" is located in the belt of beech (*Fagetum croaticum*) and sub-belt of beech and fir (*Abieti-Fagetum illyricum*), and extends at an altitude of 650 - 1,200 m.

This management unit is predominantly covered with the forest of fir with hard fern (*Blechno-Abietetum* Ht. 1950). Generally, the community of fir with hard fern occurs in the high-mountain belt over silicate rocks, 670 to 950 m above the sea. In Gorski Kotar, this community is developed at higher positions of the climatozonal area of beech and fir and inhabits mildly dry slopes or smaller valleys with deep, leached acid soils over silicates and sandstones (Vukelić & Rauš 1998).

In "Belevine", this plant community occurs in the following subassociations and facies:

- fir forest with hard fern and bedstraw (*Blechno-Abietetum galietosum rotundifoliae* Ht. 1950), with two facies: facies *Vaccinium myrtillus* and facies *Festuca sylvatica*,
- fir forest with hard fern and yellow moss (*Blechno-Abietetum hylocomietosum* Ht. 1950),
- fir forest with hard fern on red marls (*Blechno-Abietetum fagetosum* Rauš 1975).

In the management unit "Belevine" this community is located in the distribution range of beech on the boundary of the natural distribution range of fir. A beech-fir forest (*Abieti-Fagetum croaticum* Ht. 1950) is found in smaller marginal areas and is not considered characteristic for the management unit.

Table 1. Share of forest associations
Tablica 1. Prikaz zastupljenosti biljnih zajednica

Forest association *Biljna zajednica*	Area - *Površina* (ha)	%
Blechno-abietetum galietosum rotundifoliae Horv. 50	168.74	59.8
Blechno-abietetum galietosum rotundifoliae, facijes *Vaccinium myrtillus*	13.39	4.7
Blechno-abietetum galietosum rotundifoliae, facijes *Festuca silvatica*	33.45	11.8
Blechno-abietetum hylocomietosum Horv. 50	3.43	1.2
Blechno-abietetum fagetosum	34.28	12.2
Abieti-Fagetum croaticum Horv. 1938	29.15	10.3
Total - *Ukupno*	282.44	100.0

The stands in the management unit are divided into two ecological-management types. The ecological-management type I-C-40 consists of the forest of fir with hard fern (*Blechno-Abietetum* Ht.), whereas the ecological-management type I-C-10a is represented by the forest community *Abieti-Fagetum dinaricum* Horv.

Table 2. Share of ecological management types
Tablica 2. Prikaz zastupljenosti ekološko gospodarskih tipova

Ecological management type *Ekološko gospodarski tip*	Area - *Površina* (ha)	%
I-C-40	253.29	89.7
I-C-10 a	29.15	10.3
Total - *Ukupno*	282.44	100.0

The management unit covers a surface area of 293.94 ha, of which 283.20 ha is forested, 5.88 ha is a non-forested productive area and 4.86 ha is infertile soil. The management unit is internally divided into 18 compartments with an average size of 16.33 ha each.

The stands in the MU "Belevine" are seed forests of high silvicultural form managed selectively. In terms of mixture proportion by growing stock and by tree number, "Belevine" is a mixed forest of fir and beech. In the past 50 years, one of the management goals from the 1951 Management Plan relating to 20 % of beech in the mixture proportion has been achieved. Beech has increased its share in the growing stock from 3 to 24 %, and its number from 21 to 49 %. The mixture proportion per wood volume and tree number is given in Table 3.

Table 3. Mixture proportion per tree species
Tablica 3. Omjer smjese po vrstama drveća

Inventory *Inventura*	Tree species *Vrsta drveća*	Growing stock *Drvna zaliha*	Mixture proportion *Omjer smjese*	Number of trees *Broj stabala*	Mixture proportion *Omjer smjese*
		m³	%		%
1951.	Fir - *Jela*	123 670	97	91 183	79
	Beech - *Bukva*	3 891	3	24 879	21
1999.	Fir - *Jela*	99 541	76	53 862	51
	Beech - *Bukva*	30 712	24	51 129	49

The forests of "Belevine" are at the stage of thick trees because in the last 30 years, trees with breast diameters over 51 cm have accounted for more than 50 % of the basal area.

The growing stock amounts to 131,274 m^3 or 464.79 m^3/ha. Fir and spruce account for 99,585 m^3 or 352.37 m^3/ha, while beech and other tree species account for 31,689 m^3 or 112.20 m^3/ha. The annual increment is 7.86 m^3/ha, of which 5.10 m^3/ha relates to fir (with spruce), and 2.76 m^3/ha relates to beech with other tree species. The average increment percentage is 1.69 % (for fir and spruce it is 1.32 %, and for beech and other tree species it is 3.32 %).

The management unit "Belevine" is managed with selection management using the group method, which will be accomplished with selection cutting. The single tree management method is only applied to parts of the compartment along the railway line and to steep beds of hilly streams so as to prevent landslides.

This management unit is managed with the "New system of selection forest management" by Professor Klepac, so that two basic management principles can be accomplished simultaneously: the establishment of a stable condition combined with permanent satisfaction of the sustainable forest management. An optimal growing stock calculated according to the II normal model for fir and the III normal model for beech is 480 m^3/ha.

The largest part of the forest is taken up by the management class "Uneven-aged seed fir forests II" in the distribution range of the forest community of fir with hard fern. The management class "Uneven-aged seed forests of beech III and fir II" accounts for a small part of the forest within the distribution range of beech and fir. A mixed normal model of fir and beech with an 80:20 mixture proportion per growing stock and maturity dimensions for fir of 70 cm and beech of 50 cm was constructed for the first management class. A transitional mixed normal beech and fir model with a mixture proportion of 80 % beech and 20 % fir by growing stock with maturity dimensions identical to the first normal model was drawn up for the management class of beech and fir, in which fir accounts for less than 10 %.

A ten-year prescribed harvesting volume for the management unit "Belevine", based on the relationship between the existing and the optimal growing stock, past harvesting volumes, maturity dimension, measured increment, regeneration stage, health status and purpose of the forest, is approximately 32,000 m^3, which corresponds to an average intensity of 22.5 %. With regard to a 10-year cutting cycle, the annual harvesting volume will be realised every year over approximately 10 % of the total area so as to satisfy the principle of sustainable management. The volume of sanitary felling is about 2 m^3/ha annually.

RESEARCH METHODS
METODE RADA

Research was based on the sample of fir trees felled in the regular cutting cycle. Trees from sanitary felling were not considered.

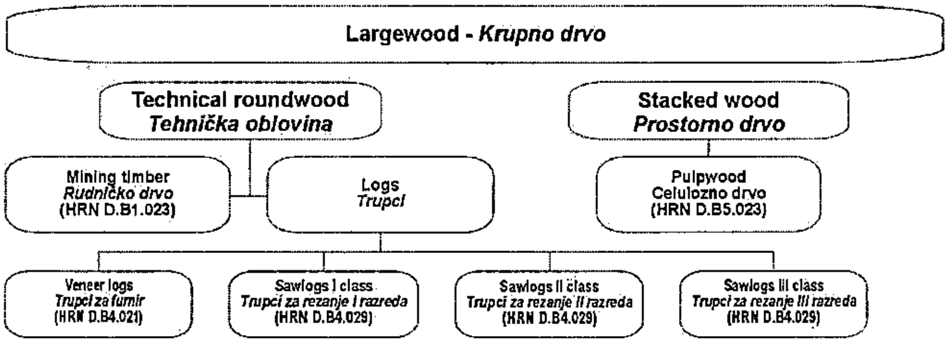
Before felling, two perpendicular breast diameters and height were measured on standing trees. The height of the trees was measured with an altimeter with an accuracy of 0.5 m, and breast diameters were rounded down to the nearest centimetre. Their arithmetic mean was also rounded down to the nearest centimetre. The trees were then measured after felling and debranching. The length (height) of the felled tree (from the root to the highest terminal bud) was measured with a measuring tape with an accuracy of one decimetre.

All sample trees were sectioned in order to obtain an accurate estimate of large timber volume (up to 7 cm) over and under bark. Trees with bark were sectioned after felling. Tree trunks were divided into sections of 2.0 m, with the end sections ranging from a minimum of 1.0 m to a maximum of 3.0 m in length. The section length was measured on each section (l) with decimetre accuracy and two mutually perpendicular diameters in the mid-section (d_1 and d_2) were measured with millimetre accuracy.

The trees were debarked up to the point on the stem where numerous knots appeared. In the process, the mid-sections of previous sectioning over bark were marked with forest chalk, which made it possible to measure mean diameters of the sections under bark in the same points. The mid-sections of the end parts were debarked so that diameters under bark could be measured. Bark thickness (k_1 and k_2) was measured during debarking on each mid-section in the two opposite samples. Bark was measured with millimetre accuracy and the sample included dead and living bark. After debarking, the trees without bark were sectioned. Diameters under bark (d_3 and d_4) were measured in the mid-sections with millimetre accuracy. The ordinal number of the section, section length, section diameters over and under bark and bark thicknesses k_1 and k_2 were entered into sectioning forms.

When tree sectioning was completed, timber assortments were bucked and crosscut. Timber assortments of fir are produced from stems, and assortment quality depends on their position on the stem. As a rule, the lower half of the stem length represents a better quality zone. As the distance from the stump increases, the mean diameter of the assortments decreases. The number and size of knots increases at the beginning of the crown, which considerably lessens the quality of assortments. In processing, special attention is paid to bucking the stem with the goal of obtaining the highest value of forest assortments from the available tree wood volume. Timber assortments were bucked, crosscut, measured, inspectioned and marked in accordance with the Croatian standards for roundwood. Timber assortments were measured according to the Croatian standard D.B0.022 "Sorting and measuring unprocessed and processed timber" Timber assortments were put into quality classes according to Croatian standards for conifer roundwood shown in Figure 1.

Figure 1. Distribution of coniferous roundwood
Slika 1. Raspodjela oblog drva četinjača



Timber inspection is a process of measuring, grading and recording saleable timber assortments. The mean diameter is an arithmetic mean of two mutually perpendicular measurements. Two mean diameters (rounded down to the nearest centimetre) and length were measured on debarked timber assortments. The timber assortments from the top part of the stem were subsequently debarked in the points of mean assortment diameters. The timber assortments from the top part of the stem were predominantly classified as pulpwood, which is also taken without bark. Log lengths were measured with a tape so that the number could be rounded down to the nearest decimetre, and length allowance was then subtracted (with conifers it is 2 cm by a current metre, on condition that one log may have a minimum of 5 cm and a maximum of 20 cm). Length allowance is not taken for veneer logs and pulpwood. Log length is measured at the shortest point. In order to accurately determine quality classes, timber defects on the logs that influence the classification into quality classes were inspected and measured. Timber defects were measured according to the Croatian standards D.AO. 101 and D.A1. 041. Information on the processed assortments (quality class, assortment length, mean assortment diameter) was entered into the felling register.

DATA PROCESSING
OBRADA PODATAKA

The measured data were transferred from field sectioning forms and felling registers into computer databases for easier availability. The first to be entered were data on the basic tree characteristics: breast diameters and tree heights.

Using the German system, the sample trees were put into diameter classes 5 cm wide with class means at 22.5 cm, 27.5 cm, 32.5 cm, etc. Classifying trees into diameter classes of 2 cm in width is not practical for research because it implies a much larger number of diameter classes. Moreover, the Croatian forestry acknowledges diameter classes of 5 cm.

Data from tree sectioning forms were entered for each tree showing mean section diameters over and under bark at a given distance from the stump and double bark thicknesses in the point of measurement. Based on the above, data were then calculated, with calculations including:

- mean diameter of each section over bark $d_{sob} = \frac{d_1 + d_2}{2}$
- mean diameter of each section under bark $d_{sub} = \frac{d_3 + d_4}{2}$
- double bark thickness in the point of mean diameter of each section $b = d_{sob} - d_{sub}$,
- volume of each section over bark (Huber's formula) $V_{sob} = \frac{d_{sob}^2 \cdot \pi \cdot l}{40000}$
- volume of each section under bark $V_{sub} = \frac{d_{sub}^2 \cdot \pi \cdot l}{40000}$
- total timber volume over and under bark of each tree obtained with summing the volume of all timber sections
- total bark volume of each tree as a difference of the total timber volume over and under bark
- proportion of bark in relation to the tree according to the equation

$$b_{\%} = \frac{\Sigma V_{sob} - \Sigma V_{sub}}{\Sigma V_{sob}}$$

d_1, d_2 - measured mean section diameters	V_{sob} - section volume over bark
d_{sob} - mean diameter of section over bark	V_{sub} - section volume under bark
d_{sub} - mean diameter of section under bark	$b_{\%}$ - proportion of bark
b - double bark thickness	

The calculated assortment timber volumes were summarized by quality classes for each tree. The processed tree volume was calculated by summing up all timber volumes of assortments. The ratio of the processed volume - the total volume shows the degree of timber yield at felling and processing, whereas the differences of these volumes show the quantity of waste at felling and processing.

All the trees possessing the above characteristics make up an elementary database. Double-entry tables and one-entry tables of timber volume, bark volume and percentage and assortment tables will be based on mathematical-statistical data processing in the elementary database.

Data relating to each section measurement were excluded from timber sectioning data entered into the computer. This database contains mean section diameters over bark, the distance of section diameter from the stump, double bark thickness in mid-section together with breast diameter and tree height at which a given section is found. The database is a foundation for the study of bark thickness in dependence on stem thickness.

Assortment timber volumes are distributed according to quality classes and diameter classes of trees. The total processed volume of diameter classes is given summarily. The summary values of assortment volumes by quality and diameter classes were divided with the number of trees in the respective diameter class. In this way, the mean tree assortment structure of diameter classes was determined and presented in absolute and relative values of quality classes.

The data were mathematically-statistically processed on a personal computer using the Microsoft EXCEL 97 programme package.

The data were subjected to descriptive statistical analyses. Various indicators of the central data dispersion trend were studied. The most favourable central trend indicators were found to be the arithmetic mean and standard deviation as a dispersion measure of this value.

In order to illustrate timber quality, research focused on establishing functional dependence of tree parameters. The data were subjected to regression analyses with one or more independent variables. Regression curves were selected on the basis of the following parameters: correlation coefficient (R), standard deviation of a dependent variable around the regression line (s_{y_x}), t-variable (*t Stat*) and the probability of error of the first kind (*P-value*) of regression coefficients (Serdar & Šošić 1981, Kachigan 1991).

The following equations were used for regression.

