ASSESSMENT OF SPECIES AND QUANTITY OF BIOMASS IN SERBIA AND GUIDELINES OF USAGE

by

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The motivation for this study is the disagreement of statistical and literature data about potential quantities of biomass in Serbia. This difference is mainly caused by changed status in practice due to several reasons: changes in ownership caused by transition, different application of technologies in practices, organization of work and economic reasons.
The main aim is to precisely establish sorts and amounts of organic biomass in Serbia that can be transformed into heat and electricity.
So far, data about the quantities of biomass residues in agriculture, forestry and communal services have been collected and published. Data collection methods are different and generally based on statistical data. The paper explains in detail methods of data collection and processing of crop production, fruit growing and viticulture, livestock, forestry and communal services.
On the basis of precise data collection, it has been established that there are 26.3 million tons of biomass residue in Serbia every year. The total amount of biomass is reduced by 20-30% in relation to the period of 10 and more years ago.
On the basis of the situation in agriculture and forest production in Serbia, it is estimated that out of the total amount of biomass, some 30-40% can be used for the production of heat energy, electricity and biofuel. The remaining biomass can be used in order to increase soil fertility, as cattle spread, for vegetable production, means for polishing in metal industry, for insulation in civil engineering, in cosmetics industry, production of animal feed, and so on.

Key words: *biomass energy intensity, energy efficiency, energy consumption*

Introduction

In agricultural production, forestry, industry, wood processing and municipal activities, huge amounts of biomass, *i. e.*, organic matter, residues from the production and waste mass are produced. The amount of biomass of produced plants in Serbia every year almost is equal to about 10 million tons. Thirty years ago, it was estimated that only in produced plants there were about 12.6 million tons of biomass. Part of the total biomass can be used as biofuel or raw material for fuel therefore, it is called renewable or sustainable energy source (RES).

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In Serbia, the first assessment of biomass was carried out in 1979. This assessment was based on the "Statistical Yearbook of Yugoslavia" and available data. These data are from 1990, and the conditions for agricultural production have changed significantly (sown areas, types of crops, varieties, agricultural practices, yield and biomass quantity). Today, after three decades, data are recollected and detailed analysis of the quantities of certain types of biomass is performed again. Also, it is still an unresolved problem how much of the total amount of biomass can be used for energy and for other purposes. Specifically, farmers believe that plant residues from agricultural production should be plowed to increase humus in the soil, *i. e.*, to improve soil fertility. Farmers also believe that biomass residues should be used partially for farm animals and thus produce manure, which can later be used as fertilizer. In the energy sector it is, however, considered that the significant part of the biomass can be used to produce heat and electricity. Namely, the fact is that large quantities of biomass are needlessly burnt in the fields, apparently due to difficulties in plowing. The biomass can be plowed if cut in small pieces, and this requires a lot of energy and represents the waste of time. Also, the fact is that the livestock significantly reduced presently due to changed technology of animal breeding (without animal bedding, *etc.*), So, this reduces the required amount of animal bedding for animals. However, it is believed that 30-40% of the total estimated amount of biomass can be used to produce heat and electricity.

The aim of this article is to identify existing sorts, biomass yields and quantities in Serbia on the basis of changed conditions in the agricultural, forestry and other industries.

Material and methods

Data about sorts, yields and amount of biomass are collected from several sources: from the "Statistical Yearbook of Serbia" [1], from literature and from investigations of experts from the Faculty of Agriculture in Novi Sad and Zemun [2]. The tab. 1, gives data on the sur-

Table 1. Biomass production of plants in Serbia (2003-2009)

No.	Culture	Surface [ha]	Yield of grain [t ha^{-1}]	Mass of grain [t per year]	Mass ratio [t t^{-1}]	Yield of straw [t per ha]	Mass of straw [t per year]
1	Wheat	566,277	3.52	1,994,068	1:1	3.52	1,994,068
2	Rye	6,178	2.13	13,139	1:1.2	2.55	15,766
3	Barley	100,698	2.96	298,569	1:1	2.96	298,569
4	Oats	44,952	1.98	89,183	1:1	1.98	89,183
5	Corn	1,000,752	5.59	5,591,972	1:1	5.59 (stalk + corncob)	5,591,972 (stalk + corncob)
	Corncob[1]	–	–	–	1:0.2	1.12	1,118,394
6	Sunflower	185,825	2.04	379,313	1:2	4.08 (stalk + head)	758,626 (stalk + head)
	Shell[2]	–	–	–	1:0.3	1.22	227,588
7	Soybean	137,827	2.41	332,726	1:2	4.83	665,452
8	Rapeseed	6,937	2.42	16,796	1:2	4.84	33,589
9	Tobacco (leaf, stem)	7,605	1.49 (leaf)	11,349 (leaf)	1:0.35	0.52 (stem)	3,970 (stem)
10	Total/mean value	2,057,051	4.24	8,727,115	1:1.11	4.71	9,678,783

