ANALYSIS OF BIOMASS UTILISATION OF ABOVEGROUND PART OF BEECH (*FAGUS SYLVATICA* L.) IN COMPARTMENT 92, MU „ŽUĆA – RIBNICA"

Analiza iskorištenosti biomase nadzemnog dijela bukve (*Fagus sylvatica* L.) u šumskom odjeljenju 92, G.J. „Žuća – Ribnica"

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Abstract:

Biomass has a huge renewable energy source potential, forest biomass in particular. Forest biomass effectively includes aboveground parts of tree trunk including: stem, treetop with leaves/needles, bark, seeds, and cones. Although it is biomass, stump is not used in natural forests. Beech (*Fagus sylvatica* L.) is a dominant tree in the forests of Bosnia and Herzegovina and it is important raw material used in wood assortment production. Once beech assortment is cut down, processing and hauled there is a significant quantity of unused wood biomass which can be effectively used as source of renewable energy. This is way the objective of this paper was to determine overall quantity of beech tree biomass in Compartment 92, Subcompartment „a", MU „Žuća-Ribnica", assess quantity of forest biomass (usable timber left after felling and branches - biomass above 7 cm), determine quantity of forest biomass (wood biomass from 3 to 7 cm), and also quantity of bark. The research included 60 beech trees. Volume of tree trunk and trunk bark was determined by sectioning method and branch mass was determined by weighting. Adjusted values of tree trunk and bark volumes were converted in dry matter mass using information provided by. The research findings showed that 73% (1,605.24 tons) of beech wood biomass is used in Compartment 92, Subcompartment „a", MU „Žuća-Ribnica", while 27% (582.59 tons) remain unused in the forest. This altogether indicates that a large portion of beech biomass is not used as energy source.

Key words: forest biomass, beech, trunk, branches, bark.

INTRODUCTION – *Uvod*

Many domestic and foreign authors dealt with biomass problem. Forestry experts for a long time deal with determination of tree and stand biomass. Therefore, there is extremely large number of published documents on a manner of determination, measurement and utilisation of tree and stand biomass. In the past, tree was the first energy matter human used, to which he owes its survival.

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According to NIKOLIĆ, (1987) tree was the main energy raw material by the mid-twentieth century, after which the tree was replaced as fuel wood and modern energy sources, such as energy of oil and its products, gas, electrical energy and other sources were used. In that period, tree/wood as fuel wood has kept in use in less developed areas – rural areas. Due to increase in price of conventional energy sources and their limited character, society more and more turns to research of utilisation of biomass potential and technology to produce it. Besides that, mankind, in its recent history, has turned to biomass as additional energy source in moments of large increase of oil prices (BURA, 1987). Mentioned author states year 1987 as turning point for initiation of research in forest biomass utilisation for energy. The same year on international level, research has been initiated in three main directions:

1. Growing of fast-growing types of trees meant exclusively for energetics,
2. Technology of harvesting, preparation and shredding of wood and
3. Conversion of biomass into liquid fuel.

PINTARIĆ, (1987) in his work „Drvni otpaci pri iskorišćavanju šuma kao izvor energije“ („Wood waste in forest utilisation as source of energy“) states that wood waste is not utilised enough in process of regular felling, processing and hauling of wood assortments and adds that significant quantities remain in forest next to the stump unutilised. Same author defines wood waste as trunk or parts of the trunk that after felling remain in the forest unused for immediate use. As un-utilisation reason he states the fact that costs of processing and hauling are larger than market price. Therefore, forest wood waste is not primary technical and technological category, but economic category falling under laws of the market (ratio of production costs and product price). Issue of wood waste and its utilisation for energy was dealt with by KULUŠIĆ, (1984) and NIKOLIĆ, (1987). On success of utilisation of forest biomass in processes of forest utilisation JELIČIĆ, (1987) states that one of the main conditions is sufficient and proper openness of forest area with proper road infrastructure network. Importance of biomass utilisation of trees that are thinned and possibilities of shredding through application of machinery through various forms of organisation is the research topic for BOJANIN, (1987). About forest biomass as energy source and sensitivity of certain areas in a sense of excessive forest utilisation is mentioned by HAKKILA, (1987). Upgrading of machinery for utilisation of biomass from the waste, that remains in forest upon completion of classic works on felling, through application of short wood method or whole wood method was researched by HAMILTON, (1987). DIMITRI, (1987) points out that biomass, as potential source of energy, can be produced also from the new, specialised, so called "energetic" or "fast-growing" plantations. Same author mentions that production of fast-growing tree types in short rotation could represent one new way of land utilisation. KRPAN, (1996) explores potentials of Croatian karst and possibilities of production of biomass for energy in those areas. GOGLIA et al (1996) are exploring current utilisation of forest biomass in Croatia, as well as possibilities to improve utilisation of this energy source in the future. Biomass of wood vegetation in the forest is divided by the part of the tree it

comes from. The largest share is of the large wood above 7 cm in diameter (71%), than the root (approximately 18%) and small branches (approximately 11%), KRSTEVSKI et al (1997). ŠTEFANČIĆ, (1998) in even-aged beech assortment explores dependence of large wood mass up to 7 cm on breast height diameter and tree height. Sample covered 450 trees. Data analysis reached the result that ratio of large wood mass up to 7 cm is in good correlation with breast height diameters and heights. High degree of correlation of measured and equalised data was determined. And for uneven aged (selection forest) beech assortment it is recommended to continue with the research in this field. For branches thinner than 7 cm research was not conducted. According to FAO/ECE (for European conditions) bark participates with 12.5%, tree tops, branches and leaves/needles with 15%, stump and roots with 20%. Losses occurred during felling, processing and transport are estimated to approximately 5%. According to some estimates, share of branches (diameter above 3 cm) in gross felling mass is 2.3 – 5.4%. As stated by DOMAC et al (2001) quantity of small branches with leaves, that is needles and tree top, remaining after felling (depending on tree type, age, tree height) is 20-25% of tree biomass, i.e. 30% of total tree. Forest wood mass is renewable energy source. By increasing its utilisation one increases share of renewable energy sources in total energy balance according to EU guidelines (directive 2001/77/EC). Use of biomass for production of heat and electric energy in modern installations results in new work places in energy sector which is particularly important for development of rural areas where main portion of works are done. According to data from DOMAC et al (2004) quantity of wood waste after regular felling is 20 – 25% of total tree mass. Also, other authors mention similar data: KRSTEVSKI et al (1997), KRPAN, (1996). These data are leading us to a conclusion that is necessary to conduct concrete research for certain tree types and determine precise indicators that talk about quantity of biomass that is possible to utilise. In his work DOMAC et al (2005) points out to assessments of production of energy from biomass in the past, present, but also the results of three worked-out scenarios of future production of energy from biomass in Croatia until year 2030. The same author further emphasises that biomass of forest origin has significant position in the structure of consumption of biomass for energy, and such trend is expected in the future as well, particularly regarding the beech biomass. As mentioned by JOVANOVIĆ et al (2005) according to some estimates share of branches (of diameter above 3 cm) in gross felling mass is 2.3-5.4%.

DANILOVIĆ and ILIĆ (2006) in their work are writing that utilisation of forest biomass for energy requires modern technological solutions in order to bring production costs to minimum. That, above all, is related to technical solutions during gathering, transport, warehousing, drying and shredding of forest biomass. KRPAN et al (2007) explore potentials of forest biomass of some forest tree types in Croatia, such as European oak (*Quercus robur*), European beech (*Fagus sylvatica*), European silver fir (*Abies alba*), ash (*Fraxinus*) and Aleppo pine (*Pinus halepensis*), and through those potentials observe possibilities to gain partial independence on import of energy generating products.