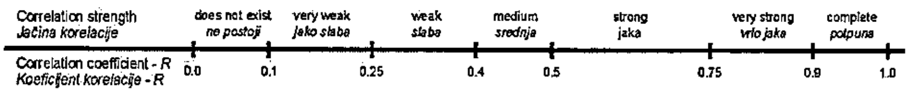
- Mihajlo's function for determining height curves of the studied tree sample $h = a_0 e^{-a1/d} + 1.3$,
- Schummacher-Hall's equation for determining timber volume of a tree over and under bark and the volume of processed timber: $V = a_0\, d^{a1}\, h^{a2}$,
- equation of the second order to formulate one-entry tables of fir trees, assortment tables and dependence of bark thickness on tree diameter

$$y\,(V,\,b) = a_0 + a_1\,d + a_2\,d^2$$

a_0, a_1, a_2, - coefficients of regression equation	*b* - double bark thickness
d - breast diameter of tree	*V* - tree volume
h - tree height	

The Roemer-Orphal's scale was used to establish a firm link between the regressed independent and dependent variable (Kump et al. 1970).

Figure 2. Roemer-Orphal distribution
Slika 2. Roemer-Orphal-ova raspodjela



RESEARCH RESULTS
REZULTATI ISTRAŽIVANJA

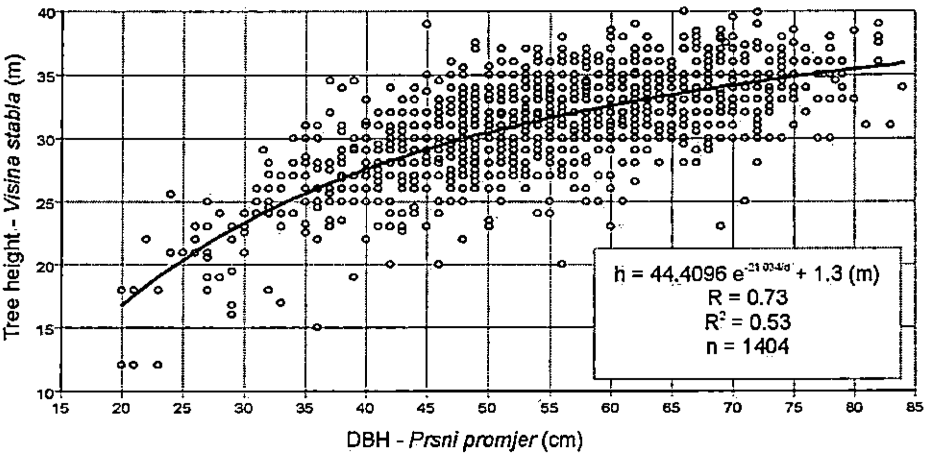
TREE SAMPLE
UZORAK STABALA

Research was conducted on a sample of 1,404 fir trees felled and processed in regular cutting operations. Breast diameters of the trees ranged between 20 cm and 85 cm, in other words, the trees were classified into 13 diameter classes from 22.5 cm to 82.5 cm. The number of trees per diameter class shows normal distribution trend with arithmetic mean in the diameter class of 52.5 cm. Tree heights ranged from 12 m to 40 m, and the trees were divided into height classes 5 m wide. Table 4 shows the number of sample trees per diameter and height classes.

Table 4. Number of trees per diameter and height classes
Tablica 4. Broj stabala uzorka po debljinskim i visinskim razredima

Tree height	Diameter class - *Debljinski razred*, cm													Total
Visina stabla, m	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	82.5	*Ukupno*
10-15	3													3
15-20	3	6	2	2										13
20-25	4	12	18	8	11	5	2	2						62
25-30		1	21	55	88	88	65	31	9	9	2			369
30-35			1	14	41	101	156	156	123	76	50	11	3	732
35-40						8	21	35	50	48	34	24	5	225
Total - *Ukupno*	10	19	42	79	140	202	244	224	182	133	86	35	8	1404

Figure 3. Height curve of sample trees
Slika 3. Visinska krivulja uzorka stabala



Based on the measured heights, a height curve of sampled trees was constructed with Mihajlo's function. Figure 3 shows the measured data with an inserted regressed height curve. The height curve of the sample trees was compared to the height curve taken from the Management Plan (* 1999) for the management unit "Belevine". It

Table 5. Comparison of height curves
Tablica 5. Usporedba visinskih krivulja

Diameter - class *Debljinski razred*	Tree height - *Visina stabala*		Difference *Razlika*
	Sample - *uzorak*	Management plan - *Osn. gosp.*	
cm	m		
22.5	18.7	18.4	0.3
27.5	22.0	21.7	0.3
32.5	24.5	24.4	0.2
37.5	26.6	26.6	0.1
42.5	28.4	28.4	0.0
47.5	29.8	29.9	-0.1
52.5	31.0	31.2	-0.1
57.5	32.1	32.3	-0.2
62.5	33.0	33.2	-0.2
67.5	33.8	34.1	-0.3
72.5	34.5	34.8	-0.3
77.5	35.2	35.5	-0.3
82.5	35.7	36.1	-0.4

can be concluded from Table 5 that the heights of diameter classes coincide almost completely (with only a few differences). The applied t-test confirmed the hypothesis that there were no differences between the quoted values ($t_{0.05} \doteq 0.115$), and that the choice of sample trees was proper.

TWO-ENTRY TABLES
DVOULAZNE TABLICE

In two-entry tables, two independent variables are in functional relation with a dependent variable. The constructed two-entry tables show the dependence of timber volume, bark volume and yield percentage on breast diameter and tree height.

TWO-ENTRY TABLES OF FIR TIMBER VOLUME
DVOULAZNE TABLICE DRVNOG OBUJMA STABALA JELE

Using the tree sectioning method, the timber volume of 1,404 sample trees up to 7 cm diameter over and under bark was determined. The processed timber volume was determined by adding up timber assortment volumes of each tree from the felling register. Figures 4, 6 and 8 show the calculated data of tree volumes over and under bark and the processed volume in dependence on breast diameters.

Figure 4. Data of tree volume over bark

Slika 4. Podaci o drvnom obujmu stabala s korom

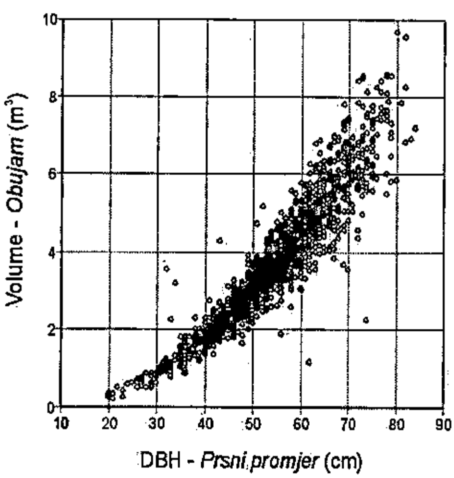


Figure 5. Tree volume over bark (Schumacher-Hall)

Slika 5. Drvni obujam stabala s korom (Schumacher-Hall)

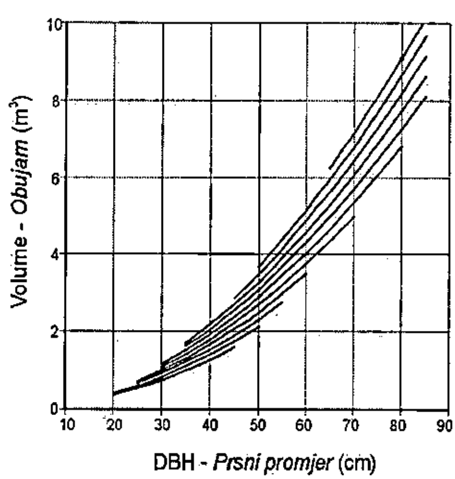


Figure 6. Data about tree volume under bark

Slika 6. Podaci o drvnom obujmu stabala bez kore

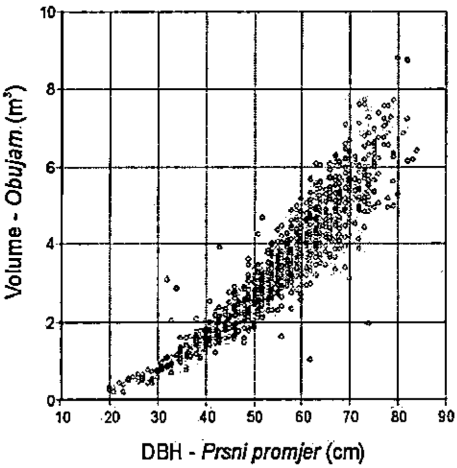


Figure 7. Tree volume under bark (Schumacher-Hall)

Slika 7. Drvni obujam stabala bez kore (Schumacher-Hall)

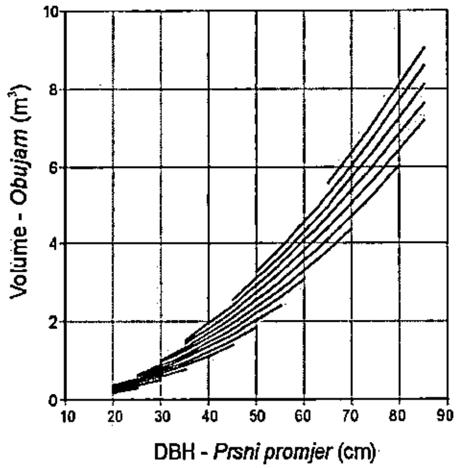


Figure 8. Data of processed tree volume

Slika 8. Podaci o iskorištenom drvnom obujmu stabala

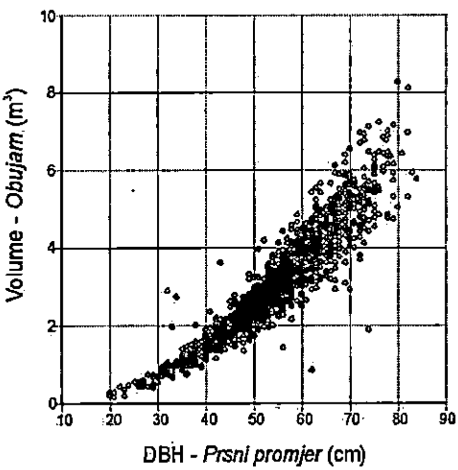


Figure 9. Processed tree volume (Schumacher-Hall)

Slika 9. Iskoristivi drvni obujam stabala (Schumacher-Hall)

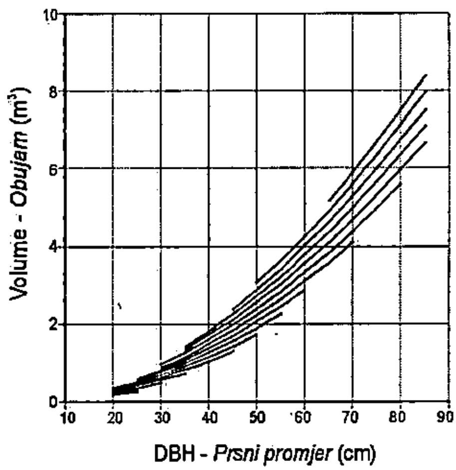


Table 6. Estimation of parameters of tree variables
Tablica 6. Procjena parametara varijabli stabala

Tree variables *Varijable stabla*	Number of trees *Broj stabala*	Arithmetic mean *Aritmetička sredina*	Standard deviation *Standardna devijacija*	Standard error *Standardna pogreška*	Range *Raspon* (min.- max.)	
DBH - *Prsni promjer*		54.3	11.53	0.31	20	85
Tree height - *Visina stabla*		31.0	3.89	0.10	10	40
Timber volume to 7 cm diameter over bark *Drvni obujam do 7 cm promjera s korom*	1404	3.73	1.69	0.04	0.22	9.66
Timber volume to 7 cm diameter under bark *Drvni obujam do 7 cm promjera bez kore*		3.31	1.50	0.04	0.19	8.81
Processed timber volume *Iskorišteni drvni obujam*		3.08	1.40	0.04	0.16	8.33

The smallest square method was used to insert regression lines into the presented data by applying the Schumacher-Hall equation for estimating timber volume in dependence on breast diameter and tree height. Total data correlation was accomplished with data regression according to Roemer-Orphal scale (correlation coefficient values of 0.97).

Table 7. Regression equations of dependence of timber volume on DBH and tree height
Tablica 7. Regresijke jednadžbe ovisnosti drvnog obujma o prsnom promjeru i visini stabala

Timber volume of trees *Drvni obujam stabala*	Regression equations *Regresijske jednadžbe*	Corellation coeficient *Koeficijent korelacije*
Tree volume to 7 cm diameter over bark *Obujam stabla do 7 cm promjera s korom*	$V = 0.000075 \cdot d^{1.81567} \cdot h^{1.01588}$	0.97
Tree volume to 7 cm diameter under bark *Obujam stabla do 7 cm promjera bez kore*	$V = 0.000064 \cdot d^{1.80674} \cdot h^{1.04000}$	0.97
Processed tree volume *Iskoristivi obujam stabala*	$V = 0.000060 \cdot d^{1.80486} \cdot h^{1.03712}$	0.97

Based on the parameters of regression lines, two-entry tables of fir tree timber volumes were constructed and presented in graph form (Figures 5, 7 and 9). Ranges of breast diameters and tree heights presented in two-entry tables were determined by recorded and measured values on sample trees. The values of tree volume in tables increase with an increase in breast diameters and tree heights. At identical breast diameter and tree height, timber volume of trees to 7 cm diameter over bark has the largest values, followed by timber volume of trees to 7 cm diameter under bark, while processed timber volume of trees has the lowest values. Within this range, timber volume to 7 cm over bark ranges from 0.216 m^3 for trees with breast diameters of 20 cm and heights of 12 m to 10.167 m^3 for trees with breast diameters of 85 cm and heights of 40 m. For these trees, the timber volume to 7 cm under bark ranges from 0.189 m^3 to 10.030 m^3, while the processed timber volume ranges from 0.177 m^3 to 9.301 m^3.

TWO-ENTRY TABLES OF FIR BARK VOLUME
DVOULAZNE TABLICE KORE STABALA JELE

The difference between the regressed timber volume values of fir trees to 7 cm diameter over and under bark represents the volume of fir tree bark shown in two-entry tables. The volume of tree bark increases with an increase in breast diameter and tree height and assumes values from 0.03 m^3 in trees with breast diameters of 20 cm and heights of 12 m to 1.12 m^3 in trees with breast diameters of 85 cm and heights of 40 m.