[1] Mass of corncob is included in the mass of cornstalk (stalk + corncob)
[2] Mass of shell is not included in mass of sunflower stalk (stalk + heads)

face, yield and total weight of grain as taken from the [1]. The mass of grain and straw (stems, heads, cobs and husks) are taken from papers: Brkic *et al.* [3], Alimpic [4], Brkic [5, 6]. These relations should be explored for each particular culture in the future. The mass ratios are given for the equilibrium (*i. e.*, storage) water content in certain products. In row 10 (Total/Mean value) the value of grain yield, the mass ratio and straw yield represents a mean value which is obtained from the ratio of grain weight and surface soil, straw weight and grain weight and straw weight and surface soil.

The data in tab. 2 give surfaces under plants, fruit yield and fruit mass as taken from [1]. The ratio of masses of fruit and pruned branches (fruit trees and vines) is obtained by measuring the amount of cut off orchard nursery as in [7], at the school "Radmilovac" of the Faculty of Agriculture in Zemun [8] and vineyard in Sremski Karlovci, Department of Pomology and Viticulture, at the Faculty of Agriculture in Novi Sad. Sabo and Ponjičan [7] have made measurements at plantations of apples per one tree and have found out that 2.69 kg or 4.57 t/ha cut branches can be obtained with the moisture content of 42%. This means that the equilibrium water content of 14% in cut apple branches is 3.08 tons/ha. At the school "Radmilovac", the mass of cut vineyard peaches is 7.2 kg per one tree or 3.59 t/ha, plum "Dzenarika" is 7.68 kg per one tree or 3.84 t/ha and 1.60 kg of apples per one tree, or 3.09 t/ha with storage moisture content. Therefore, the yield of cut branches of orchard is based on the average measured mass of cut apple trees, plums and peaches per hectare by storage moisture content of 3.40 t/ha. It is recommended to perform measurements at other types of fruit plantations in order to accurately determine the average yield of cut branches for each type of fruit trees.

Table 2. Biomass production in orchards and vineyards in Serbia (2003-2009)

No.	Culture	Surface [ha]	Yield of grain [t ha^{-1}]	Mass of grain [t per year]	Mass ratio [t t^{-1}]	Yield of cut off [t ha^{-1}]	Mass of cut off [t per year]
1	Fruit tree	120,691	8.82	1,064,810	1:0.39	3,399	410,229
2	Grape vine	62,874	5.83	366,800	1:0.52	3,020	189,879
3	Total/Mean value	183,565	7.80	1,431,610	1:0.42	3,27	600,108

According to Novakovic and Djevic [9], the division into ripe or green per one grape vine in the vineyard it is possible to obtain 1.2-1.8 kg of pruned grape vines or the equivalent relevant to the area of 4-6 t/ha. By measuring the mass of cut vines in a vineyard in Sremski Karlovci, it is found that the weight cut off is 2.94-3.10 t/ha, at storage moisture content [2]. Because of that, years of data measurement for the calculation of average accepted cut off of vine 3.02 t/ha (tab. 2). Ratio masses of fruit and cut off are calculated based on total weight and the weight of cut off.

The tab. 3, gives data on the number of heads of certain types of cattle obtained from [1]. The average weight of animals is calculated by weighting the value of animals: calves, heifers, cows and heifers, bulls and breeding bulls with an average weight of individual animals. For example, for calves up to three months, the average weight is 80 kg, for heifers from three months to one year, it is 253 kg, for heifers over one year, it is 500 kg, for cows and pregnant heifers, it is 550 kg, for breeding bulls, it is 900 kg and for steers, it is 700 kg. Based on these data, the average weight is calculated to be 438.4 kg of cattle.