When this aspect is the issue, BAJIĆ et al (2007) point out the importance of forest biomass of sessile oak (*Quercus petraea*), application of assortment and trunk method during felling and processing of forest wood assortments of sessile oak in Serbia, and then the possibility to improve forestry by introduction of new technologies with humanisation of work in forest utilisation.

GLAVONJIĆ, (2009) concludes that total energy potentials of wood biomass for heating in Bosnia and Herzegovina are 23.31 PJ on annual level and mostly in form of fuel wood. In Croatia researches were conducted for beech, European oak, narrow-leafed ash and European or common hornbeam (LUKIĆ and KRUŽIĆ, 2007).

In Serbia research was conducted for assessment of total aboveground beech biomass, as well as assessment of biomass of its components (trunk, branches), (KOPRIVICA et al 2009). From mentioned research of KOPRIVICA et al (2009) average dry biomass of beech stand in the sample is 337.69 tons/ha or 85.9% aboveground biomass, and underground biomass makes 55.49 tons/ha or 14.1% of total biomass. Percentage of the tree in aboveground biomass is 89.7%, small branches 9.3%, and leaves 1.0%.

According to many researches done on biomass, each study foresees its increase in total consumption as in the world, as well as locally. According to the study done by GTZ for Innotech HT GmbH, Berlin, un-utilised potentials of residual wood and wood waste for year 2003 were approximately in amount of 1 million m^3 which could ensure heat energy for 130,000 households or 300,000 citizens.

In Bosnia and Herzegovina share of biomass in total energy supply is 4.2% (AGIĆ and STIFF, 2009). The oldest, but still the most common form of utilisation of biomass is combustion-burning of wood. Technically speaking, combustion-burning of wood is considered as form of utilisation of biomass, therefore, renewable energy. But, it is far from being the only or most profound way (AGIĆ and STIFF, 2009). According to researches of HUSIKA, (2010) participation of fuel wood in total needs for energy in Bosnia and Herzegovina in year 2008 was in 22.04%, and in total consumption of energy for household heating was 75.62%. DOLOČEK and KARABEGOVIĆ, (2011) state that for production of energy the most significant source of biomass in Bosnia and Herzegovina is forest wood mass (fuel wood and forest residues), and wood waste from wood industry. From the amount of total forest felling, there is only 3.7 million m³ of round wood, while remaining 0.7 million m³ remains as wood waste. More than one third of round wood is used as fuel wood (1.3 million m³), and the rest is forwarded for industrial use (2.4 million m³), out of which almost one third in sawmill wood waste (0.8 million m³). Out of 0.7 million m³ of remaining after felling as wood waste, two thirds are available for use (0.5 million m³). Annual production of forest residues and sawmill wood waste is estimated to approximately 1.3 million m³.

Beech in Bosnia and Herzegovina is economically most important tree type. Its wood has large heating power, and therefore is used a lot as wood for production of heat energy, especially in rural areas. In forests of FB&H large quantities of beech fuel

wood remains next to the stump in a form of log, as well as in form of various waste. This is particularly expressed in the last few years (especially after war), because forestries in their possession do not have the boom, and large number of private entrepreneurs that provided these services before the war, are no longer continuing this tradition that was expressed a lot in Bosnia. Also, not much effort is focused on introduction of new machinery and technologies whose primary role would be more utilisation of fuel wood whether as primary or as secondary energy generating product. With development of certain technology processes like production of briquette and pellets it has contributed to more efficient use of those products even in urban areas due to improved combustion properties – more calories, less waste during combustion and better cost-effectiveness.

In forestry operations according to valid standards, wood with diameter less than 7 cm is left in the forest as wood waste. Share of wood waste during felling, processing and hauling amounts to 20 to 30%. Share of wood waste is in correlation with breast height diameter of the tree, length and width of the canopy, tree height and other. Therefore, in order to determine potential of biomass of certain assortment it is necessary to make adequate graphs and make calculations for them. Based on that it is possible to make spreadsheets of wood assortments based on which we assess real potential of beech trees biomass for specific habitat and assortment circumstances. This is important in development of plans for possibilities of utilisation of beech wood waste.

MATHERIAL AND METHODS OF RESEARCH – *Materijal i metode istraživanja*

Motives and need for this research comes from the fact that significant quantity of forest biomass remains un-utilised, and it could be utilised by use of modern machinery for extraction/hauling, transport and processing of the biomass. Quantity of biomass as business cost-effectiveness indicator, represents starting point for planning of utilisation of this resource for energy purposes. Regarding this, main objective of the research is to determine energy potential of beech wood biomass that remains un-utilised in forest after felling, processing and hauling of assortments.

In order to reach this knowledge, we need individual or partial research tasks in function of achieving common objective. Therefore, research tasks are:
- ✓ Field surveys and measurements,
- ✓ Determine quantity of forest biomass (usable timber that remains after felling and branches– wood mass above 7 cm),
- ✓ Determine forest biomass quantity (wood mass from 3 to 7 cm),
- ✓ Determine quantity of bark,
- ✓ Determine overall total quantity of beech biomass in compartment 92. and
- ✓ Perform statistical processing of gathered data.

Analysis of utilisation of biomass of aboveground parts of beech shall be determined through study of literature sources, field data gathering and their processing. After introduction with issues of beech wood biomass and selection of research area, field data gathering was executed. Field measurements were conducted in period November–December 2012 in the area of Forestry „Ribnica – Kakanj", MU „Žuća – Ribnica" in compartment 92, subcompartment „a". In selection of trees for data gathering we followed the principle where from each diameter sub-class starting from 12.5 cm up to 77.5 cm we selected at least three trees from lower diameter sub-class and for higher diameter sub-class up to five trees that would represent average trees for that diameter sub-class. We selected total of 60 trees in the sample. Coordinates were recorded for selected trees (Figure 1). During recording of positions of model trees we used so-called „Global position system" - GPS technology and they are presented in GIS design.
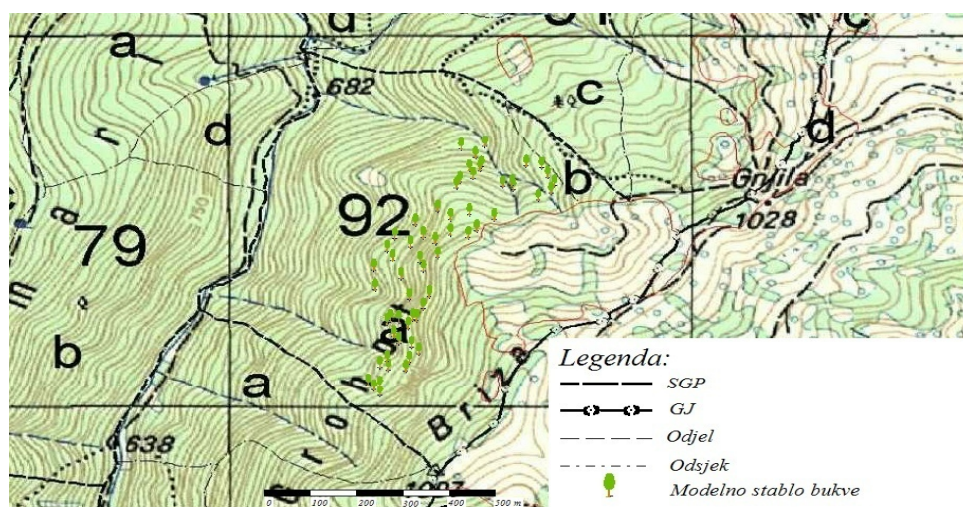

Figure 1. Position of model trees in compartment 92; Source: Delić, Š., 2014;
Slika 1. Položaj modelnih stabala u odjelu 92; Izvor: Delić, Š., 2014;