Apart from two-entry tables of bark volume, tables of bark percentages were also constructed using the formula:

$$b_{\%} = \frac{\Sigma V_{ob} - \Sigma V_{ub}}{\Sigma V_{ob}} \cdot 100$$

(V_{ob} - tree volume over bark; V_{ub} - tree volume under bark; $b_{\%}$ - proportion of tree bark)

where tree volumes over and under bark (V_{ob}, V_{ub}) represent the regressed values shown in the constructed two-entry tables. The percentage of bark proportion is within the limits from 12.45 % to 10.67 %. Within the same diameter class, the percentage of bark declines as tree height increases. The proportion of bark in trees of equal heights is directly proportionate to breast diameter. However, in analysing mean values of bark percentage of diameter classes, bark percentage decreases with an increase in tree breast diameter, which confirms former research stating that the percentage of bark decreases as breast diameter increases (Bojanin 1966b, Klepac 1972, Krpan 1986).

Figure 10. Bark volume
Slika 10. Obujam kore

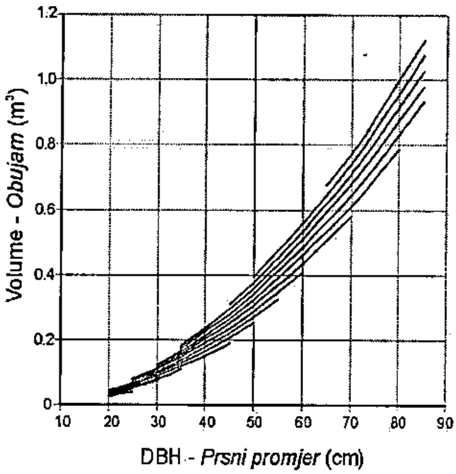
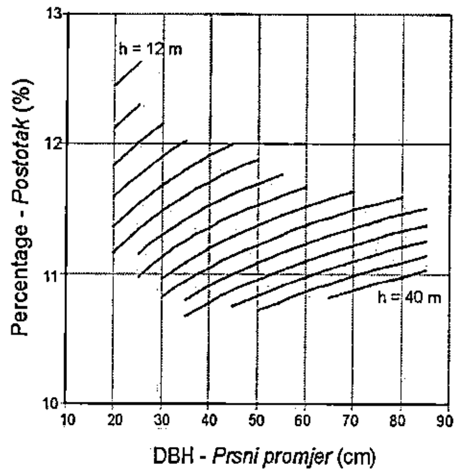


Figure 11. Bark volume percentage
Slika 11. Obujmeni postotak kore



TIMBER VOLUME YIELD AND WASTE ACCORDING TO TWO-ENTRY TABLES

ISKORIŠTENJE DRVNOG OBUJMA I OTPAD PREMA DVOULAZNIM TABLICAMA

The percentage of fir timber volume yield is determined as the ratio between the processed timber volume (the sum of volumes of timber assortments made from a tree) and the timber volume of tree to 7 cm diameter over bark. In the sample, the yield ranged from 70.18 % to 94.90 % with an arithmetic mean of 82.54 %. The calculated yield values of sample trees were not subjected to regression analysis due to a statistically unreliable correlation coefficient.

For this reason, yield tables were calculated from the regressed values of the processed timber volumes of trees and the total timber volume of trees to 7 cm diameter over bark.

For data on breast diameters and heights in the sample, yield values range from 81.7 % to 83.0 %. The yield rises with an increase in the height of trees at identical breast diameters (Figure 12).

Waste consists of bark and losses in timber volume resulting from felling and processing. Losses in timber volume from felling and processing relate to real waste, or to parts of large wood of trees which remain unused in a forest for a variety of reasons, as well as to losses incurred by the prescribed measuring methods (rounding down assortment diameters and lengths, the prescribed log length allowance and er-

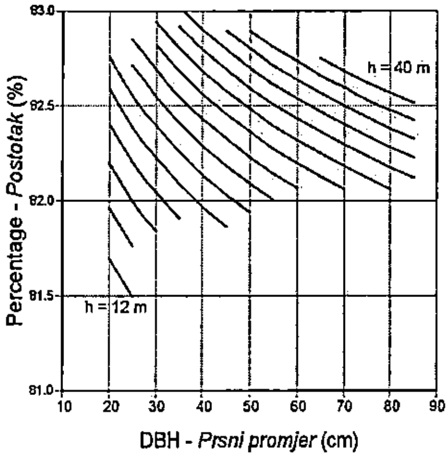


Figure 12. Timber volume yield according to tables
Slika 12. Iskorištenje drvnog obujma prema tablicama

rors in Huber's formula). It should be pointed out that, in case of debarking, bark on technical assortments and on conifer pulpwood is included in the waste structure.

Accordingly, if bark is excluded from waste structure, a part of losses from felling and processing may be expressed

Figure 13. Volume of timber losses from felling and processing
Slika 13. Obujam gubitaka pri sječi i izradi stabala

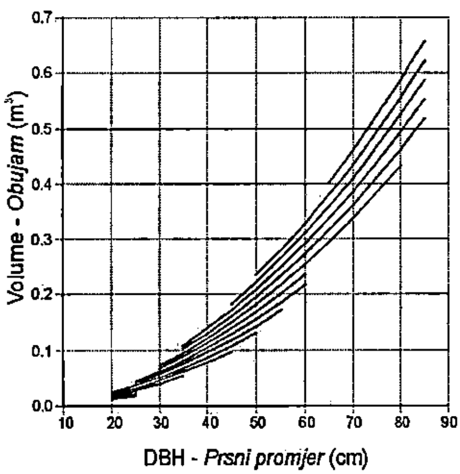
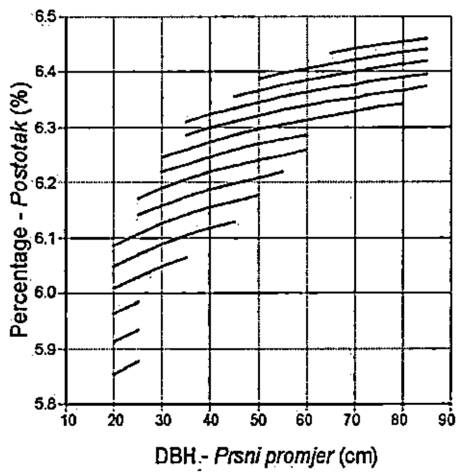


Figure 14. Percenatge of timber volume losses from felling and processing
Slika 14. Obujmeni postotak gubitaka pri sječi i izradi stabala



- in absolute values - by subtracting the processed timber volume of trees and bark volumes of trees from the total timber volume to 7 cm diameter over bark,
- in relative values - from the ratio of the quoted difference and the total timber volume of trees.

Absolute and relative values of losses from felling and processing increase from 0.01 m^3 to 0.66 m^3 or from 5.85 % to 6.46 % with an increase in either the breast diameter or the height of trees

ONE-ENTRY TABLES
JEDNOULAZNE TABLICE

One-entry tables represent a regression model in which the volume of a tree is the function of its breast diameter. One-entry tables of fir timber and bark volume were constructed mathematically and the structure of yield and waste from felling and processing was calculated in absolute and percentage values.

ONE-ENTRY TABLES OF FIR TIMBER VOLUME
JEDNOULAZNE TABLICE DRVNOG OBUJMA STABALA JELE

To construct one-entry tables, the same data for tree sectioning were used as in the construction of two-entry timber volume tables. The data were regressed with the curve of the second order (parabola), which is known as the model of Hohenadl-Kren (Kružić 1993a):

$$V = a_0 + a_1 d + a_2 d^2$$

(a_0, a_1, a_2 - coefficients of regression equation; d- tree breast diameter; V- tree volume)

The highest correlation coefficients were obtained with regression analysis by applying the mentioned regression line without a free member b_0. The analytical expression of dependence of volume on breast diameter shows that it is possible to estimate tree volumes if tree heights exceed the height of breast diameters at 1.3 m. Data on tree volumes to 7 cm diameter over and under bark and the processed volumes were regressed. Identical correlation coefficients of 0.94 were obtained in all regressions. The value of correlation coefficient points to full linkage according to the Roemer-Orphal scale.

Table 8. Regression eqations of dependence of timber and bark volume on DBH
Tablica 8. Regresijke jednadžbe ovisnosti obujma drva i kore o prsnom promjeru stabala

Timber volume of trees *Drvni obujam stabala*	Regression equations *Regresijske jednadžbe*	Corellation coeficient *Koeficijent korelacije*
Tree volume to 7 cm diameter over bark *Obujam stabla do 7 cm promjera s korom*	$V = -0.00638\ d + 0.00132\ d^2$	0.94
Tree volume to 7 cm diameter under bark *Obujam stabla do 7 cm promjera bez kore*	$V = -0.00601\ d + 0.00118\ d^2$	0.94
Processed tree volume *Iskoristivi obujam stabala*	$V = -0.00521\ d + 0.00109\ d^2$	0.94
Bark volume *Obujam kore*	$V = -0.00038\ d + 0.00014\ d^2$	0.87

According to the regressed values (Figures from 15 to 17), timber volume to 7 cm diameter over bark ranges from 0.401 m^3 for trees with breast diameters of 20 cm to 8.790 m^3 for trees with breast diameters of 84 cm. For the same breast diameters, timber volume to 7 cm diameter under bark ranges from 0.352 m^3 to 7.822 m^3, while the processed timber volume ranges from 0.332 m^3 to 7.252 m^3.

Figure 15. Dependence of tree volume over bark on DBH
Slika 15. Ovisnost drvnog obujma stabala s korom o prsnom promjeru

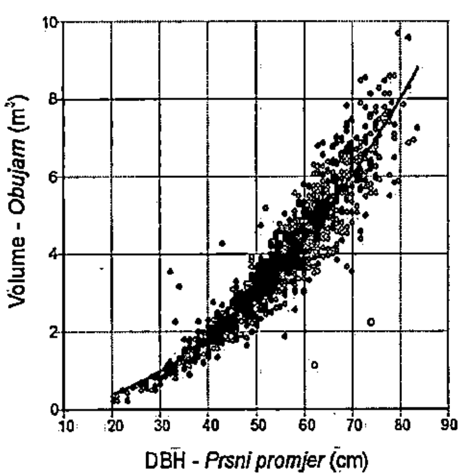


Figure 16. Dependence of tree volume under bark on DBH
Slika 16. Ovisnost drvnog obujma stabala bez kore o prsnom promjeru

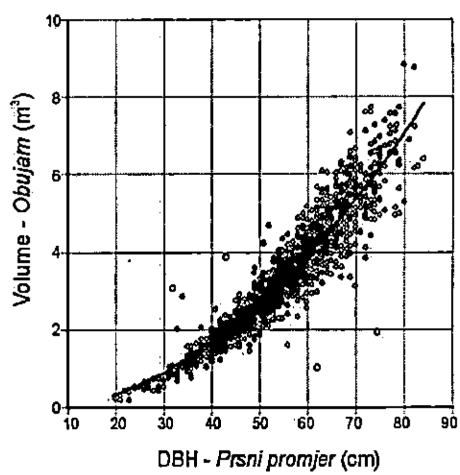


Figure 17. Dependence of processed tree volume on DBH

Slika 17. Ovisnost iskorištenog drvnog obujma o prsnom promjeru

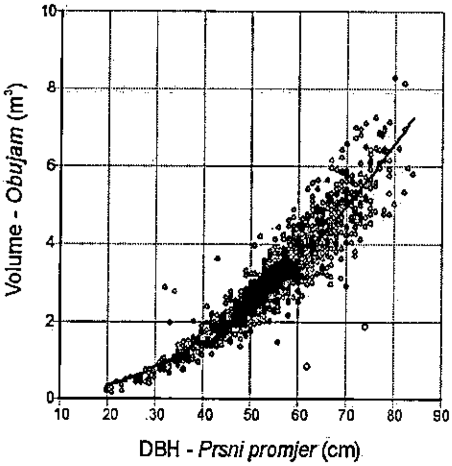
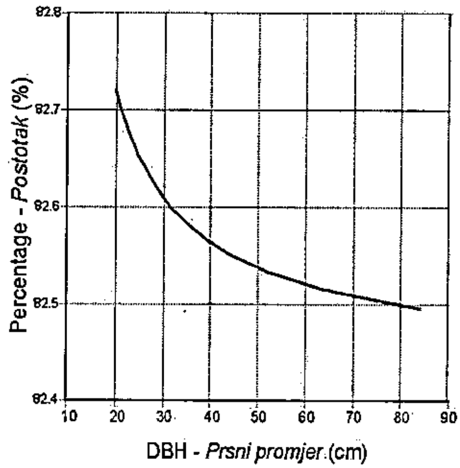


Figure 18. Dependence of timber volume yield on DBH

Slika 18. Ovisnost iskorištenja drvnog obujma prema prsnom promjeru



Tables of bark volumes were constructed from calculated values of bark volumes of individual trees. Bark volume of a tree represents the difference between tree volume over and under bark obtained by sectioning. The same analytical expression was used for data regression and the correlation coefficient of 0.87 was obtained. Bark volume increases with a rise in breast diameter and ranges from 0.049 m^3 for trees with breast diameters of 20 cm to 0.968 m^3 for trees with breast diameters of 84 cm. (Figure 19)

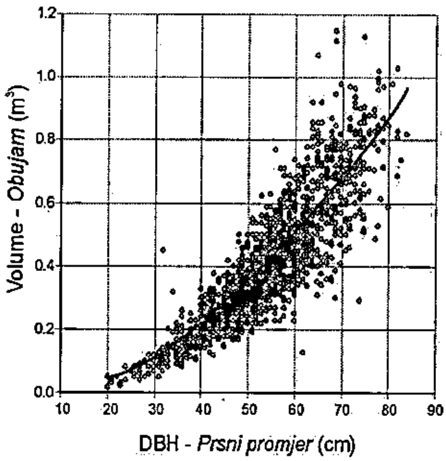


Figure 19. Dependence of bark volume on DBH

Slika 19. Ovisnost obujma kore o prsnom promjeru

TIMBER VOLUME YIELD AND WASTE ACCORDING TO ONE-ENTRY TABLES
ISKORIŠTENJE DRVNOG OBUJMA I OTPAD PREMA JEDNOULAZNIM TABLICAMA

Based on the constructed one-entry tables, the structure of yield and waste was established in dependence on breast diameter. Waste is the difference between regressed values of tree volumes to 7 cm diameter over bark and the processed volume. Losses at felling and processing represent the difference between waste and bark volume. In the preceding chapter it was stated that bark volume is completely included in the structure of waste, and losses at felling and processing contain real waste and losses due to standard-related measurement method.

Timber volume yield, waste and losses at felling and processing are presented in absolute and percentage values. Percentage values of yield at felling and processing decrease only slightly with an increase in breast diameter. For the volume of trees with breast diameters from 20 cm to 84 cm, yield decreases from 82.72 % to 82.50 %, making the difference of 0.22 %. Waste percentage at felling and processing has a reverse trend. With an increase in breast diameters, the percentage of tree bark also decreases from 12.26 % for the thinnest trees (breast diameter of 20 cm) to 11.02 % for the trees with breast diameters of 84 cm, while the percentage of real waste and other losses at felling and processing rises from 5.02 % to 6.49 % for the same marginal values of breast diameters.