In order to obtain the total amount of manure, it is necessary to multiply the number of cattle with an average weight and divide the resulting value by the mass of conditional head of cattle (1 CN = 500 kg). One conditional head of cattle gives 26 kg of manure per day [10]. Therefore, the value of the mass of manure produced per day should be divided by 1000 to get

Table 3. Biomass production in cattle breeding in Serbia (2003-2009)

No.	Sort	Number of heads	Mass of heads [kg]	Number of conditional heads [No. of CN[1]]	Mass of manure [kg/CN[1] per day]	Mass ratio [kgkg^{-1}]	Mass of manure [t per year]
1	Cattle	1,090,500	438.3	956,150	26	1:18.98	9,073,864
2	Pigs	3,610,500	54.8	395,711	22	1:16.06	3,177,559
3	Sheep	1,574,167	38.0	119,637	26	1:18.98	1,135,355
4	Goats	156,833	35.0	10,978	26	1:18.98	104,181
5	Horses	21,667	400.0	17,334	26	1:18.98	164,500
6	Poultry	16,798,833	1.5	50,396	26	1:18.98	478,258
7	Total/ Mean value	23,252,500	33.33	1,550,206	24.98	1:18.24	14,133,717

[1] 1 CN = 500 kg

tons and multiply it by 365 days a year. The ratio of the weight of cattle and manure produced is obtained by dividing these masses. The manure is 30-35% solid and 70-75% liquid part (called slurry). If in case of cattle, animal bedding is added then, the content of the solid part will be increased. For the purpose of mechanized transportation of manure through the pipelines to biogas plants or in tanks for spreading of liquid manure on fields, it is necessary to dilute manure with water and the proportion of the solid part will fall 8-10% (design value for the construction of biogas plants).

In the same way, the average weight of pigs is calculated. In the "Statistical Yearbook of Serbia" [1], the numbers for the mass range of registered pigs is give: pigs to 20 kg, pigs 21-50 kg, fattening pigs 51-80 kg, fattening pigs 81-110 kg and fattening pigs over 110 kg, breeding pigs (suckling over 50 kg), sows and boars. To be able to calculate the average weight of approximate pig adopted mean values listed weight: pigs I category 15 kg, pigs II category 30 kg, fattening pigs I category 70 kg, fattening pigs II category 90 kg, fattening pigs III category (over 110 kg) 115 kg, suckling (50-125 kg) 87.5 kg, 147.5 kg of sows and boars 160 kg [10]. The average weight of pigs is calculated by weighting the value of animals and average weight of individual animals. The obtained average pig weight is 54.8 kg. In order to obtain the total amount of manure, the same method is applied as for cattle [10]. The calculation of the amount of manure in sheep, goats, horses and poultry is based on adopted average weight of animals according to the information provided by Kovcin [10]. The exceptions are the horses, where the adopted average weight is 400 kg.

The tabs. 4 and 5 show data of biomass in the forests of Serbia. Data are taken from [1]: the surface under forest, felled trees, forest residues and in wood, expressed in cubic meter and converted into tons. Also, we have used data from the paper [11]. According to this paper, out of the total volume of tree trunks, 58% of technically round lumber is obtained, and 42% is potential waste (leaves, chips, twigs, logs, stumps, roots and sawdust). Wood processing of round lumber produces 35% of processed lumber, and 65% of potential waste (bark, chips, logs, cuttings, hems, twigs, sawdust, dust and flour). It is adopted that the mass of one spatial cubic meter is 750 kg/m^3 and residues from wood processing (chips, sawdust, *etc.*) are 375 kg/m^3. The data are taken for deciduous and coniferous trees and for the mixture of deciduous and conifer trees, *i. e.* for the rest of trees. The deciduous tree lumber is suitable for heating, and that of coniferous trees is not because of increased amount of resin material.

Table 4. Biomass production in forestry and wood processing in Serbia (2003-2009)

No.	Sort	Surface [ha]	Pruned trees [m^3]	Forest residue [m^3]	Remaining in processing [m^3]	Volume ratio [m^3m^{-3}]	Total remaining [m^3]
1	Deciduous	1,988,800	2,317,667	973,420	873,760	1:0.80	1,847,180
2	Conifers	209,600	226,000	94,920	85,202	1:0.80	180,122
3	Mixture	54,000	34,333	14,420	12,944	1:0.80	27,364
4	Total/Volume Ratio	2,252,400	2,578,000	1,082,760	971,906	1:0.80	2,054,666

Table 5. Biomass production in forestry and wood processing in Serbia (2003-2009), in tons

No.	Sort	Surface [ha]	Pruned trees [t]	Forest residue[1] [t]	Remaining in processing[2] [t]	Mass ratio [$kgkg^{-1}$]	Total remaining [t]
1	Deciduous	1,988,800	1,738,250	365,033	327,660	1:0.40	692,693
2	Conifers	209,600	169,500	35,594	31,951	1:0.40	67,546
3	Mixture	54,000	25,750	5,408	4,854	1:0.40	10,261
4	Total/Mass Ratio	2,252,400	1,933,500	406,035	364,465	1:0.40	770,500

[1] 1 m^3 = 750 kg, [2] 1 m^3 = 375 kg

The data presented in tab. 6 for the determination of municipal waste, *i. e.* namely, the determination of organic waste, which can be used for combustion or for biogas. Data are taken from reports in the project "Establishing the Composition of the Waste and Estimates of the Amount of Waste in Order to Define the Strategy of Secondary Material in the Sustainable Development of the Republic of Serbia", Vujic *et al.* [12]. The total amount of organic waste is 1.2 million tons per year. Since this amount is 59.3% of organic waste, which can be used for energy purposes. Garden waste, which is in significant quantities, can be used to produce biogas, and other organic waste can be incinerated to produce heat and electricity.