It is important to mention that this sample is relatively small comparing to observed group – marked trees in compartment 92, subcompartment „a". In order to get precise data to execute this type of work we have to take larger sample, and that requires mobilisation of more work assets due to the nature of field data gathering itself. This represents certain limitation during research and because of that we have decided to use a sample of 60 trees. In this way researches were done in Republic of Croatia. Relationship between a sample and marked trees is presented in Graph 1.
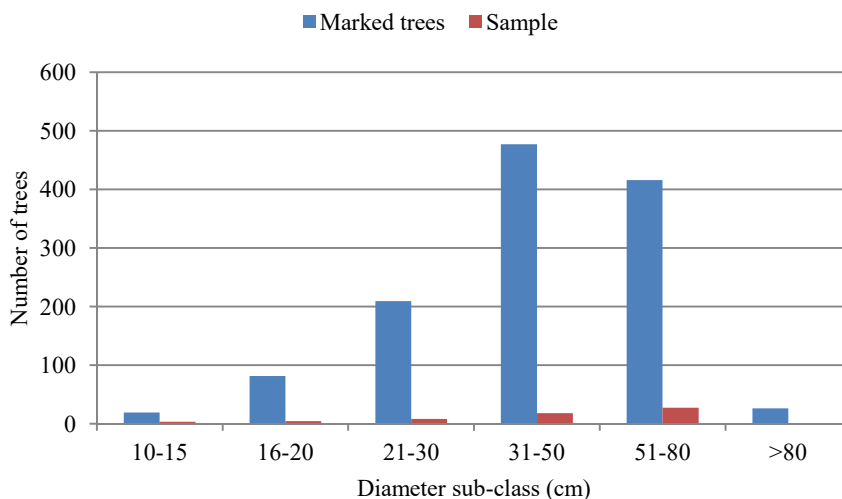
Graph 1. Distribution of marked and sample trees
Grafik 1. Distribucija doznačenih i stabala uzorka

Prior to research start we have selected what data for trees and wood assortments to measure. For data gathering we have used proper form, with data on trees and processed wood assortments, and form with data on processed stacked wood and usable timber that remains after felling. Besides that:

✓ Research was done in regular felling using random sample method.
✓ Measurements included trees with breast height diameter from 12 to 79 centimetres.
✓ Processing, measurement and classification of wood assortments was done using criteria prescribed by JUS standard.
✓ During research we have also measured thinner round wood that remains after felling to determine total biomass for sample and compartment.
✓ Tailoring, measuring and classification of wood assortments were done by forestry engineer, burdened by up-to-date habits.
✓ Prior to research start, hired forestry expert had to get himself familiar in detail with JUS standard.

Prior to tree felling, to trees in the sample, we have measured breast height diameters ($d_{1,30\_1}$, $d_{1,30\_2}$) that are perpendicular between the two, and two diameters of visible part of the canopy ($D_{max – maksimalni}$, $D_{min –minimalni}$) that are perpendicular between the two, i.e. two vertically projected canopy diameters on the ground.

After tree felling, in proper form we have written ordinal number of the tree. Prior to processing of model tree, we measured the height to the first live branch to determine coefficient cleanliness of the trunk from the branches and total height. Formula to determine coefficient cleanliness of the trunk from the branches is: k $=\dfrac{h_1}{H}$. H – Total

tree height, h_1 – height to the base of first live branch. On the stump with forestry chalk we wrote ordinal number of the tree, then we measured measurement and tailoring of the assortment, determine quality of assortment and wrote it in the form. Based on these data we calculated volume of assortment using Huber formula, $v = d^2 \frac{\pi}{4} l$ (MIRKOVIĆ, 1971). On the end of each stem section with forestry chalk in form of fraction we wrote ordinal number of the tree above ordinal number of the stem section of model tree, which enabled us to additionally control executed measurements and classifications. When this process is done on 2-3 trees, workers would haul the assortment, and remaining branches after hauling of the assortment was measured and written into the form. Mean diameters of wood assortments were measured and written in with the bark, and on measured assortment we measured double bark thickness with accuracy to a millimetre (Figure 2).

Figure 2. Measurement of bark thickness; Source: Delić, Š., 2014;
Slika 2. Mjerenje debljine kore; Izvor: Delić, Š., 2014;

After cutting stacked wood, we measured mean diameter of each round wood up to 3 cm, (Figure 3) and wrote it in a form, and after that worker could pile the stacked wood.

Figure 3. Measured round wood after felling; Source: Delić, Š., 2014;
Slika 3. Izmjerene oblice poslije sječe; Izvor: Delić, Š., 2014;

Model tree branches mass of diameter up to 3 cm with the bark are tied in bundle – for practical reasons of conducting measurements. Weighing was done with accuracy of half a kilogram (Figure 4). Based on density factor for beech wood we have determined a volume of branches which is presented in the research results.

Figure 4. Weighing of branches thinner than 3 cm; Source: Delić, Š., 2014;
Slika 4. Vaganje granjevine tanje od 3 cm; Izvor: Delić, Š., 2014;

During field research we have conducted a control of measurements and classification of wood assortments per quality. After field data gathering which are written in proper manuals, we started with data processing. Data processing was done in Microsoft Office 2007, Microsoft Word 2007 and Microsoft Excel 2007. In the process we took care of basic statistical procedures of calculations while respecting dendrometry formula defined in advance. To calculate biomass of aboveground part of beech we used statistical methods – regression analysis.

RESEARCH AREA - *Područje istraživanja*

For research in this document we have selected compartment 92, subcompartment „a" that belongs to MU „Žuća – Ribnica", FMA „Kakanjsko" (Figure 5).
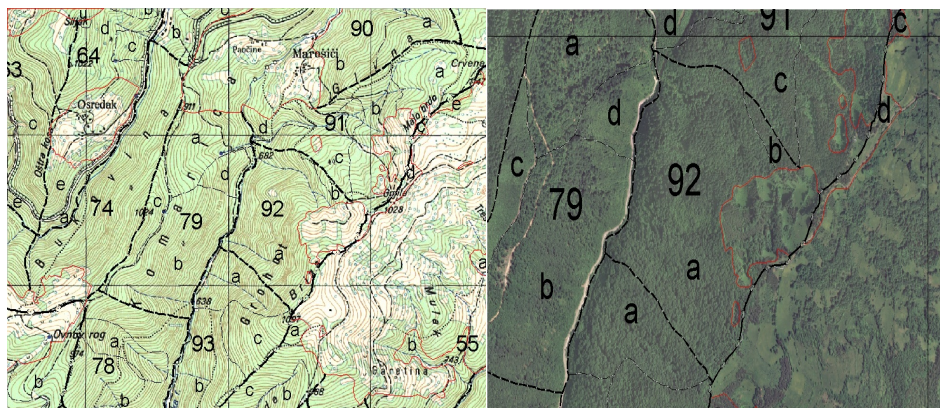

Figure 5. Map of compartment 92 MU „Žuća – Ribnica", topographic layer (left), orthophoto image (right), R: 1: 10 000; Source: Delić, Š., 2014;
Slika 5. Karta odjeljenja 92 G.J. „Žuća – Ribnica", topografska podloga (lijevo), ortofotosnimak (desno), R: 1: 10 000; Izvor: Delić, Š., 2014;

Compartment has two subcompartments, area of „a", subcompartment covers 47.5 hectares and „b", covers 1.9 hectares. Subcompartment „a", according to 10-year forest management plan is classified as management class 05. It is beech assortment where beech is included in 84% of the total growing stock of the subcompartment, while sessile oak and other valuable broad-leaved species equally are included in the remaining growing stock. Group system of management is foreseen for mentioned management class. In subcompartment „a", we have marked total of 1.600 broad-leaved trees and 56 conifer trees. From beech broad-leaved species we have marked 1.228 trees with the volume of large wood of 2,813.8 m^3 on III site class, while the share of other broad-leaved species was negligible. Out of conifers, we have marked 56 trees of Scots pine with large wood volume of 32.3 m^3 on III site class. Subcompartment „b", belongs to management class 06. According to 10-year forest management plan these are high secondary forests of Scots pine and European black pine with sessile oak. This management class foresees group management system. We have marked 301 trees, out of which 90 broad-leaved trees with large wood volume of 37.9 m^3 on IV site class, and 211 conifer trees with large wood volume of 91.1 m^3 on III site class.