Figure 20. Dependence of waste volume on DBH

Slika 20. Obujmeni udio otpada ovisno o prsnom promjeru

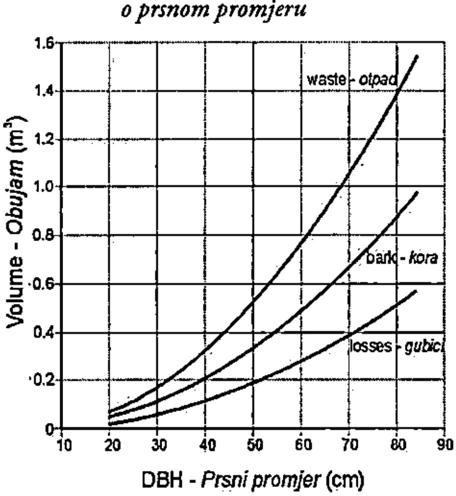
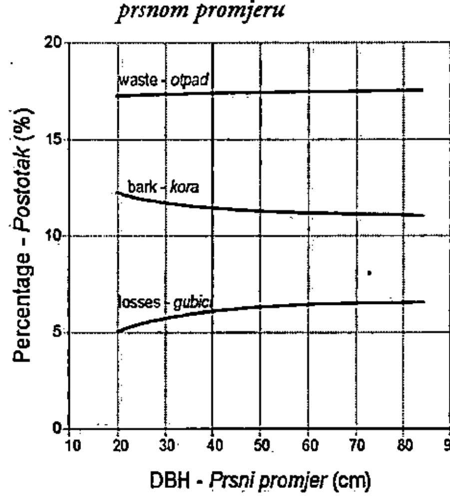


Figure 21. Dependence of waste percentage on DBH

Slika 21. Postotni udio otpada ovisno o prsnom promjeru



BARK THICKNESS
DEBLJINA KORE

The sectioning method was used to measure the diameter and double bark thickness at each mid-section. Based on measuring 14,614 sections, pairs of data of mean mid-section diameters and double bark thicknesses were established. Research was aimed at determining the dependence of double bark thickness on roundwood diameter. Bojanin (1966a, b) proved that the thickness of bark on assortments did not depend on the thickness of trees or the distance from the ground or the position; in other words, it did not depend on whether the bark was on the crown or on the pure part of the stem; it only depended on the diameter of roundwood. Past research on the dependence of bark thickness on roundwood diameter established a correlation in the form of a straight line (Bojanin 1966b, Klepac 1972) or parabola (Krpan 1986). In regression data analysis, a curve of the second order was chosen (parabola), achieving a correlation coefficient of 0.7, that is, higher than the one achieved with regressing data with a line.

Regression equation of double bark thickness is:

$$b = 0.73259 + 0.04439\, d - 0.00018\, d^2.$$

(d - breast diameter of tree; b - double bark thickness)

By subtracting double bark thickness from roundwood diameters over bark, roundwood diameters under bark were determined and basal areas for diameters over and under bark were calculated. Bark percentage was determined according to basal areas over and under bark on a given tree diameter.

According to Figure 22, an increase in diameter results in thicker bark and smaller percentage. Double bark thickness at roundwood diameter of 10 cm is 1.16 cm, and at roundwood diameter of 84 cm it is 3.16 cm. The percentage of bark is the highest with roundwood diameter of 20 cm (21.8 %). It drops distinctly with an increase in diameter and amounts to 7.4 % with roundwood diameter of 84 cm.

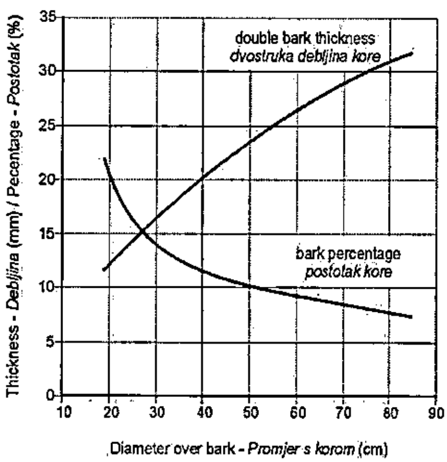


Figure 22. Bark thickness and percentage
Slika 22. Debljina i postotak kore

Research into bark thickness is particularly important from the standpoint of forestry practice, when timber assortments are measured over bark and double bark thickness has to be subtracted so that the mean diameter of assortments under bark can be determined according to the Croatian standards for roundwood.

With regard to roundwood diameters and minimal values of mean assortment diameters, a conclusion may be drawn on the volume of bark on individual assortments. For sawmill logs in quality classes I and II with mean diameters exceeding 25 cm (according to the standards), the percentage of bark ranges from 13.0 % for diameter of 25 cm under bark to 7.4 % for diameter of 81 cm under bark. Since the average mean diameter falls between these values, it can be concluded that these timber assortments will have the percentage of bark of about 10%. For sawmill logs in quality class III, a little higher bark percentage may be expected due to the allowed minimal mean diameter of 20 cm. Since mean diameters of mining timber under bark are between 9 cm and 25 cm, bark percentages are within the limits of 21.8% and 13 %. Bark percentage of pulpwood is within similar limits.

ASSORTMENT STRUCTURE
SORTIMENTNA STRUKTURA

Timber assortments were processed from felled fir trees and classified according to the Croatian standards for roundwood into the following quality classes: veneer logs, sawlogs (quality classes I, II and III), mining timber and pulpwood. Based on assortment measurements, their volume was established and assortment volumes summarised by quality classes and tree. A total of 4,319.31 m^3 of timber assortments were made. Table 10 shows the processed volume of timber assortments according to diameter classes and quality classes.

The sample contained only 12 veneer logs divided into 7 diameter classes. The total volume of veneer logs accounts for only 9.24 m^3or 0.23 % of the entire processed volume. Plavšić & Golubović (1963), in their study of percentage ratio of fir assortments in a sample of 1,607 trees, did not register one single veneer log. In constructing assortment tables for fir stemwood, Rebula (1996) does not mention the quality class of veneer logs either. Based on earlier research and on the studied sample, it may be concluded that veneer logs of fir trees in selection stands are very rare and are the result of a large number of favourable factors, from stand, site and climatic factors to genetic properties of individual trees. Although veneer logs are the most valuable assortments, their very low proportion excludes them from the study of assortment structure.

Table 10. Total timber volume of the sample according to diameter classes
Tablica 10. Ukupni drvni obujam uzorka po debljinskim razredima

Diameter classes *Debljinski razred*	Number of trees *Broj stabala*	Tree volume *Obujam stabala*	Timber assortments - *Drvni sortimenti*								
			Veneer logs *Furnirski trupci*	Sawlogs I. class *Pilanski trupci I.*	Sawlogs II. class *Pilanski trupci II.*	Sawlogs III. class *Pilanski trupci III.*	Logs total *Trupci ukupno*	Mining timber *Rudničko drvo*	Technical roundwood *Tehnika ukupno*	Pulpwood *Celulozno drvo*	Total *Ukupno*
cm		m^3									
22.5	10	4.01			0.65		0.65	2.48	3.13	0.19	3.32
27.5	19	12.18			2.37	2.13	4.50	4.96	9.46	0.63	10.09
32.5	42	50.72		6.20	15.21	11.42	32.82	8.18	41.00	1.06	42.06
37.5	79	120.62		19.27	30.77	34.67	84.71	10.76	95.47	4.02	99.49
42.5	140	290.77	0.43	41.09	86.49	83.75	211.76	16.34	228.09	11.13	239.22
47.5	202	535.82	1.41	78.63	168.47	159.62	408.14	17.33	425.47	17.71	443.18
52.5	244	815.93	2.04	114.22	233.22	273.41	622.90	18.31	641.21	30.14	671.35
57.5	224	902.00		113.21	268.27	313.90	695.38	12.14	707.52	39.87	747.39
62.5	182	881.94	1.87	122.36	235.62	310.32	670.17	7.95	678.13	50.24	728.37
67.5	133	753.09	1.09	117.80	184.43	268.98	572.29	3.99	576.28	43.83	620.11
72.5	86	547.61	1.41	67.86	168.10	176.57	413.94	1.96	415.90	33.98	449.88
77.5	35	253.23	0.99	41.28	65.67	86.53	194.47	1.14	195.61	14.12	209.73
82.5	8	65.87		3.97	26.01	20.23	50.20		50.20	4.92	55.12
Total *Ukupno*	1404	5233.80	9.24	725.89	1485.27	1741.52	3961.92	105.55	4067.46	251.84	4319.31

Table 11. Proportion of quality classes in total timber volume of the sample according to diameter classes
Tablica 11. Postotni udjeli razreda kakvoće u ukupnom drvnom obujmu uzorka po debljinskim razredima

Diameter classes *Debljinski razred*	Timber assortments - *Drvni sortimenti*								
	Veneer logs *Furnirski trupci*	Sawlogs I. class *Pilanski trupci I.*	Sawlogs II. class *Pilanski trupci II.*	Sawlogs III. class *Pilanski trupci III.*	Logs total *Trupci ukupno*	Mining timber *Rudničko drvo*	Technical roundwood *Tehnika ukupno*	Pulpwood *Celulozno drvo*	Total *Ukupno*
cm	%								
22.5	0.00	0.00	19.58	0.00	19.58	74.70	94.28	5.72	100.00
27.5	0.00	0.00	23.49	21.11	44.60	49.16	93.76	6.24	100.00
32.5	0.00	14.74	36.15	27.14	78.03	19.45	97.48	2.52	100.00
37.5	0.00	19.37	30.92	34.85	85.14	10.81	95.96	4.04	100.00
42.5	0.18	17.18	36.15	35.01	88.52	6.83	95.35	4.65	100.00
47.5	0.32	17.74	38.01	36.02	92.09	3.91	96.00	4.00	100.00
52.5	0.30	17.01	34.74	40.73	92.78	2.73	95.51	4.49	100.00
57.5	0.00	15.15	35.89	42.00	93.04	1.62	94.67	5.33	100.00
62.5	0.26	16.80	32.35	42.60	92.01	1.09	93.10	6.90	100.00
67.5	0.18	19.00	29.74	43.38	92.29	0.64	92.93	7.07	100.00
72.5	0.31	15.08	37.37	39.25	92.01	0.44	92.45	7.55	100.00
77.5	0.47	19.68	31.31	41.26	92.72	0.54	93.27	6.73	100.00
82.5	0.00	7.19	47.18	36.69	91.07	0.00	91.07	8.93	100.00
Total -	0.21	16.81	34.39	40.32	91.73	2.44	94.17	5.83	100.00
Ukupno					97.41	2.59	100.00		
	0.23	18.32	37.49	43.96	100.00				

Sawlogs in quality class I occur from the diameter class of 32.5 cm upwards with a proportion of 16.81 % in the total processed volume. In the total processed timber volume, sawlogs in quality classes II and III have the highest proportion participating with 34.39 %, or 40.32 % in the total processed volume.

The diameter class of 22.5 cm does not contain any sawlogs in quality class III, which can be explained by a regular form of higher stem parts of thinner trees and by small-dimension knots. The processed assortments were consequently classified into mining timber, which is represented with 74.7 % in this diameter class. The proportion of mining timber abruptly declines with an increase in tree breast diameters. The mining timber was not processed from the thickest trees in the sample, which is related to higher knottiness in the upper stem parts and a greater taper, which is an eliminating defect for this assortment. The proportion of pulpwood in the total processed volume is only 5.83 %.

The proportions of quality classes in absolute values were calculated on the basis of mean trees of diameter classes in the following way: the sum values of timber assortment volumes by quality classes and diameter classes (from Table 10) were divided by the number of trees in a respective diameter class.

Minimum assortment volumes were determined on the basis of the minimum permitted dimensions of assortments in an individual quality class according to roundwood standards (Table 12).

Table 12. Minimum dimensions of assortments according to quality classes
Tablica 12. Najmanje dimenzije sortimenata po razredima kakvoće

Dimension *Veličina*	Unit *Jedinica mjere*	Timber assortment - *Drvni sortiment*					
		Veneer F	Sawlog I.	Sawlog II.	Sawlog III.	Mining timber *Rud. dr.*	Pulpwood *Cel. dr.*
Minimum diameter *Najmanji promjer*	cm	35	25	20	20	9	7
Minimum length *Najmanja duljina*	m	2	4	4	3	1.5	1
Volume *Obujam*	m^3	0.19	0.19	0.13	0.09	0.01	0.004

The values of volumes of individual quality classes lower than the minimum assortment volumes were detected in the assortment structure of mean trees of diameter classes, which is unacceptable for data processing.

For these reasons, a regression analysis of quality class volumes was done in dependence on breast diameter based on the assortment structure of all trees.

The regressed values of a quality class are shown in diameter classes, where they appeared in the sample, and the regression line was chosen not only with statistical criteria, but attention was paid to the fact that the value of an individual quality class satisfies the minimal timber volume value of this class.

With regard to the requirement for minimal assortment volumes in a quality class, regression lines combined with reliable statistical parameters were chosen. The regression analysis was done with curves of the second order (parabolas) with or without a free member:

$$V = a_0 + a_1 d + a_2 d^2 \qquad \text{ili} \qquad V = a_1 d + a_2 d^2$$

(a_0, a_1, a_2 - coefficients of regression equation; d- breast diameter of tree; V- tree volume)

Coefficients of regression equation and correlation coefficients according to quality classes are shown in Table 13.

Table 13. Regression analysis data
Tablica 13. Podaci o regresijskoj analizi

Timber assortment *Drvni sortiment*	Coeficients of regression equation *Koeficijenti regresijske jednadžbe*			Statistical parameters *Statistički parametri*		Number of trees *Broj stabala*	
	a_0	a_1	a_2	R	R^2	possible *moguć*	real *stvarni*
Sawlogs I. *Pilanski trupci I.*	-0.10288	0.00481	0.00013	0.27	0.08	1375	614
Sawlogs II. *Pilanski trupci II.*		-0.00046	0.00035	0.46	0.21	1404	1108
Sawlogs III. *Pilanski trupci III.*		-0.00662	0.00052	0.52	0.27	1394	1240
Mining timber *Rudničko drvo*	0.55113	-0.01439	0.00010	0.46	0.22	1396	761
Pulpwood *Celulozno drvo*	0.123827	-0.00847	0.00017	0.45	0.20	1404	1258

Correlation indexes indicate poor connection among parameters and higher data dispersion, but the possibility of error in the data on quality class volume in the regression analysis was removed. Figures 23 to 27 show data relating to volumes of quality classes in dependence on tree breast diameter, as well as data regression lines.

The basic problem in the study of assortment structure stems from the fact that a certain number of trees do not contain assortments in all quality classes. In his work, Vuletić (1999) claims that this phenomenon leads to grouping the measured data into two separate sets, of which one represents real values, and the other lies on the x-axis and contains all values equalling zero. The values on the x-axis do not indicate low tree quality; rather, they indicate its incomplete assortment structure, because a tree may contain only one or two assortments and still have very high quality. The author calls zero values on the x-axis false zeros, because although their volume values equal zero, a certain quality class may be expected from the trees in view of their breast diameters.

Sawlogs in quality class I with the lowest minimal diameter of 25 cm occur in trees in the diameter class of 32.5 cm, or more accurately, from breast diameters of 34 cm. It is assumed that trees with breast diameters over 34 cm yield sawlogs in quality class I, and so do all other trees in the diameter class 32.5 cm. In the regression analysis, it was assumed that sawlogs in quality class I may be expected from all trees in diameter class 32.5 cm and more. Timber assortment in the mentioned quality class occurs on only 614 trees, although this assortment could be obtained from 1,375 trees in view of their breast diameters.

Figure 23. Dependence of sawlog volume in I. quality class on DBH

Slika 23. Obujam pilanskih trupaca I. razreda kakvoće ovisno o prsnom promjeru

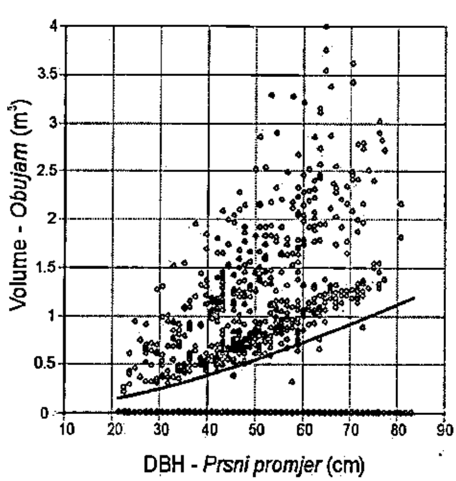


Figure 24. Dependence of sawlog volume in II. quality class on DBH

Slika 24. Obujam pilanskih trupaca II. razreda kakvoće ovisno o prsnom promjeru

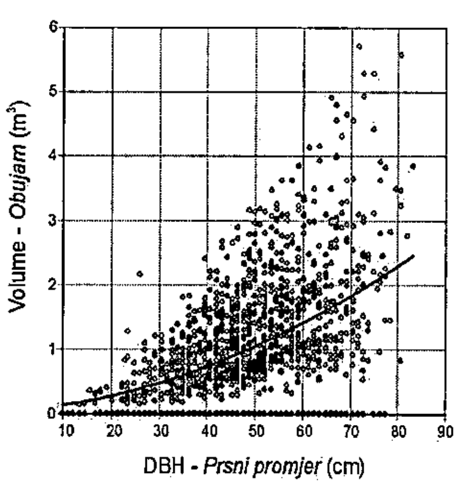


Figure 25. Dependence of sawlog volume in III. quality class on DBH

Slika 25. Obujam pilanskih trupaca III. razreda kakvoće ovisno o prsnom promjeru

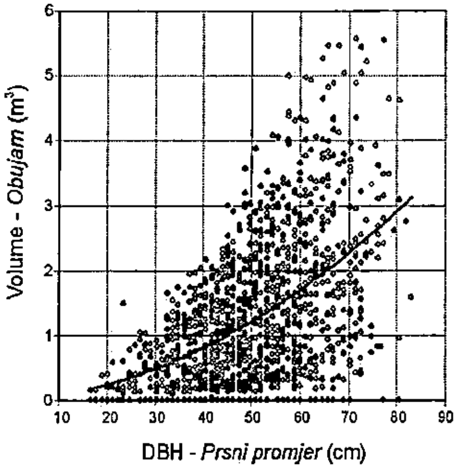


Figure 26. Dependence of mining timber volume on DBH

Slika 26. Obujam rudničkog drva ovisno o prsnom promjeru

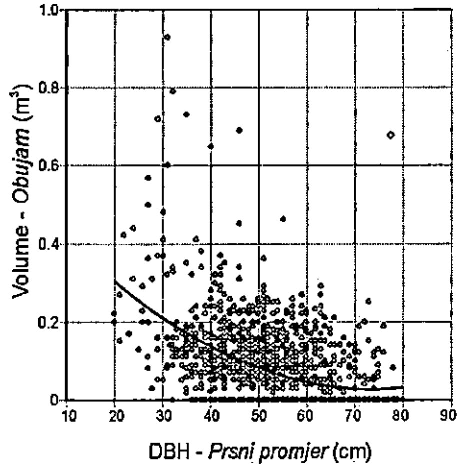
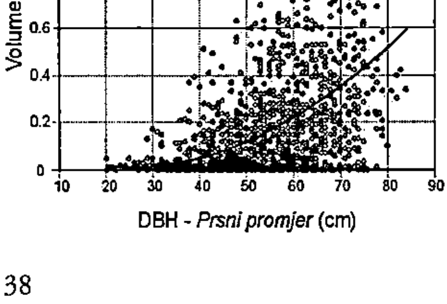


Figure 27. Dependence of pulpwood volume on DBH

Slika 27. Obujam celuloznog drva ovisno o prsnom promjeru



In terms of breast diameter, sawlogs in quality class II may be expected in all sample trees; however, they were measured only in 1,108 trees. Sawlogs in quality class III occur from breast diameter of 26 cm, or diameter class of 27.5 cm upward. A total of 1,240 trees with quality class III sawlog assortment were measured.

Mining timber in the sample was not measured in any tree in the last diameter class of 82.5 cm; therefore, these trees were not included in the regression analysis. Of 1,396 trees in all, mining timber was measured in 761 trees.

Pulpwood was registered in all diameter classes, but was measured on 1,258 trees. The values of pulpwood volumes in other trees are considered false zeros.

Table 14. Regressed assortment volume values of sample trees according to diameter and quality classes

Tablica 14. Izjednačene vrijednosti drvnog obujma sortimenata stabala uzorka po razredima kakvoće i debljinskim razredima

Diameter class *Debljinski razred*	Timber assortment - *Drvni sortimenti*						Processed volume (tables) *Iskoristivi obujam (tablice)*	Diference *Razlika*
	Sawlogs I. class *Pilanski trupci I*	Sawlogs II. class *Pilanski trupci II*	Sawlogs III. class *Pilanski trupci III*	Mining timber *Rudničko drvo*	Pulpwood *Celulozno drvo*	Total *Ukupno*		
cm	m^3						m^3	
22.5		0.17		0.28	0.02	0.46	0.43	-0.03
27.5		0.25	0.21	0.23	0.02	0.71	0.68	-0.03
32.5	0.19	0.36	0.33	0.19	0.03	1.09	0.98	-0.11
37.5	0.25	0.48	0.48	0.15	0.04	1.41	1.34	-0.07
42.5	0.33	0.61	0.66	0.12	0.07	1.79	1.75	-0.04
47.5	0.41	0.77	0.86	0.09	0.10	2.23	2.21	-0.02
52.5	0.49	0.94	1.09	0.07	0.14	2.73	2.73	0.00
57.5	0.59	1.13	1.34	0.05	0.19	3.30	3.30	0.00
62.5	0.69	1.34	1.62	0.04	0.25	3.93	3.93	0.00
67.5	0.79	1.57	1.92	0.03	0.31	4.63	4.61	-0.02
72.5	0.90	1.81	2.25	0.03	0.39	5.39	5.35	-0.04
77.5	1.02	2.07	2.61	0.03	0.47	6.21	6.14	-0.07
82.5	1.15	2.35	2.99		0.56	7.05	6.99	-0.07

Timber volume of sawlogs rises with an increase in tree breast diameter for all quality classes. The volume of sawlogs in quality class I ranges from 0.19 m^3 for diameter class 32.5 cm to 1.15 m^3 for diameter class 82.5 cm, while the volumes for quality class II range from 0.17 m^3 to 2.35 m^3 for all diameter classes of the sample. Sawlogs in quality class III occur from diameter class 27.5 cm and display the highest growth in volume values with an increase in breast diameter (from 0.21 m^3 to 2.99 m^3). The volume of this class has the highest values in the structure of volumes of mean trees from diameter class 42.5 cm to 82.5 cm (Table 14).

The volume of mining timber decreases from 0.28 m^3 to 0.03 m^3, and that of pulpwood increases from 0.02 m^3 to 0.56 m^3 for all diameter classes of the sample where recorded.

The sum of regressed quality class volumes of diameter classes was compared with processed timber volumes according to one-entry tables. The total processed volume in terms of assortment structure is slightly higher than the table volume, and the differences vary in values by 0.11 m^3. For diameter classes from 47.5 cm to 67.5 cm, there are no differences or they are very small (0.02 m^3), which indicates a sufficient number of trees of these diameter classes in the sample. In the distribution of breast diameters of sample trees, the curve ends are questionable due to an insufficient number of the thinnest and the thickest trees. However, with regard to cutting maturity of fir trees in the studied management unit (70 cm) and the principles of selective cutting, it is very hard to ensure a statistically sufficient number of trees with breast diameters less than 40 cm and more than 70 cm. If these criteria were satisfied, the comparison of assortment structure with one-entry tables of processed timber volume would probably be more accurate. Although the regression analysis of all values is not sufficiently reliable in terms of statistics due to data dispersion within diameter classes, the results are still applicable because of regular data sequences.

Based on volume values of quality and diameter classes, proportionate values were constructed (Table 15)

Sawlogs in quality class II assume the highest values in the first two diameter classes of the sample (36.18 % and 35.53 %). After that, the proportion varies slightly with an increase in breast diameters (32.69 % in diameter class 32.5 cm, 34.59 % in diameter class 47.5 cm and 33.35 % in diameter class 82.5 cm). The proportions in quality class III rise from 29.66 % to 42.43 % with an increase in tree breast diameters.

The proportion of mining timber is the highest in diameter class 22.5 cm (59.96 %). With an increase in breast diameters, it decreases to as much as 0.51 % in diameter class 77.5 cm. The proportions of pulpwood are below 8 % for all diameter classes of the sample. The lowest values were recorded in diameter class 32.5 (2.31 %), and the highest in diameter class 82.5 cm (7.98 %).

Table 15. Proportion of regressed values of sample tree assortment volumes according to diameter and quality classes

Tablica 15. Postotni udjeli izjednačenih vrijednosti drvnog obujma sortimenata stabala uzorka po razredima kakvoće i debljinskim razredima

Diameter class *Debljinski razred*	Timber assortment - *Drvni sortimenti*					
	Sawlogs I. class *Pilanski trupci I*	Sawlogs II. class *Pilanski trupci II*	Sawlogs III. class *Pilanski trupci III*	Mining timber *Rudničko drvo*	Pulpwood *Celulozno drvo*	Total *Ukupno*
cm	%					
22.5		36.18		59.96	3.86	100
27.5		35.53	29.66	32.37	2.43	100
32.5	17.04	32.69	30.67	17.29	2.31	100
37.5	18.04	33.91	34.36	10.75	2.94	100
42.5	18.36	34.45	36.85	6.66	3.69	100
47.5	18.32	34.59	38.55	4.11	4.43	100
52.5	18.10	34.53	39.72	2.53	5.12	100
57.5	17.80	34.36	40.53	1.57	5.74	100
62.5	17.46	34.14	41.11	1.00	6.29	100
67.5	17.12	33.89	41.52	0.69	6.78	100
72.5	16.78	33.64	41.82	0.55	7.21	100
77.5	16.46	33.40	42.04	0.51	7.59	100
82.5	16.25	33.35	42.43		7.98	100

VALUE ANALYSIS
VRIJEDNOSNA ANALIZA

The value of timber and timber assortments changes in accordance with changes in the society and in market and economic relationships, with the application of new technologies and with the effects of other factors. The resulting problem entails finding a unit that will represent the perpetual value of assortments. Monetary units are not suitable. The value of assortments is better expressed with a ratio which expresses relative value relationships of individual assortment classes (Rebula 1996).

Relative relationships used in research to date have been called *quality numbers* (Plavšić 1967), *value ratio* (Svetličić 1983), *value coefficient* (Svetličić 1983, Čop 1983), and others, among which the German *measuring numbers* (Messzahlen) are the best known.

Determining monetary value of trees is based on the structure of quality class volume and the tariffs for main forest products on the home market; A - 02.01, "Hrvatske šume" p.o. Zagreb. To calculate monetary tree value, the price of timber assortments on the stump was used. According to the tariffs, the monetary value of assortments was classified by mean diameters of sawlogs (mean diameter up to 39 cm, mean diameter from 40 to 49 cm, and mean diameter over 50 cm).

Therefore, in analysing monetary values, sample trees had to be divided according to the above classification so that the tariffs could be accurately applied. Trees with breast diameters up to 39 cm can only contain logs with the same mean diameter at most. Breast diameter of trees is taken 1.3 m from the ground. When a tree is felled, the stump height is assumed to be 30 cm at most. The first log with a minimal length of 2 m is found on the stem 0.3 to 2.3 m from the ground; in other words, the mean diameter of the first log is at the point of breast diameter. Logs with mean diameters exceeding the breast diameter cannot be made from these trees since the minimal log length is 2 m. For this reason, monetary values are taken from the tariff that relate to the above diameter assortment degree according to quality classes.

Trees with breast diameters from 40 to 49 cm can contain assortments with mean diameters to 49 cm. To analyse the monetary value of these trees, the arithmetic mean is taken from the tariff of the values of the first two diameter degrees of assortments. The same procedure is applied to the thickest trees.

Table 16. Average prices of timber assortments and value coefficients
Tablica 16. Prosječne cijene drvnih sortimenta i vrijednosni koeficijenti

DBH *Prsni promjer stabla*	Average prices of timber assortments *Prosječne cijene drvnih sortimenata*				
	Sawlogs I. class *Pilanski trupci I*	Sawlogs II. class *Pilanski trupci II*	Sawlogs III. class *Pilanski trupci III*	Mining timber *Rudničko drvo*	Pulpwood *Celulozno drvo*
cm	kn/m^3				
20-39	321.40	235.88	139.24	190.30	164.50
40-49	369.70	273.50	164.77	190.30	164.50
> 50	418.00	311.11	190.30	190.30	164.50
	Value coefficient - *Vrijednosni koeficijent*				
20-39	1.03	0.76	0.45	0.61	0.53
40-49	1.19	0.88	0.53	0.61	0.53
> 50	1.34	1.00	0.61	0.61	0.53

Value coefficients were calculated from the obtained monetary values of assortments for diameter classes in the tariff. The value coefficient of 1.00 was chosen for sawlog quality class II of trees with breast diameters exceeding 50 because the proportion of this quality class and tree diameter in the sample was the highest. For other diameter and quality classes, the value coefficient is a ratio of monetary class value and monetary values of sawlog quality class II of trees with breast diameters exceeding 50 cm.