RESULTS AND DISCUSSION – *Rezultati i diskusija*

Taxation elements of beech model trees

Taxation elements of beech model trees were measured in the field and written in proper manual prepared for this. Object of the research were beech trees in diameter of 12 to 79 cm, height from 12 to 35 m, with large wood volume from 0.0392 m^3 to 6.89 m^3, with total volume from 0.0855 m^3 to 7.8714 m^3. Data served as basis to assess biomass of beech trees in subcompartment „a", of compartment 92. We need to emphasise we have performed conversion of volume of specific parts of beech trees based on data from CIENCIALA and OTHERS (2006), where the weight of dry beech wood is 575.5 kg/m^3 while the weight of branches and other parts of the tree is 560.1 kg/m^3.

Correlation and regression analysis of beech trees taxation elements

After we have calculated amounts of beech model trees taxation elements, we have started with analysis of interdependency between taxation elements of the trees. Partial coefficients of correlation were calculated during selection of independent variables (taxation elements of the trees) for assessment of dependable variables (biomass of aboveground part of trees, biomass of total wood mass, biomass of branches and other). Based on correlation coefficients we can see that a strong correlation link exists between diameter at breast height with wood biomass, biomass of usable timber and branches thicker than 7 cm (R^2=0.745, biomass of branches in diameter of 3 to 7 cm (R^2=0.873), biomass of bark (R^2=0.983) and biomass of branches (R^2=0.975), (researched types of biomass). Tree height, also has strong correlation with researched types of biomass. Length and width of canopy is in strong correlation with researched types of biomass. Length of the stem and degree of canopy cover is in weak correlation with researched types of biomass.

Based on defined independent variables we have examined impact of those on quantity of biomass of remaining usable timber and branches over 7 cm, biomass of branches in diameter from 3 to 7 cm, biomass of branches, biomass of bark and total biomass of aboveground part of beech trees as dependable variables. These examinations were done with the method of simple regression analysis.

Calculation of beech trees biomass using regression functions

Based on data we have calculated regression function models to assess biomass of particular parts of beech trees. Based on these functions it is possible to calculate biomass of beech trees and assortments. Development of models for beech biomass estimation was the topic of different researches (ZIANIS and MENCUCCINI, 2003; STANKIĆ et al, 2014; CHAKRABORTY et al, 2016). We should have in mind that mentioned functions enable reliable assessment of biomass of beech trees and assortments for habitat and assortment circumstances that exist in subcompartment „a" of compartment 92. Each deviation in habitat and assortment characteristics initiates

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differences in accuracy given by previously defined regression function models for assessment of biomass of beech trees and its parts.

Before we present variants for calculation of beech tree biomass it is necessary to emphasise that biomass in our sense we share we divide into the one that is utilised/used (hauled from the forest) and the one that remains un-utilised in the forest. Utilised biomass is the biomass of large wood, while biomass of remaining usable timber, branches and other is most often un-utilised. This division is important to assess potential of biomass that remains un-utilised in subcompartment „a" of compartment 92. Therefore, variants for calculation of biomass that is utilised (variant 1) and biomass that remains in the forest (variant 2) are gained by adding gained values of beech wood components, which are calculated using function model for calculation of biomass of certain parts of beech trees:

Variant 1 = y_1 (kg),

Variant 2 = $y_2+y_3+y_4+y_5$ (kg).

Total biomass of aboveground portion of the tree = variant 1 + variant 2 (kg),

Where is: y_1 – biomass of large wood without bark (kg),

y_2 – biomass of remaining usable timber and branches of diameter above 7 cm (kg),

y_3 – biomass of branches of diameter from 3 to 7 cm (kg),

y_4 – biomass of branches (kg) and

y_5 – biomass of bark (kg).

Based on previously given equations we have calculated biomass that is utilised and the one that remains in forest, and is presented per diameter sub-class (table 1. and graph 2).

Table 1. Equalised amounts of dependable variables according to regression functions

*Tabela 1. Izravnate veličine zavisnih varijabli prema funkcijama regresije*

$d_{1,3}$ (cm)	"Equalised" amounts of dependable variables					Variant 1	Variant 2	Total
	y_1	y_2	y_3	y_4	y_5			
7,5	7,84	1,64	1,55	8,28	0,83	7,84	12,31	20,15
12,5	36,39	5,85	4,68	17,90	2,81	36,39	31,24	67,63
17,5	90,95	13,50	9,68	29,76	6,23	90,95	59,17	150,12
22,5	175,66	25,21	16,66	43,49	11,32	175,66	96,68	272,35
27,5	293,88	41,51	25,70	58,88	18,22	293,88	144,32	438,19
32,5	448,44	62,87	36,87	75,78	27,09	448,44	202,61	651,05
37,5	641,87	89,71	50,23	94,06	38,04	641,87	272,04	913,91
42,5	876,42	122,44	65,82	113,62	51,20	876,42	353,09	1.229,51
47,5	1154,16	161,43	83,69	134,40	66,66	1154,16	446,19	1.600,34
52,5	1476,98	207,01	103,89	156,33	84,53	1476,98	551,76	2.028,74
57,5	1846,66	259,52	126,45	179,35	104,90	1846,66	670,22	2.516,88
62,5	2264,86	319,27	151,40	203,41	127,86	2264,86	801,94	3.066,79
67,5	2733,14	386,56	178,78	228,48	153,47	2733,14	947,29	3.680,43
72,5	3252,99	461,67	208,62	254,51	181,84	3252,99	1106,64	4.359,63
77,5	3825,83	544,89	240,95	281,48	213,02	3825,83	1280,33	5.106,15
82,5	4452,99	636,47	275,78	309,34	247,08	4452,99	1468,69	5.921,68
87,5	5135,78	736,69	313,16	338,09	284,11	5135,78	1672,04	6.807,82
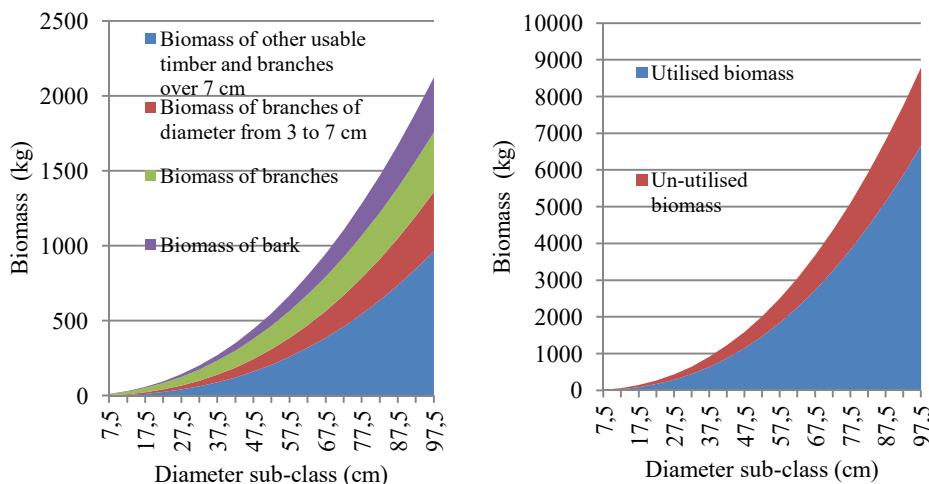
Graph 2. Depiction of equalised amounts of biomass of beech trees as per diameter sub-class
Grafik 2. Prikaz izravnatih veličina biomase bukovih stabala po debljinskim stepenima

On a basis of previous analysis, we can conclude, among other, that diameter on breast height as independent variable best determines researched types of beech tree biomass, because it has in average the largest coefficient of determination. ZIANIS and MENCUCCINI, (2003) cited that diameter at breast height as an independent variable explained most of the variability in the dependent variables (total aboveground, stem and branch biomass). Besides, good side of chosen independent variable is that the most plan documents in forestry – detailed design and 10-year forest management plan, are expressed through diameters at breast height, so there is simplified possibility of biomass assessment for entire subcompartment or compartment. Graph 3. Presents relative ratio of tree utilisation per diameter sub-class.
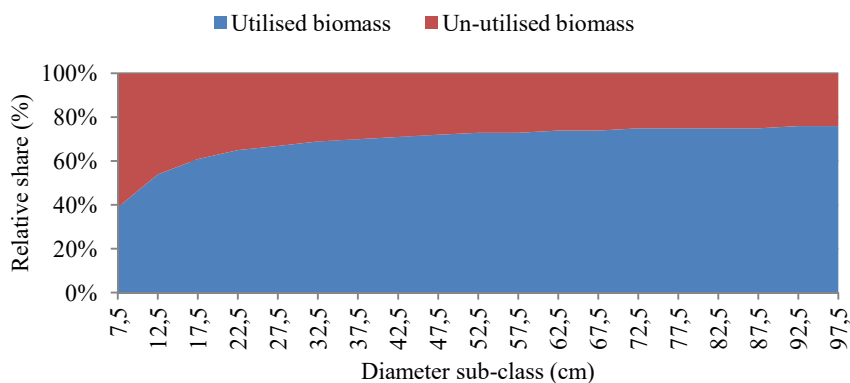
Graph 3. Relative share of utilised and un-utilised wood as per diameter sub-class
Grafik 3. Relativni odnos iskorištenog i neiskorištenog drveta po debljinskim stepenima

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Based on graph 3. we can recognise that large portion of wood of beech tree is utilised, while smaller portion stays in forest. Percentage of utilisation increases with increase of diameter sub-class. Relatively observed, the largest percentage of utilisation of wood is of the trees that belong to larger diameter sub-classes – ratio of utilised and un-utilised wood for diameter sub-class 82.5 cm amounts to 75%: 25%. The smallest percentage of utilised wood is of the trees that belong to lower diameter sub-classes – ratio of utilised and un-utilised wood for diameter sub-class 7.5 cm amounts to 39%: 61%. ZEČIĆ et al (2015) cited that during tree felling and processing of wood assortments average annual production is about 40% of technical roundwood, about 40% of stacked wood and the remaining 20% is wood waste after felling. From graph 3. we can clearly see that below diameter sub-class 27.5 cm, share of utilised wood is reduced, while later we see slight increase in share of utilised wood. Basic reason is the fact that trees of lower diameter sub-class, in process of realisation of wood mass from compartment 92, have low degree of utilisation of wood mass. Data supporting this are the data from table 1. and graph 2., where it is visible that in diameter sub-class 7.5 we have larger ratio of un-utilised related to utilised wood mass, and with increase of diameter sub-class we have increase of wood utilisation share.

When we are observing biomass that remains un-utilised in the forest after felling we can recognise that largest share in average is biomass of usable timber and branches above 7 cm (average share in un-utilised mass amounts to 42%), biomass of branches (average share amounts to 23%), biomass of branches of diameter from 3 to 7 cm (average share amounts to 19%), while the smallest share is in biomass of bark (average share amounts to 16%).

It was determined that the share of other usable timber and branches over 7 cm increases as the diameter at breast height increase. Similar results were found by STANKIĆ et al (2014) during analysis of structure of the common beech aboveground tree biomass in different stand conditions.

Calculation of potential of beech tree assortment biomass

a) Calculation of biomass of beech trees in subcompartment "a" of compartment 92

Calculation of beech tree biomass for entire subcompartment or assortment is done on a basis of data on number of trees from working plan/forest management plan and detailed design for compartment 92, subcompartment „a". From working plan/forest management plan we read number of trees in growing stock as per diameter sub-class, and from detailed design for compartment 92., we read marked number of trees as per diameter sub-classes. Earlier we provided amounts of dependable variables, i.e. researched variables (biomass of large wood, biomass of branches and other) as per diameter sub-classes. With simple multiplication of number of trees with amounts of biomass of beech trees and its parts as per diameter sub-class we have calculated total biomass for entire subcompartment „a" and showed it in tables 2. and 3. and on graphs 4. and 5.
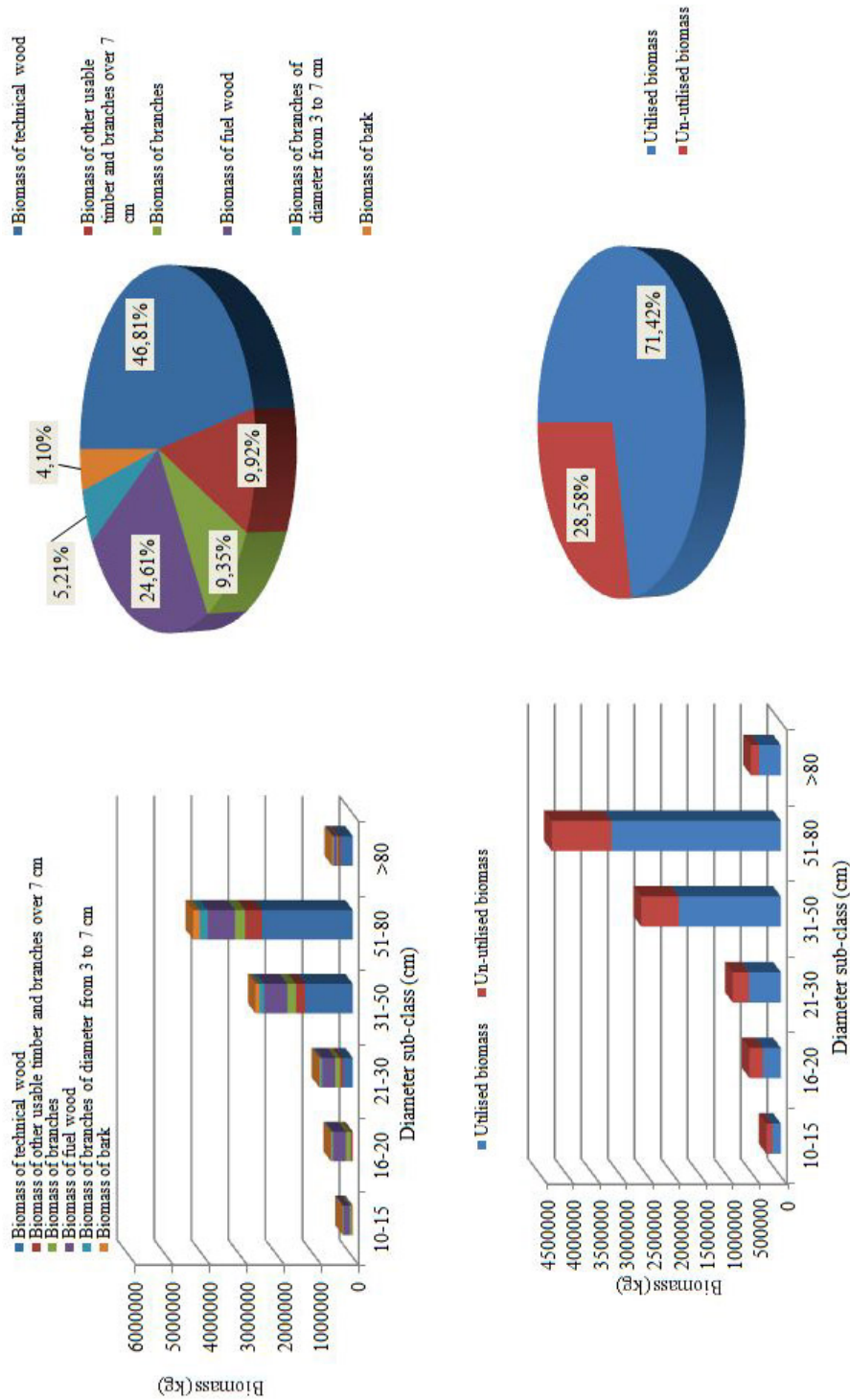
Graph 4. Biomass of growing stock of subcompartment „a", compartment 92
Grafik 4. Biomasa drvne zalihe odsjeka „a", odjel 92