Value coefficients were multiplied with values of quality class volumes. Value coefficients for trees to 39 cm breast diameter were applied to diameter classes reaching 37.5 cm. For diameter classes 42.5 cm and 47.5 cm, value coefficients of trees with breast diameters from 40 to 49 cm were used, and for the next diameter classes, value coefficients of trees with breast diameters exceeding 50 cm were used.

Value analysis was based on processed assortment structures of diameter classes. Based on the assortment volume by quality classes and value coefficients, stem values and values per timber volume unit were determined for each diameter class.

Stem value represents the sum of products of quality class volumes and the associated value coefficients. It shows the amount by which the value of stem timber volume (the sum values of all assortments) is higher than 1 m^3 sawlog assortment in class II of a given diameter class.

Value per timber volume unit is the value of 1 m^3 of all processed stem assortments, expressed with the quotient of stem value and total processed timber volume of the tree.

Stem value increases with an increase in tree breast diameter and ranges from 0.27 to 6.18 for breast diameters from 20 cm to 84 cm. A rise in breast diameters is accompanied by a rise in the height of trees and the length of stem. A longer stem provides larger processed volume, which leads to a higher value of the stem.

The value per unit of timber volume changes irregularly with tree thickness, which is the consequence of the absence of some quality classes in the thinnest tree class and of classifying monetary values according to assortment diameter.

The value per timber volume unit in diameter class 22.5 cm is 0.661 and is higher than the value in diameter class 27.5 cm (0.613). The assortment structure of diameter class 22.5 cm does not contain any sawlogs in quality class III, but it contains a large proportion of mining timber.

Judging from the average prices of timber assortments (Table 16), the price of mining timber of trees with breast diameters to 39 cm is higher than the price of sawlogs in class II. The difference in the assortment structure of diameter classes and the relations of prices of assortments in certain quality classes has led to the lowest value per unit of timber volume in diameter class 27.5 cm.

Trends in values per timber volume unit of diameter classes show value grouping in terms of division of assortments into diameter classes according to the tariff. Thus, in trees with breast diameters less than 39 cm, the value per timber volume unit changes distinctly with breast diameter, in trees with diameter classes 42.5 cm and 47.5 cm it is almost identical (0.775 and 0.776), while the value per timber volume unit in the thickest trees (diameter classes from 52.5 upwards) exceeds 0.85.

Table 17. Values of stem and timber according to diameter classes
Tablica 17. Vrijednost debla i drva po debljinskim razredima

Diameter class *Debljinski razred*	Timber assortment - *Drvni sortimenti*					Value - *Vrijednost*	
	Sawlogs I. class *Pilanski trupci I*	Sawlogs II. class *Pilanski trupci II*	Sawlogs III. class *Pilanski trupci III*	Mining timber *Rudničko drvo*	Pulpwood *Celulozno drvo*	stem *debla*	timber *drva*
cm	m^3						
22.5		0.17		0.28	0.02	0.31	0.661
27.5		0.25	0.21	0.23	0.02	0.44	0.613
32.5	0.19	0.36	0.33	0.19	0.03	0.74	0.679
37.5	0.25	0.48	0.48	0.15	0.04	0.95	0.679
42.5	0.33	0.61	0.66	0.12	0.07	1.39	0.776
47.5	0.41	0.77	0.86	0.09	0.10	1.73	0.775
52.5	0.49	0.94	1.09	0.07	0.14	2.39	0.874
57.5	0.59	1.13	1.34	0.05	0.19	2.88	0.871
62.5	0.69	1.34	1.62	0.04	0.25	3.41	0.867
67.5	0.79	1.57	1.92	0.03	0.31	4.00	0.863
72.5	0.90	1.81	2.25	0.03	0.39	4.63	0.859
77.5	1.02	2.07	2.61	0.03	0.47	5.31	0.856
82.5	1.15	2.35	2.99		0.56	6.02	0.853

In diameter classes from 52.5 upwards, the value per timber volume unit mildly drops with an increase in tree breast diameter. The highest value per unit of timber volume is shown in diameter class 52.5 cm and amounts to 0.874, and falls slightly to 0.853 in diameter class 82.5 cm. The effects of the above value trend per unit of timber volume is the result of a faster rise of the volume in sawlog quality class III with an increase in breast diameter compared to sawlogs of higher quality.

According to the value analysis based on the currently valid tariff of "Hrvatske šume" p.o. Zagreb, trees in diameter class 52.5 cm achieve the highest value per unit of timber volume.

Recent research into values of fir trees has shown identical or similar patterns, which are in contradiction with the earlier research into fir trees in Gorski Kotar. Plavšić (1967) finds the highest values of fir trees in diameter classes 72.5 cm, whereas Golubović (1967) finds that trees in diameter classes 62.5 cm and 67. 5 cm are the economically most profitable for sawmill processing. However, Rebula (1996) claims that the value per unit of timber volume increases rapidly with thickness, but reaches its maximum at breast diameter between 40 cm and 50 cm, to decrease after that. Knoke (1997) finds that the relative value of logs with large mean diameters in comparison with logs with smaller mean diameters decreases as breast diameter increases.

FELLING MATURITY OF FIR TREES
SJEČIVA ZRELOST STABALA JELE

To manage selection forests, it is very important to know and apply the most suitable felling maturity of trees. The felling maturity of trees in a selection stand is expressed with breast diameters. Selection felling involves marking and felling trees above the determined diameter of felling maturity.

Determining felling maturity is important in forest management because of its effects on the quantity of annual harvesting volume. Depending on the method of determining felling maturity, there is biological and economical maturity.

Biological maturity includes the bottom and the top boundary. The bottom boundary is described with the smallest breast diameter at which trees begin to bear seed. The top boundary of biological maturity is the boundary of physical death of trees and is therefore not used in intensive management.

The economic felling maturity of trees is the result of commercial needs expressed in management goals (Plavšić 1967). A tree is mature for felling when its dimensions, shape or other characteristics are capable of satisfying a given need (Miletić 1960). To determine the economic felling maturity, there are material or financial indicators.

Material indicators express the following:

- production maturity of maximum timber volume yield – defined by breast diameters of trees with the highest average annual current increment,
- technical maturity – defined by breast diameter of trees whose processing achieves the highest percentage share of main assortments

Financial indicators express the following maturities:

- the maturity of the highest quality of tree timber volume – defined by breast diameter at which the highest mean price per timber volume unit is achieved
- production maturity of the most valuable yield of timber volume – defined by breast diameter at which the highest average value of annual current increments is achieved

- maturity of maximal profitability – defined by breast diameter at which maximal profitability of invested means is achieved
- maturity of the maximal forest rent – defined by breast diameter at which the maximal forest rent value is achieved

Technical maturity and the maturity of the maximal quality of timber volume is determined in forest exploitation.

Technical maturity at a diameter class of 42.5 cm (18.32 % of I class sawlogs in the processed timber volume) is based on the assortment structure and percentage values of the most valuable quality class. However, due to a small share of this quality class in the assortment structure, it is better to regard the total quantity of sawlogs in quality classes I and II as the most valuable assortments. In percentage relations, the sum of the two most valuable assortments achieves the highest value at the diameter class 47.5 cm (52.9 %).

The maturity of the maximal quality of tree timber volume indicates the diameter class at which quality begins to decline. This maturity is an indication of the need to remove from the stand overly strong fir trees, unless they are indispensable out of silvicaltural and protection measures (Plavšić 1967). Based on the value analysis of the assortment structure of diameter classes, the highest value per unit of timber volume is achieved at diameter class 52.5 cm.

In the management unit "Belevine", the felling maturity of trees is at breast diameters of 70 cm. The current felling maturity does not yield the highest quality of tree timber volume, or the highest value per timber volume unit. From the aspect of forest exploitation, the determined maturity of the maximal timber volume quality at diameter class 52.5 cm points to the need to decrease the felling breast diameter and consequently to manage selection forests more intensively. A decrease in breast diameters of trees to be felled would lead to the introduction of high technologies into forestry practice. However, in view of the small differences between the value of trees of felling maturity and trees in the diameter class 52.5 cm, a change in felling maturity should be justified with complex investigations into tree increment, silvicultural, ecological and protective characteristics of fir trees in this area so that the selection structure may be preserved.

CONCLUSIONS
ZAKLJUČCI

Research was based on a sample of 1,404 fir trees felled in regular felling of cutting cycle. All sample trees were sectioned in order to make accurate estimation of the volume of large wood (to 7 cm) over and under bark. Timber assortments were bucked, crosscut, measured and inspected in accordance with Croatian standars for roundwood.

The volume of trees with diameters to 7 cm over and under bark, as well as the processed tree timber volume, was shown in two-entry and one-entry tables. The values of timber volume increase with an increase in tree breast diameter and height. The constructed two-entry tables of timber volume for fir are of a local character. The sample of 1,404 fir trees, which were felled and processed in the same management unit, vouches for the accuracy in using these tables to determine the timber volume in the mentioned area.

Bark volume of the trees ranges from 12.45% to 10.67%. In trees with equal breast diameters, bark percentage decreases with an increase in tree height. The percentage of bark in trees of equal heights rises with an increase in breast diameter. Mean values of bark percentage decrease with an increase in tree breast diameter. Double bark thickness rises with an increase in tree diameter, while the percentage decreases.

The yield percentage assumes values between 81.7% and 83.0%, and decreases slightly with an increase in breast diameter.

Based on past research and on the studied sample, it can be concluded that veneer logs of fir in selection stands are very rare and are the result of a number of favourable factors, ranging from site, stand and climatic factors to genetic traits of individual trees.

Timber volume of sawlogs increases with an increase in tree breast diameter for all quality classes. In a regressed assortment structure, sawlogs in quality class I attain the highest values in the diameter class of 42.5 cm (18.4%) and sawlogs in quality class II attain the highest values in the group of thinnest sample trees (36.2%). Sawlogs in quality class III have the highest values in the volume structure from diameter class 42.5 cm to 82.5 cm. The share of mining timber is the highest in diameter class 22.5 cm (59.96%) and decreases to 0.51 % in the diameter class of 77.5 cm. The percentage share of pulpwood in all diameter classes is below 8 %.

The highest value per timber volume unit, determined on the basis of value coefficients and the volume structure of quality classes, is achieved at diameter class 52.5 cm and decreases slightly until diameter class 82.5 cm.

REFERENCES
LITERATURA

Bojanin, S., 1960: Učešće sortimenata i količine gubitaka kod sječe i izrade jelovih stabala u fitocenozi jele s rebračom. Šumarski list 84(1-2): 21-34.

Bojanin, S., 1966a: Debljina kore na raznim visinama od tla kod jelovih stabala. Drvna industrija 17(4-5): 76-84.

Bojanin, S., 1966b: Učešće kore kod jelove oblovine raznih debljina i njen odnos prema debljini stabala od kojih oblovina potječe. Drvna industrija 17(11-12): 187-195.

Božić, M., 1999: Modeli uređivanja jelovih šuma Gorskog kotara. Magistarski rad, Šumarski fakultet Sveučilišta u Zagrebu, 140 pp.

Božić, M., 2000: Kolika je stvarna zaliha jele u našim šumama? Šumarski list 124(3-4): 185-195.

Čop, B., 1983: Pilanska prerada i odnosi sa šumarstvom. Savez inž. i tehn. šumarstva i drvne industrije Hrvatske, Zagreb.

Emrović, B., 1960a: Dvoulazne tablice drvnih masa za jelu u Gorskom kotaru. Šumarski list 84 (11-12): 345-356.

Emrović, B., 1960b: O najpodesnijem obliku izjednačenja funkcije potrebne za računsko izjednačenje pri sastavu dvoulaznih drvno-gromadnih tablica. Glasnik za šumske pokuse 14: 49-126.

Emrović, B., 1972: Konstrukcija jednoulaznih tablica - tarifa (Tarife za jelu na silikatnoj podlozi). Glasnik za šumske pokuse 16: 123-157.

Hubač, K., 1973: Sortimentačne tabulky ihličnate dreviny. Priroda, Bratislava, 224 pp.

Kachigan, S. K., 1991: Multivariate statistical analysis – A conceptual introduction. Radius Press, New York, 303 pp.

Kirschner, R., 1976: Bark thickness of the major tree species of Tirol. Allgemeine Forstzeitschrift 32: 455-456.

Klepac, D., 1960b: O nekim normalama u jelovim prebornim šumama. Šumarski list 85 (3-4): 85-90.

Klepac, D., 1965: Uređivanje šuma. Znanje, Zagreb, 340 pp.

Klepac, D., 1972: Istraživanja o debljini i volumenu jelove kore u različitim fitocenozama. Glasnik za šumske pokuse 16: 105-122.

Knoke, T. 1997: Economic aspects of timber production in uneven-aged forests: preliminary studies on forest management planning in the Kreuzberg municipal forest. Forstwissenschaftliches Centralblatt. 116 (3): 178-196.

Križanec, R., 1987: Distribucija i projekcija krošanja u korelaciji s prsnim promjerom stabala u jelovim šumama. Disertacija, Šumarski fakultet Sveučilišta u Zagrebu, 399 pp.

Križanec, R., 1993: Uloga evidencije sječe u praćenju kretanja drvne zalihe preborne šume. Glasnik za šumske pokuse, pos. izd. 4: 111-120.

Krpan, A. P. B., 1986: Kora bukve s aspekta eksploatacije šuma. Zbornik radova "Kolokvij o bukvi" Velika, 22.-24. 11. 1984., Šumarski fakultet Zagreb, 77-88.

Krpan A.P.B., S. Govorčin & T. Sinković, 1995: Ispitivanje kojih fizičkih svojstava te kvalitete drva oštećenih stabala jele obične (Abies alba Mill.). Šumarski list 119(11-12): 391-406.

Krpan, A.P.B. & Pičman, D., 2001: Neka obilježja iskorištavanja hrvatskih jelovih šuma. Znanstvena monografija "Obična jela (Abies alba Mill.) u Hrvatskoj", Akademija šumarskih znanosti, Zagreb, pp. 659-687.

Kružić, T., 1993a: Primjena jednoulaznih tablica u inventarizaciji šuma. Glasnik za šumske pokuse pos. izd. 4: 139-146.