Table 2. Biomass of growing stock of subcompartment „a", compartment 92
*Tabela 2. Biomasa drvne zalihe odsjeka „a", odjel 92*

Diameter sub-class (cm)	Number of trees in stock	"Equalised" amounts of dependable variables								
		Biomass of technical wood (kg)	Biomass of fuel wood (kg)	Biomass of remaining usable timber and branches above 7 cm (kg)	Biomass of branches of diameter from 3 to 7 cm (kg)	Biomass of branches (kg)	Biomass of bark (kg)	Utilised biomass (kg)	Un-utilised biomass (kg)	Total (kg)
10 to 15	3515	0	162900	20566	16454	62930	9863	162900	109812	272712
16 to 20	4322,5	0	334752	58355	41853	128623	26950	334752	255781	590533
21 to 30	2565	259642	342338	84016	53662	130790	37282	601980	305750	907730
31 to 50	2280	1293490	623433	240130	131648	236397	101093	1916923	709269	2626191
51 to 80	1282,5	2453608	735656	451377	211339	276792	179969	3189264	1119478	4308742
over 80	95	332681	82059	65121	27945	30743	25196	414740	149005	563745
Sum (kg)		4.339.421	2.281.138	919.565	482.901	866.275	380.353	6.620.559	2.649.095	9.269.654
Average (kg/ha)		91.356	48.024	19.359	10.166	18.237	8.007	139.380	55.770	195.151

Table 3. Biomass of marked trees of subcompartment „a", compartment 92
Tabela 3. Biomasa doznačenog drveta odsjeka „a", odjel 92

Diameter sub-class (cm)	Marked number of trees	"Equalised" amounts of dependable variables								
		Biomass of technical wood (kg)	Biomass of fuel wood (kg)	Biomass of remaining usable timber and branches above 7 cm (kg)	Biomass of branches of diameter from 3 to 7 cm (kg)	Biomass of branches (kg)	Biomass of bark (kg)	Utilised biomass (kg)	Un-utilised biomass (kg)	Total (kg)
10 to 15	19	0	881	111	89	340	53	881	594	1474
16 to 20	81	0	6273	1094	784	2410	505	6273	4793	11066
21 to 30	209	21156	27894	6846	4372	10657	3038	49050	24913	73963
31 to 50	477	270612	130429	50238	27542	49457	21150	401040	148386	549427
51 to 80	416	795868	238622	146412	68551	89782	58376	1034490	363121	1397612
over 80	26	91050	22458	17823	7648	8414	6896	113508	40780	154288
Sum (kg)	1.228	1.178.686	426.557	222.522	108.987	161.060	90.018	1.605.242	582.587	2.187.830
Average (kg/ha)		24.814	8.980	4.685	2.294	3.391	1.895	33.795	12.265	46.060
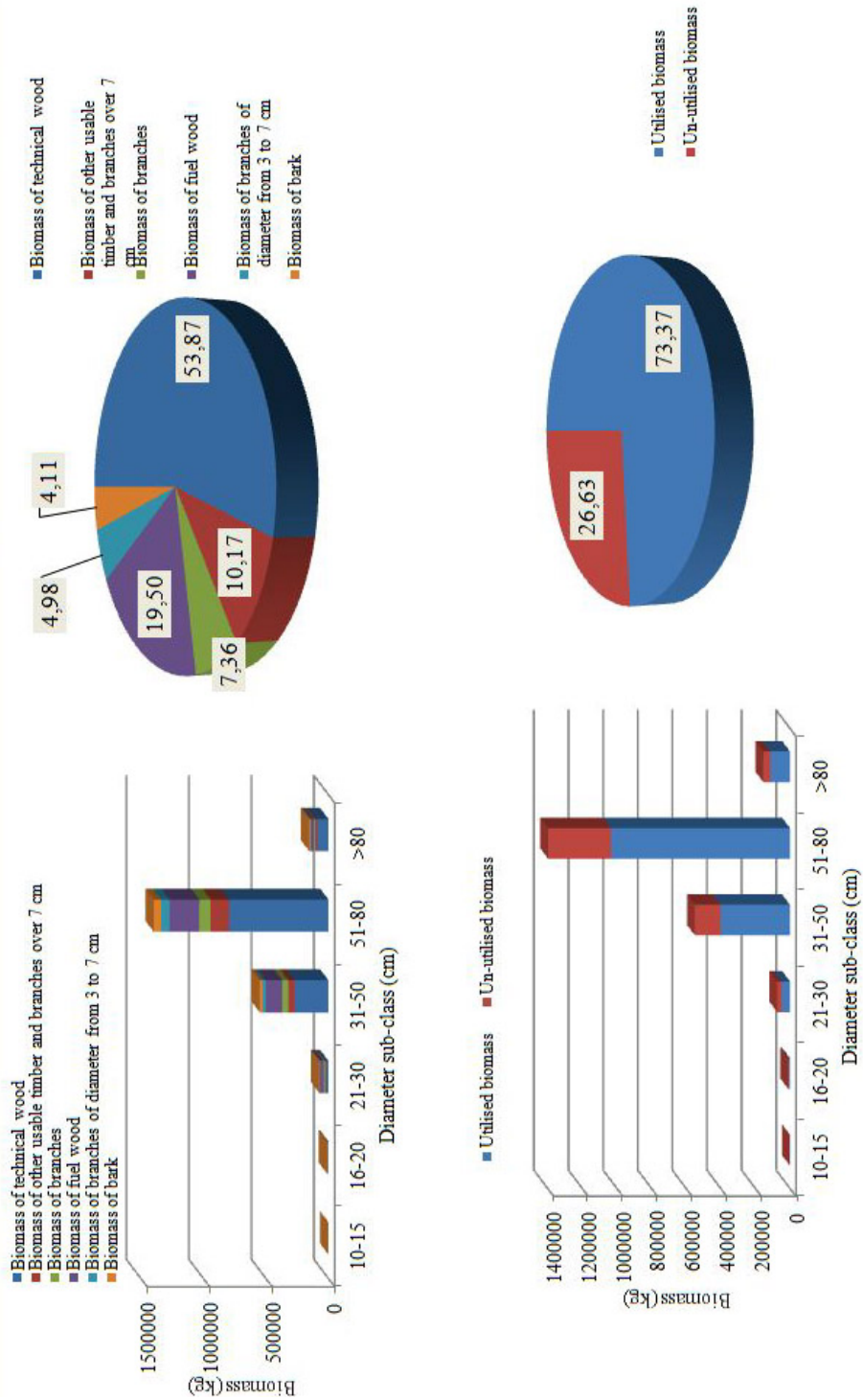
Graph 5. Biomass of marked wood of subcompartment „a", compartment 92
Grafik 5. Biomasa doznačenog drveta odsjeka „a", odjel 92

Based on table 2., and graph 4. We can recognise that total quantity of aboveground biomass of beech trees that constitute growing stock of subcompartment „a", compartment 92 amounts to 9,269.65 tons of dry matter. The total quantity of aboveground biomass of beech trees was 195.15 t/ha. KOPRIVICA et al (2013) found that estimated biomass of the living wood above and below the ground in investigated uneven-aged beech stands amounts to 288.29 +/- 20.15 t/ha in average, while the ratio of the aboveground biomass to the belowground biomass is about 85% and 15%. Out of that quantity, biomass of large wood covers 71.42% and in process of regular felling it could be utilised, while 28.58% would remain in forest, under condition that clear cutting is performed. This data is in accordance with researches made by many authors which state that share of waste that remains in the forest (un-utilised biomass) ranges from 20 to 30%. Besides, with graph 4. We can conclude that with increase of diameter sub-class share of utilised biomass is increased. Potential of biomass is possible to express also in MJ (mega joule). Average heat value of dry beech wood[1] amounts to 18.4 MJ/kg. Therefore, in subcompartment „a", compartment 92 the total potential of growing stock biomass on entire area of subcompartment amounts to 170,561,634 MJ which is equivalent to 4,715,555 litres of light distillate oil (1l of light distillate oil = 36.17 MJ)[2]. If we consider retail price of light distillate oil[3] in 2013, which was 2.15 BAM/l, we can see what valuable resource this is.

Based on table 3. and graph 5. we can recognise that total quantity of dry matter biomass amounts to 2,187.83 tons. Out of that, 1,605.24 t was utilised in 2012, while remaining 582.59 tons or 27% remained in forest un-utilised. Therefore, we can recognise that beech tree biomass potential that could be used from compartment 92 is 582.59 tons. Potential of biomass is also possible to express in MJ. Therefore, in subcompartment „a ", compartment 92 un-utilised potential of biomass is 9,418,040 MJ which is equivalent to 296,367.41 litres of light distillate oil. Expressed in monetary terms, according to retail prices of light distillate oil in 2013, un-utilised potential of biomass of beech trees in subcompartment „a", compartment 92 has a value of 637,189 BAM.

b) Comparison of results with data from detailed design for compartment 92

In forestry praxis at calculation of wood mass of growing stock or markings for subcompartment or compartment we use „Tablice taksacionih elemenata visokih i izdanačkih šuma u Bosni i Hercegovini" ("Tables of taxation elements of high and coppice forests in Bosnia and Herzegovina") (MATIĆ and OTHERS, 1980). We calculate overall wood mass and wood mass of large wood. Simply said, overall wood mass (so-called gross mass) corresponds to total aboveground tree mass, while wood mass of large wood is the mass of processed assortments (so-called net mass).

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[1]*http://www.regea.org/assets/files/objavilismo2012/D32_Biofuel_hanbook_REGEA.pdf*
[2]*http://www.regea.org/assets/files/objavilismo2012/D32_Biofuel_hanbook_REGEA.pdf*
[3] *http://www.petrol.ba/za-vas-dom/loz-ulje/loz-ulje/kretanje-cijene-loz-ulja*
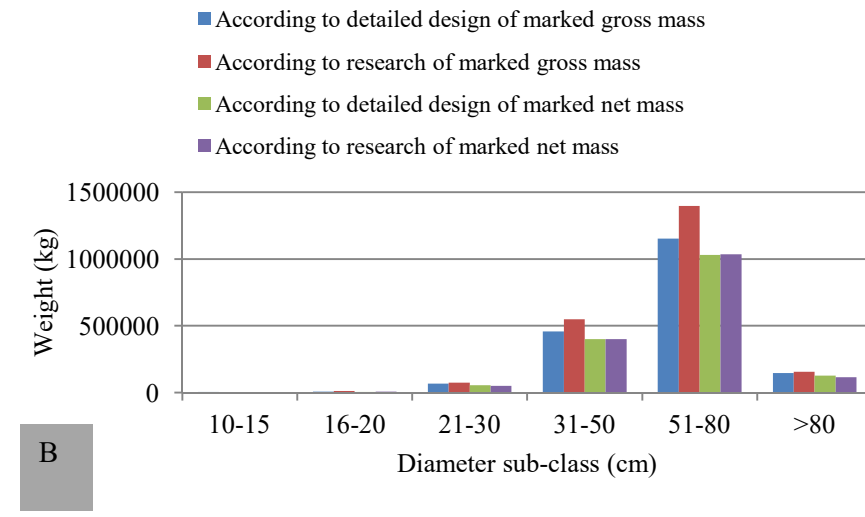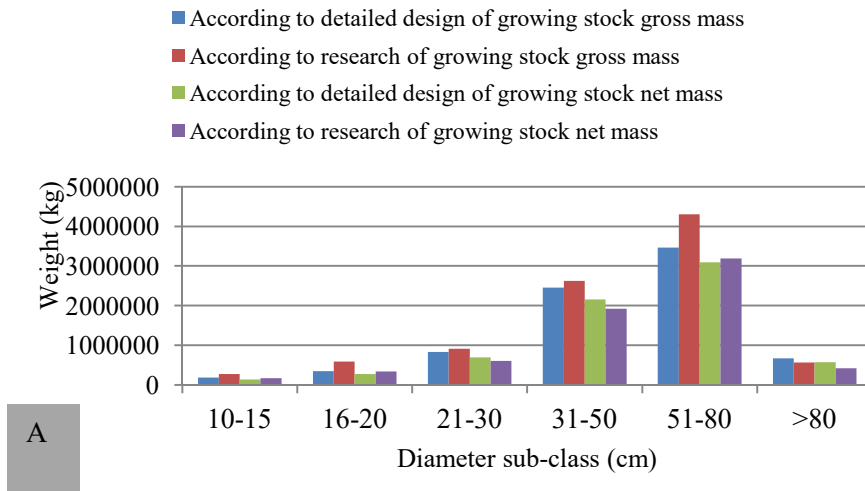
Difference between overall wood mass and wood mass of large wood represents forest waste that remains un-utilised in the forest.

However, data that tables provide are valid in average and it happens that in real conditions there are certain deviations. Deviations are caused, among other, by habitat and assortment characteristics, errors during performance of taxation measurements (especially errors of standing trees measured heights from which tree type site class of given assortment depends) and others. In that sense, this analysis has the objective to show are there any deviations in wood masses expressed through weight units – mass of dry matter (kg) between the data from detailed design and 10-year forest management plan, on one hand, and data gathered as part of these researches, on the other hand. In table 4. and graph 6. we presented result comparison.
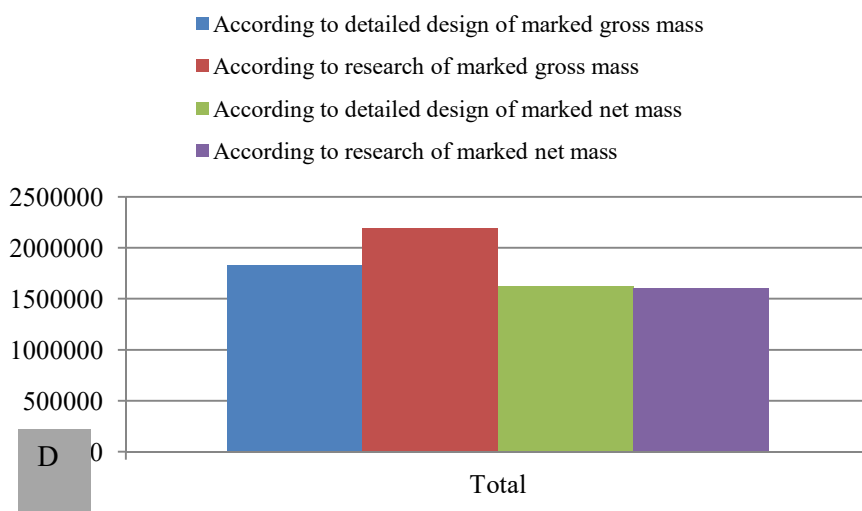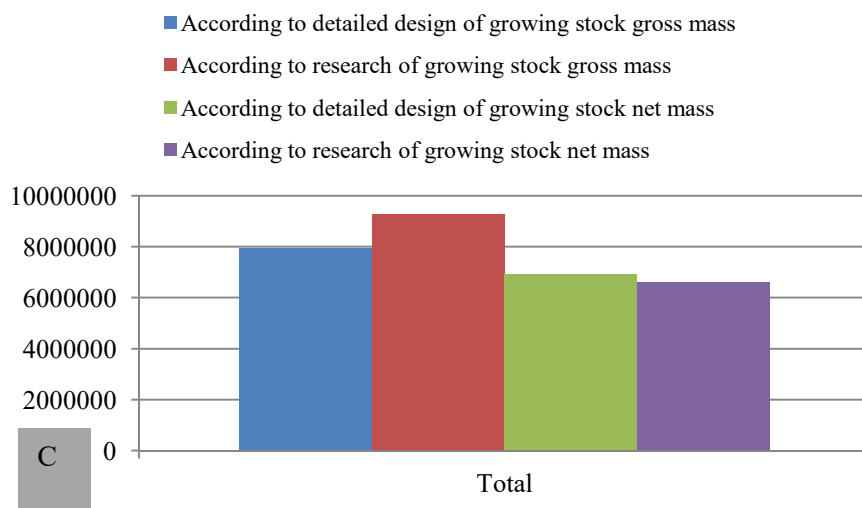
Table 4. Comparative overview of growing stock and marked wood mass according to detailed design and measurements
Tabela 4. Uporedni prikaz zalihe i doznačene drvne mase prema IP i mjerenjima