Kružić, T., 1993b: Izbor regresijskog modela za izjednačenje drvno-gromadnih tablica. Glasnik za šumske pokuse 98: 149-198.

Kump, M. et al., 1970: Poljski pokusi (Metodika postavljanja i statistička obrada). Centar za primjenu nauka u poljoprivredi SR Hrvatske, Zagreb, 86 pp.

Lipoglavšek, M. 1996: Določanje kakovosti proizvodov. Zbornik savjetovanja "Izzvi gozdne tehnike" Ljubljana, Slovenija, pp. 67-72.

Macek, J. & Korinek, J., 1972: Volume tables for unbarked Spruce and Fir sawlogs. Drevo 27 (6): 156-159.

Matić, S., Oršanić, M. & Anić, I., 1996: Neke karakteristike i problemi prebornih šuma obične jele, Šumarski list 120(3-4): 91-100.

Meštrović, Š., 2001: Uređivanje šuma obične jele. Znanstvena monografija "Obična jela (Abies alba Mill.) u Hrvatskoj", Akademija šumarskih znanosti, Zagreb, pp. 529-560.

Mikhov, I., 1980: The assortments structure of the growing stock. Nauchni trudove 25: 67-71.

Miletić, Ž., 1960: Zrelost stabala za seču u prebirnoj šumi. Glasnik Šumarskog fakulteta (Univerzitet u Beogradu) 20: 1-34.

Petraš, R. & Nociar V., 1991: Nové sotrimentačné tabul'ky hlavnych ihličnatych drevin. Lesnicky časopis 37 (5): 377-392.

Petraš, R., 1992: Matematicky model sortimentačnych tabuliek hlavnych drevin. Lesnicky časopis 38 (4): 323-332.

Plavšić, M. & Golubović, U., 1963: Istraživanje postotnog odnosa sortimenata kod jele (*Abies alba* Mill.). Šumarski list 87(9-10): 367-388.

Plavšić, M., 1967: Istraživanje sadašnje najpovoljnije sječive zrelosti u jelovim prebornim šumama. Studija Zavoda za ekonomiku i organizaciju šumske privrede i drvne industrije. Šumarski fakultet Sveučilišta Zagrebu. 114 pp.

Pranjić, A., 1990: Šumarska biometrika. Sveučilišna naklada Liber, Zagreb, 204 pp.

Pranjić, A. & Lukić, N., 1997: Izmjera šuma. Udžbenik. Šumarski fakultet Sveučilišta u Zagrebu, 405 pp.

Prpić, B. & Seletković, Z., 1996: Istraživanja u hrvatskim prašumama i korišćenje rezultata u postupku s prirodnom šumom. Skrb za hrvatske šume od 1846. do 1996., Knjiga 1: Unapređenje proizvodnje biomase šumskih ekosustava, Hrvatsko šumarsko društvo, Zagreb, pp 97-104.

Rebula E., 1994b: Sortimentne i vrijednosne tablice za deblovinu jele. Mehanizacija šumarstva 21 (4): 201-222.

Rebula, E., 1996: Uporabnost prirejenih Alganovih in Schaefferjevih ter Vmesnih tarif za računanje lesne mase naše jelke. Gozdarski vestnik 54 (10): 480-501.

Rebula, E., 1998a: Vpliv debeline in višine jelovega drevesa na njegovo vrednost in donosnost. Zbornik referata, XIX gozdarski študijski dnevi. pp. 191-205.

Rebula, E., 1998b: Vrednost jelovih hlodov, njeni kazalci in njihova uporabnost pri razvrščanju hlodov. Zbornik gozdarstva i lesarstva 55: 151-200.

Schoper, W. & Dauber, E., 1989: Bestandessortenttafeln. Mitteilungen der Forstlichen und Versuchs und Forschungsanstalt, Baden-Wurttemberg, 33 pp.

Serdar, V. & Šošić, I., 1981: Uvod u statistiku. Školska knjiga Zagreb, 452 pp.

Sterba, H., Kleine, M. & Eckmullner, O., 1986: Sortentafeln fur Tanne, Larche, Kiefer und Buche. Osterreucher Agrarverlag, Vienna, 182 pp.

Svetličić, A., 1983: O soodvisnosti gozdnega i lesnoga gospodarstva s posebnim ozirom na medsebojna in ekonomska razmerja med proizvodnjo hlodov in žaganim lesom smreke, jele in bukve - 1. del. Strokovna in znanstvena dela 70, Biotehniška fakulteta, Ljubljana.

Šafar, J., 1981: Drveće naših šuma. Monografija "Gorski kotar", Delnice, pp. 505-509.

Špiranec, M., 1976: Tablice drvnih masa jele i smreke. Radovi 29, Šumarski institut Jastrebarsko, 119 pp.

Šurić, S., 1949: Jednoulazne tablice drvnih masa za jelu - smreku i za bukvu. Mali Šumarski tehnički priručnik, Zagreb.

Vidaković, M., 1993: Četinjače, morfologija i varijabilnost. Grafički zavod Hrvatske i JP"Hrvatske šume" Zagreb, 741 pp.

Vukelić, J., Rauš, Đ., 1998: Šumarska fitocenologija i šumske zajednice u Hrvatskoj. Šumarski fakultet Sveučilišta u Zagrebu, 310 pp.

Vuletić, D., 1999: Prilog poznavanju sortimentne strukture hrasta lužnjaka (*Quercus robur* L.) u EGT-u II-G-10. Radovi 34 (2): 5-22.

www.hrsume.hr

* CD-ROM: Forestry compendium. Global module. CAB International, Wallingford, Oxon, UK, 1999.

* Cjenik šumskih proizvoda. J.P. "Hrvatske šume" p.o. Zagreb, 2001.

* Hrvatske norme proizvoda iskorištavanja šuma. II izdanje, Državni zavod za normizaciju i mjeriteljstvo, Zagreb, 1995.

* Osnova gospodarenja G. J. "Belevine", 1999-2009.

NEKE ZNAČAJKE KAKVOĆE STABALA OBIČNE JELE (*ABIES ALBA* MILL.) U GOSPODARSKOJ JEDINICI "BELEVINE" NASTAVNO-POKUSNOG ŠUMSKOG OBJEKTA ZALESINA

SAŽETAK

Rad prikazuje rezultate istraživanja značajki kakvoće stabala obične jele (*Abies alba* Mill.) provedenih na području prebornih šuma Gospodarske jedinice "Belevine" Nastavno-pokusnog šumskog objekta Zalesina Šumarskog fakulteta u Zagrebu. Gospodarsku jedinicu "Belevine" prekriva pretežito jelova šuma s rebračom (*Blechno-Abietetum* Ht. 1950).

Osnovu istraživanja predstavlja uzorak od 1 404 stabla jele koja su posječena u redovnoj sječi etata ophodnjice. Stabla iz sanitarne sječe nisu uzeta u uzorak. Prsni promjeri stabala uzorka su se kretali u rasponu od 20 cm do 85 cm tj. stabla su razvrstana u 13 debljinskih razreda od 22,5 cm do 82,5 cm. Visine stabala kretale su se u rasponu od 12 m do 40 m. Stabla jele su mjerena nakon obaranja i kresanja grana. Sekcioniranje je stabla u svrhu preciznog utvrđivanja obujma krupnog drva s korom i bez kore provedeno na svim stablima uzorka. Drvni sortimenti su prikrajani, trupljeni, mjereni i preuzimani u skladu s hrvatskim normama za oblo drvo.

Svi podaci mjerenja su uneseni u terenske obrasce, a potom u računalne datoteke radi lagane dostupnosti pri obradi podataka. Obrada podataka je izvršena na temelju mjerenih i izračunatih veličina značajki stabala uzorka. Za svako stablo unošeni su podaci iz obrazaca sekcioniranja stabla koji prikazuju srednje promjere sekcija s korom i bez kore na određenoj udaljenosti od panja i dvostruke debljine kore na mjestu izmjere. Na osnovu su podataka izračunati: srednji promjeri svake sekcije s korom i bez kore, dvostruke debljine kore na mjestu srednjih promjera svake sekcije, obujmi sekcija s krom i bez kore te sumiranjem obujama svih sekcija stabla ukupni obujmi stabala s korom i bez kore.

Izračunati drvni obujmi sortimenata sumirani su po razredima kakvoće za svako stablo. Sumiranjem svih drvnih obujama sortimenta stabla izračunava se iskorišteni obujam stabla. Odnos iskorištenog i ukupnog obujma stabla izražava iskorištenje stabla pri sječi i izradbi, a razlika navedenih obujama prikazuje količinu otpada pri sječi i izradi.

Iz podataka sekcioniranja stabala unošenih u računalo izdvojeni su podaci o mjerenju svake sekcije. Ova baza podataka sadrži srednje promjere sekcija s korom, visinu promjera sekcije od panja, dvostruku debljinu kore na sredini sekcije te prsni promjer i visinu stabla na kojem se određena sekcija nalazi. Izrađena baza podataka čini osnovu za istraživanje debljine kore u ovisnosti o debljini debla. Sva stabla opisana navedenim značajkama tvore osnovnu bazu podataka. Izrada dvoulaznih i jed-

noulaznih tablica obujma stabala, obujma i postotka kore stabala i sortimentnih tablica temeljila se na matematičko-statističkoj obradi osnovne baze podataka. Podaci su podvrgnuti regresijskim analizama s jednom ili više nezavisnih varijabli kako bi se utvrdila funkcionalna ovisnost između značajki stabala te prikazala kakvoća stabala.

Na osnovu izmjerenih visina izrađena je visinska krivulja stabala uzorka primjenom Mihajlove funkcije. Visinska je krivulja uzorka stabala uspoređena s visinskom krivuljom preuzetom iz Osnove gospodarenja (* 1999) za Gospodarsku jedinicu "Belevine" te su za sve debljinske razrede utvrđene vrlo male razlike vrijednosti visina stabala (Tablica 5). Provedenim t-testom održala se hipoteza da ne postoji razlika između navedenih vrijednosti ($t_{0,05} = 0,115$) te se potvrđuje ispravnost odabira stabala uzorka.

Izrađene dvoulazne tablice iskazuju ovisnost drvnog obujma, obujma i postotka kore i postotka iskorištenja o prsnom promjeru i visini stabala. Drvni obujam stabala prikazan je dvoulaznim tablicama na osnovu izjednačenja podataka obujma stabala Schumacher-Hallovom jednadžbom. Izjednačenjem se podataka obujma stabla s korom i bez kore te iskorištenog obujma u ovisnosti o prsnom promjeru stabala postigla potpuna korelacija podataka prema Roemer-Orphal-ovoj skali (vrijednosti koeficijenta korelacije 0,97). Obujam stabala je obujam krupnog drva s korom i bez kore te iskoristivi drvni obujam stabala. Prikazani je opseg prsnih promjera i visina stabala u dvoulaznim tablicama određen prema evidentiranim i izmjerenim vrijednostima na uzorku stabala te predstavlja granične vrijednosti tih parametara. Vrijednosti se drvnog obujma u tablicama povećavaju s povećanjem prsnog promjera i visine stabala (Slika 5, 7, 9). Pri istom prsnom promjeru i visini stabla najveće vrijednosti prikazuje drvni obujam stabla do 7 cm promjera s korom, zatim drvni obujam stabala do 7 cm promjera bez kore, a najmanje vrijednosti iskazuje iskoristivi drvni obujam stabla. U promatranom opsegu drvni obujam do 7 cm s korom se kreće od 0,216 m^3 za stabla 20 cm prsnog promjera i 12 metara visine do 10,167 m^3 za stabla 85 cm prsnog promjera i 40 m visine. Za navedena stabla drvni obujam do 7 cm bez kore kreće se od 0,189 m^3 do 10,030 m^3, a iskoristivi drvni obujam od 0,177 m^3 do 9,301 m^3.

Izrađene tablice drvnog obujma stabala jele su lokalnog karaktera. Uzorak od 1 404 stabla jele posječenih i izrađenih u istoj gospodarskoj jedinici jamče nam točnost pri korištenju tih tablica za određivanje obujma stabla na navedenom području.

Tablice su obujma i udjela kore stabala izračunate iz vrijednosti drvnog obujma sa i bez kore iz dvoulaznih tablica. Obujam kore stabla raste s povećanjem prsnog promjera i visine stabala te poprima vrijednosti od 0,03 m^3 kod stabala 20 cm prsnog promjera i visine 12 m do 1,12 m^3 kod stabala 85 cm i 40 m visine (Slika 10). Postotni se udio kore na temelju izjednačenih vrijednosti drvnog obujma stabala do 7 cm promjera s i bez kore kreće u granicama od 12,45 % do 10,67 % (Slika 11). Kod stabala istog prsnog promjera, postotak kore opada s porastom visine stabala.

Stabla jednake visine imaju veći postotak kore što im je veći prsni promjer. Srednje vrijednosti postotka kore opadaju s porastom prsnog promjera stabla.

Na osnovu vrijednosti tablica iskorištenog drvnog obujma stabla i ukupnog drvnog obujma stabala do 7 cm promjera s korom određeni su postoci iskorištenja pri sječi i izradi. Postotak iskorištenja poprima vrijednosti u rasponu od 81,7 % do 83,0 % za opseg prsnih promjera i visina iz dvoulaznih tablica drvnog obujma (Slika 12). Postotak iskorištenja se povećava s porastom visine kod stabla istih prsnih promjera. Stabla iste visine imaju manji postotak iskorištenja što im je veći prsni promjer.

Za izradu jednoulaznih tablica upotrebljeni su isti podaci sekcioniranja stabala kao kod izrade dvoulaznih tablica drvnog obujma. Izjednačenje podataka prikazanih na slikama od 15 do 17 je izvršeno krivuljom drugoga reda (parabola), koja se u literaraturi navodi kao Hohenadl-Krenov model (Kružić 1993a). Izjednačeni su podaci o obujmima stabala do 7 cm promjera s korom i bez kore te iskorištenog obujma. Pri svim su izjednačenjima dobiveni jednaki koeficijenti korelacije i to 0,94.

Prema jednoulaznim tablicama, drvni obujam do 7 cm promjera s korom se kreće od 0,401 m^3 za stabla 20 cm prsnog promjera do 8,790 m^3 za stabla 85 cm prsnog promjera. Za iste se prsne promjere stabala drvni obujam do 7 cm promjera bez kore kreće od 0,352 m^3 do 7,822 m^3, a iskoristivi drvni obujam od 0,332 m^3 do 7,252 m^3.