| Diameter sub-class (cm) | According to detailed design | | | | According to research | | | |
| | growing stock | | marked | | growing stock | | marked | |
	gross mass (kg)	net mass (kg)	gross mass (kg)	net mass (kg)	gross mass (kg)	net mass (kg)	gross mass (kg)	net mass (kg)
10 to 15	182999	132608	3677	2665	272712	162900	1474	881
16 to 20	344620	269235	6924	5410	590533	334752	11066	6273
21 to 30	826648	688874	66450	55375	907730	601980	73963	49050
31 to 50	2456569	2154885	456979	400859	2626191	1916923	549427	401040
51 to 80	3466682	3095252	1153040	1029500	4308742	3189264	1397612	1034490
over 80	669598	572306	146875	125534	563745	414740	154288	113508
Total	7.947.117	6.913.159	1.833.945	1.619.342	9.269.654	6.620.559	2.187.830	1.605.242

A

B

- According to detailed design of growing stock gross mass
- According to research of growing stock gross mass
- According to detailed design of growing stock net mass
- According to research of growing stock net mass

C

- According to detailed design of marked gross mass
- According to research of marked gross mass
- According to detailed design of marked net mass
- According to research of marked net mass

D

Graph 6. Comparative overview of data on growing stock according to detailed design and measurements: A – Growing stock expressed in gross and net amount as per diameter sub-class, B – Marked wood mass expressed in gross and net amount as per diameter sub-class, C – Growing stock expressed in gross and net amount for subcompartment and D – Marked wood mass expressed in gross and net amount for subcompartment

Grafik 6 . Uporedni prikaz podataka o zalihi i doznačenoj drvnoj masi prema IP i mjerenjima: A – Zaliha izražena u bruto i neto iznosu po debljinskim klasama, B – Doznačena drvna masa izražena u bruto i neto iznosu po debljinskim klasama, C - Zaliha izražena u bruto i neto iznosu za odsjek i D - Doznačena drvna masa izražena u bruto i neto iznosu za odsjek

Based on data presented in graph 6. we can conclude that marked wood mass and growing stock according to measurements is higher than the one according to detailed design in gross amount, while in net amount we have it somewhat smaller. Basic reason lies in the error of habitat site class assessment, because wood mass in detailed design was calculated for the third site class, and based on our calculation it is the second site class. This caused significant difference in wood masses according to detailed design and results of measurements. Besides, it is important to recognise that difference between gross (smaller) and net (larger) mass according to data from detailed design (as in absolute, as well as in relative amount) from the difference according to measurement results. That practically means that in cut material are larger quantities of wood waste than it is estimated within detailed design.

CONCLUSIONS – *Zaključci*

Research of utilisation of biomass of aboveground parts of beech (*Fagus sylvatica* L.) was done within forest management area (FMA) „Kakanj" management unit „Žuća – Ribnica", compartment 92. After conducted analysis we can recognise the following:
Share of un-utilised biomass varies from 12,31 kg to 1.280,33 kg of absolute dry matter, relative share of un-utilised biomass is from 61% to 25%. Therefore, it is clearly visible that by moving from lower toward the higher diameter sub-classes the share of utilised biomass increases and share of un-utilised biomass decreases.

Total biomass of marked trees is 2.159.806,14 kg of absolute dry matter which is equivalent to 1.098.713 l of light distillate oil. Out of this quantity, in regular felling process 73% was utilised, while remaining quantity that stays in forest as wood waste is in amount of 27%. Wood waste represents beech trees biomass potential. This potential amounts to 582.587 kg of absolute dry matter which equivalents to 296.367 l of light distillate oil. Market value of beech trees biomass potential that remains in forest un-utilised amounts to 637.189 BAM.

Forestry as branch of economy whose objective, among other, is to supply society with necessary quantities of wood for energy production, has to deal with the issue of possibilities of utilisation of wood remains that stays in forest after felling, and possibilities to raise so-called energy plantations. Considering that one of the most common tree species in Bosnia and Herzegovina is beech (*Fagus sylvatica* L.), the issue of possibility to utilise remains in cut material needs to be systematically researched.

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Analysis of Biomass utilisation of aboveground part of Beech (Fagus sylvatica L.) in Compartment 92, MU „Žuća – Ribnica"

SAŽETAK

Veliki potencijali energije iz obnovljivih izvora se nalaze u biomasi, a posebno šumskoj biomasi. Pod šumskom biomasom se podrazumijevaju nadzemni dijelovi stabla, a to su: deblo, krošnja sa lišćem/iglicama, kora, sjeme i šišarice. Iako je biomasa, panj se ne koristi u prirodnim šumama.

Bukva (*Fagus sylvatica* L.) dominira u šumama Bosne i Hercegovine i predstavlja važnu sirovinu u proizvodnji šumskih sortimenata. Nakon sječe, izrade i privlačenja bukovih sortimenata u sječini ostane značajna količina neiskorištene drvne mase, koja je energetski potencijal iz obnovljivih izvora. Zbog toga je cilj ovog rada utvrditi sveukupnu količinu biomase bukve u odjelu 92, odsjek „a", GJ „Žuća-Ribnica", ustanoviti količinu šumske biomase (deblovinu koja ostaje iza sječe i grane - drvna masa iznad 7 cm), ustanoviti količinu šumske biomase (drvna masa od 3 do 7 cm) te količinu kore. Istraživanje je provedeno na 60 stabala bukve. Zapremina drveta debla i kore debla utvrđena je metodom sekcioniranja, a masa grana utvrđena je vaganjem. Izjednačene vrijednosti zapremine drveta debla i kore debla pretvorene su u masu suhe tvari .

Na osnovu rezultata istraživanja utvrđeno je da se u odjelu 92, odsjek „a", GJ „Žuća-Ribnica" iskoristi 73% (1.605,24 tona) drvne biomase bukve, dok u šumi ostane neiskorišteno 27% (582,59 tona). Što pokazuje da veliki energetski potencijal iz biomase bukve ostaje neiskorišten.

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