Tablice obujma kore su izrađene iz izračunatih vrijednosti obujma kore pojednih stabala. Obujam kore stabla predstavlja razliku između obujma stabla s i bez kore dobiven sekcioniranjem. Pri izjednačenju podataka korišten je isti analitički izraz te postignut koeficijent korelacije 0,87 (Slika 19). Obujam kore se povećava s rastom prsnog promjera te iznosi od 0,049 m^3 za stabla prsnog promjera 20 cm do 0,968 m^3 za stabla prsnog promjera 84 cm.

Iskorištenje pri sječi i izradi prema jednoulaznim tablicama se u postotnim vrijednostima neznatno smanjuje s povećanjem prsnog promjera. Za opseg stabala prsnog promjera od 20 cm do 84 cm postotak iskorištenja opada od 82,72 % do 82,50%.

Na osnovu izmjere 14 614 sekcija postavljeni su parovi podataka srednjih promjera sredina sekcija i dvostruke debljine kore. Istraživanje je provedeno s ciljem određivanja ovisnosti dvostruke debljine kore o promjeru drva. Pri regresijskoj analizi podataka odabrana je krivulja drugog reda (parabola) pri čemu je postignut koeficijent korelacije od 0,7 (Slika 22).

Odbijanjem dvostruke debljine kore od promjera drva s korom određeni su promjeri drva bez kore te izračunate temeljnice za promjere s korom i bez kore. Postotak kore je određen prema temeljnicama s korom i bez kore na određenom promjeru drva.

Dvostruka debljina kore raste s povećanjem promjera drva, a postotak opada. Kod 10 cm promjera drva iznosi 1,16 cm, a kod 84 cm promjera drva 3,16 mm. Postotak kore najveći je kod promjera drva od 20 cm (21,8 %), izrazito opada s povećanjem promjera te kod promjera drva 84 cm iznosi 7,4 %.

Kod pilanskih trupaca I. i II. razreda kakvoće, najmanjeg srednjeg promjera prema normama od 25 cm, postotak kore približno iznosi 10 %. Za pilanske trupce III. razreda kakvoće treba očekivati malo viši postotak kore zbog dopuštenog najmanjeg srednjeg promjera od 20 cm. Postoci se kore na rudničkom i celuloznom drvu nalaze u granicama od 21,8 % do 13 %.

Iz posječenih stabla jele izrađeni su drvni sortimenti te razvrstani prema hrvatskim normama za oblo drvo u slijedeće razrede kakvoće: furnirski trupci, pilanski trupci (I., II. i III. razred kakvoće), rudničko drvo i celulozno drvo. Na osnovu izmjere sortimenata utvrđen je njihov obujam te su sumirani obujmi sortimenta po razredima kakvoće i stablu (Tablica 10). Ukupno je izrađeno 4 319,31 m^3 drvnih sortimenata.

U uzorku se pojavljuje svega dvanaest furnirskih trupaca razvrstanih u sedam debljinskih razreda. Ukupni obujam furnirskih trupaca čini svega 9,24 m^3 ili 0,23 % od ukupno izrađenog obujma. Plavšić & Golubović (1963), pri istraživanju postotnog odnosa jelovih sortimenata u uzorku od 1607 stabala, nisu evidentirali niti jedan furnirski trupac. Rebula (1996) također pri izradi sortimentnih tablica deblovine jele ne spominje razred kakvoće furnirskih trupaca. Na osnovu prijašnjih istraživanja te istraživanog uzorka zaključuje se da su furnirski trupci kod jele u prebornim sastojinama vrlo rijetki te su rezultat velikog broja povoljnih čimbenika, od stanišnih, sastojinskih i klimatskih do genetskih svojstava pojedinih stabala. Iako su furnirski trupci najvrijedniji sortimenti zbog vrlo malih vrijednosti ne mogu se uvrstiti u istraživanje strukture sortimenata.

Pilanski trupci I. razreda pojavljuju se od debljinskog razreda 32,5 cm, točnije od prsnog promjera 34 cm. Pilanski trupci II. razreda kakvoće su izmjereni unutar svih debljinskih razreda uzorka. Debljinski razred 22,5 cm ne sadrži pilanske trupce III. razreda kakvoće već su izrađeni sortimenti razvrstavani u rudničko drvo, što možemo objasniti malim padom promjera tanjih stabala i prisustvom zdravih kvrga malih promjera. Rudničko drvo nije izmjereno niti na jednom stablu debljinskog razreda 82,5 cm, što se veže na činjenicu veće kvrgavosti ovršina te većeg pada promjera koji je eliminirajuća greška za taj razred kakvoće. Celulozno je drvo evidentirano u svim debljinskim razredima.

U strukturi su sortimenata srednjih stabala debljinskih razreda uočeni manji obujmi od obujama razreda kakvoće s obzirom na dopuštene najmanje dimenzije drvnog sortimenta prema normama za oblo drvo.

Iz navedenih je razloga izvršena regresijska analiza obujama razreda kakvoće u ovisnosti o prsnom promjeru na temelju sortimentne strukture svih stabala. Za regresijski su model odabrane krivulje drugog reda (parabole) s ili bez slobodnog člana ovisno o zahtjevu za postizanjem najmanjeg obujma razreda kakvoće izjednačenih vrijednosti. Izjednačene vrijednosti određenog razreda kakvoće su prikazane prema debljinskim razredima gdje su se pojavile u uzorku. Indeksi korelacije su ukazali na slabu povezanost parametara i veće rasipanje podataka, ali je otklonjena mogućnost greške podataka o obujmu razreda kakvoće u regresijskoj analizi (Tablica 13).

Osnovni problem koji se javlja pri istraživanju sortimentne stukture proizilazi iz činjenice da određeni broj stabala ne sadrži sortimente svih razreda kakvoće. Vuletić (1999) u svom radu tvrdi da je posljedica te pojave grupiranje izmjerenih podataka u dva odvojena oblaka od kojih jedan predstavlja prave vrijednosti, a drugi leži na x-osi i sadrži sve vrijednosti jednake nuli. Vrijednosti na x-osi nisu pokazatelj male kakvoće stabla već njegove nepotpune sortimentne strukture, jer stablo može sadržavati samo jedan ili dva sortimenta i biti visoke kakvoće. Nulte vrijednosti na x-osi autorica naziva nepravim nulama, jer se na stablima s obzirom na prsni promjer može očekivati izrada određenog razreda kakvoće.

Pilanski trupci I. razreda kakvoće s najmanjim srednjim promjerom od 25 cm pojavljuju se od debljinskog razreda 32,5 cm, točnije od prsnog promjera 34 cm. Pretpostavka je da se na stablima prsnog promjera većeg od 34 cm očekuje prisustvo pilanskih trupaca I. razreda kakvoće, kao i na ostalim stablima debljinskog razreda 32,5 cm. U regresijskoj analizi za pretpostavku je uzeto da se na svim stablima od debljinskog razreda 32,5 cm na više može očekivati izrada pilanskih trupaca I. razreda kakvoće. Navedeni je razred kakvoće izrađen na svega 614 stabala, iako se s obzirom na prsni promjer mogao izraditi na 1 375 stabala.

Pilanski trupci II. razreda kakvoće s obzirom na prsni promjer mogu se očekivati na svim stablima uzorka, ali su izmjereni na 1 108 stabala. Pilanski trupci III. razreda kakvoće se pojavljuju od prsnog promjera 26 cm u uzorku te broj stabala nižeg debljinskog razreda nismo uvrstili u broj stabala gdje se može pojaviti ovaj sortiment, već samo na svim stablima od debljinskog razreda 27,5 cm naviše. Ukupno je izmjereno 1 240 stabla sa sortimentom III. razreda kakvoće pilanskih trupaca.

Rudničko drvo u uzorku nije izmjereno niti na jednom stablu zadnjeg debljinskog razreda od 82,5 cm te navedena stabla nisu uključena u regresijsku analizu. Od ukupno 1 396 stabala rudničko je drvo izmjereno na 761 stablu.

Celulozno drvo je evidentirano u svim debljinskim razredima, ali je izmjereno na 1 258 stabala. Vrijednosti obujama celuloznog drva kod ostalih stabala smatramo nepravim nulama.

Drvni obujam pilanskih trupaca raste s povećanjem prsnog promjera stabla za sve razrede kakvoće. Obujam se pilanskih trupaca I. razreda kakvoće kreće u rasponu od 0,19 m^3 do 1,15 m^3, a za II. razred kakvoće pilanskih trupaca obujmi se kreću od 0,17 m^3 do 2,35 m^3 u rasponu svih debljinskih razreda uzorka. Pilanski trupci

III. razreda kakvoće iskazuju najveći rast vrijednosti obujma s povećanjem prsnog promjera (od 0,21 m^3 do 2,99 m^3). Obujam ovog razreda ima najveće vrijednosti u strukturi obujama srednjih stabala od debljinskog razreda 42,5 cm do 82,5 cm (tablica 14).

Obujam rudničkog drva opada od 0,28 m^3 do 0,03 m^3, a celuloznog drva raste od 0,02 m^3 do 0,56 m^3 u rasponu debljinskih razreda uzorka u kojima su zabilježeni.

Pilanski trupci II. razreda kakvoće najveće vrijednosti poprimaju u prva dva debljinska razreda uzoraka (36,18 % i 35,53 %). Postotni udio III. razreda kakvoće raste sa povećanjem prsnog promjera stabla od 29,66 % do 42,43 % (Tablica 15).

Udio rudničkog drva je najveći u debljinskom razredu 22,5 cm (59,96 %), a s povećanjem prsnog promjera se smanjuje sve do 0,51 % u debljinskom razredu 77,5 cm. Postotni udjeli celuloznog drva su ispod 8 % za debljinske razrede uzorka. Najmanje vrijednosti su zabilježene u debljinskom razredu 32,5 (2,31 %), a najveće u debljinskom razredu 82,5 cm (7,98 %).

Ukupno izrađeni obujam prema sortimentnoj strukturi je veći od obujma iskoristivog drva prema jednoulaznim tablicama, u vrijednostima do 0,11 m^3. Za debljinske razrede od 47,5 cm do 67,5 cm razlike ne postoje ili su vrlo male (0,02 m^3), što ukazuje na dovoljan broj stabala tih debljinskih razreda u uzorku. U distribuciji prsnih promjera stabala uzorka nedovoljan je broj najtanjih i najdebljih stabala. No, s obzirom na sječivu zrelost jelovih stabala u promatranoj gospodarskoj jedinici (70 cm) i principe preborne sječe vrlo je teško osigurati statistički dovoljan broj stabala prsnih promjera manjih od 40 cm i većih od 70 cm.

Novčana je vrijednost stabala određena na osnovu strukture obujma razreda kakvoće i cjenika glavnih šumskih proizvoda za domaće tržište; A - 02.01, "Hrvatske šume" d.o.o. Zagreb. Pri obračunu novčane vrijednosti stabala iz cjenika je korištena cijena šumskih sortimenata na panju. Prema cjeniku, novčana je vrijednost sortimenata razdijeljena s obzirom na srednji promjer pilanskih trupaca (do 39 cm srednjeg promjera, od 40 do 49 cm srednjeg promjera i srednjeg promjera većeg od 50 cm). Prema tome u analizi novčanih vrijednosti morali smo podjeliti stabla uzorka prema istoj podjeli kako bi mogli točno primjeniti cjenik. Stabla prsnog promjera do 39 cm mogu sadržavati jedino sortimente najviše istog srednjeg promjera. Stoga iz cjenika uzimamo novčane vrijednosti za navedeni debljinski stupanj sortimenta prema razredima kakvoće. Stabla prsnog promjera od 40 do 49 cm mogu sadržavati sortimente srednjeg promjera do 49 cm te za analizu novčane vrijednosti tih stabala uzimamo aritmetičku sredinu vrijednosti prva dva debljinska stupnja sortimenata iz navedenog cjenika. Isti postupak je primjenjen kod najdebljih stabala.

Vrijednosni koeficijent 1,00 određen je za II. razred kakvoće pilanskih trupaca kod stabla prsnog promjera većeg od 50 zbog toga što je u uzorku najveći udio navedenog razreda kakvoće i promjera stabla. Za druge debljinske razrede i razrede kakvoće vrijednosni koeficijent je omjer novčane vrijednosti razreda s novčanom vrijednosti II. razreda kakvoće pilanskih trupaca kod stabla prsnog promjera većeg od 50 cm.

Vrijednost debla i vrijednost po jedinici drvnog obujma je određena na osnovu vrijednosnih koeficijenata i strukture obujama razreda kakvoće.

Vrijednost debla predstavlja sumu umnožaka obujama razreda kakvoće i pripadajućih vrijednosnih koeficijenata. To nam govori za koliko je obujam drva u deblu (suma vrijednosti svih sortimenata) vrijedniji od 1 m^3 pilanskih trupaca II. klase srednjeg promjera većeg od 50 cm.

Vrijednost po jedinici drvnog obujma je vrijednost 1 m^3 svih izrađenih sortimenata iz debla, izražena kvocjentom vrijednosti debla i ukupno iskorištenog drvnog obujma stabla.

Vrijednost debla raste s povećanjem prsnog promjera stabala i kreće se od 0,27 do 6,18 za prsne promjere od 20 cm do 84 cm. Porastom prsnog promjera stabala raste visina stabla te time ujedno i duljina debla. Veća duljina debla omogućava veći izrađeni obujam stabla što uzrokuje veću vrijednost debla.

Najmanja je vrijednost po jedinici drvnog obujma u debljinskom razredu 27,5 cm (Tablica 17). Vrijednost po jedinici drvnog obujma je jednaka u debljinskim razredima 32,5 cm i 37,5 (0,679) te u debljinskim razredima od 42,5 cm i 47,5 cm (0,775 i 0,776). Najveća vrijednost po jedinici drvnog obujma se pokazuje kod debljinskog razreda od 52,5 cm i iznosi 0,874 te lagano opada do 0,853 kod debljinskog razreda 82,5 cm.

U Gospodarskoj jedinici „Belevine" se pri odabranoj sječivoj zrelosti za jelu od 70 cm prsnog promjera ne postiže najveća vrijednost po jedinici drvnog obujma. S obzirom na male razlike u vrijednosti drva stabla sječive zrelosti i stabla debljinskog razreda 52,5 cm, promjena sječive zrelosti se mora opravdati kompleksnim istraživanjima prirasta stabla, uzgojnih, ekoloških i zaštitnih osobitosti stabala jele na tom području s ciljem očuvanja preborne strukture.

Istraživanje je navednih značajki kakvoće stabla prilog intenzivnom gospodarenju šumama. Određivanje strukture značajki kakvoće stabala daje nam odgovore o uporabljivosti drvnog obujma te racionalnim i najisplativijim načinima pridobivanja drva.