The tab. 7 shows total data of produced biomass or organic matter, *i. e.*, residues from agricultural, forestry production and wood processing industry, and municipal organic waste. Based on these data it is shown that the total annual amount of biomass is 26.3 million tons. It is believed that 30-40% of the total estimated amount of biomass each year can be used to produce energy, *i. e.* heat and electricity.

Results and discussion

Data on the average amount of biomass produced from plant production in one year in Serbia are presented in tabs. 1 and 2. These data refer to the production period of 6 years (2003-2009). Ten years ago, Serbia produced each year 12.6 million tons of biomass, and today it produces 10.2 million tons. Analyzing these data in relation to the previous period from 10 or more years ago, it can be concluded that the amount of biomass in crop production, fruit growing and viticulture in Serbia dropped by 19%, and in the Province of Vojvodina by 32%. As for the sorts of biomass, data are from the "Statistical Yearbook of Serbia" [1], it can be concluded that even this situation has changed. The production of oat is smaller, of hop is negligible, there is less tobacco, domestic seeds are reduced, rape, as well. The production of major crops has

also been reduced. For example, wheat production is about one-third lower, corn is reduced by one quarter, and so on. In tab. 1, it can be seen that the highest biomass can be obtained from cornstalks 57.76% with reference to the total mass produced in farming. Out of this, 20% of biomass are cobs. Biomass produced by green plants corn (silage) is very useful and it can be used to produce biogas. The production of fruit biomass is based on data reduced by 5%, and the vineyard biomass by 20%, due to removing the vines. According to current data, it turns out that the production of fruit biomass is doubled. It has not been achieved, but it is the result of bad estimates of biomass yield in the previous period of 10 years and over. However, looking at the amount of biomass (cut off) in orchards and vineyards in relation to the total amount of biomass produced, it can be found that they are not large (a total of 600,000 tons per year). The remains of biomass from farming and horticulture can be used for heat and electricity [13].

The tab. 3 shows the amount of manure produced in animal breeding in Serbia. The average amount is about 14 million tons per year. The fact is that in Serbia, especially in the Province of Vojvodina [1], the number of cattle has been reduced recently and therefore, the amount of manure is also reduced. Thus, the number of cattle in Serbia fell by almost double, up to 16% of pigs, sheep 38% and poultry 42%. In the Province of Vojvodina, the number of cattle is increased by11%, pigs are decreased by 12%, sheep and poultry by 29-30%. The manure produced can be used for producing biogas, and to obtain fermented substrate which is very nutritious organic fertilizer.

Biomass production in forestry and wood processing industry in Serbia is shown in tabs. 4 and 5. In Serbia, there is about 27.3% of forest surface in relation to the total area. On the average, there are forest and wood processing residues of 770,000 tons in Serbia every year. At the territory of Vojvodina, deciduous trees prevail, *i. e.*, mostly soft wood (poplar, willow, *etc.*). It is necessary to plant fast growing energy crops at poor quality soil in the Province of Vojvodina for the purpose of their use in the production of heat energy and electricity.

The amount of municipal waste is significant in Serbia (tab. 6). The Republic has totally 2,445,601 households, and the average number of persons per household is 3.01. It is determined by measuring the weight of municipal waste of 0.76 kg per inhabitant per day. On the average, there is 2 million tons of municipal solid waste every year. The share of organic waste is 59.3%. In most organic waste, biodegradable waste is 30.96% and 11.88% of garden waste in the total municipal solid waste. This waste can be used to produce biogas, compost, *etc.* and can be burned. Other organic waste, leather, cardboard and paper, can be burned to produce heat or electricity.

Table 6. The amount of municipal residues in Serbia (2009)

No.	Period of year	Amount of refuse [t per year]	Mass of refuse [kg per inhabitant per day]	Portion of organic refuse [%]	Mass of organic (biodegradable) refuse [t]
1	Summer	2,226,427	0.83	59.28	1,319,802
2	Winter	1,857,598	0.69	59.26	1,100,800
3	Average	2,042,013	0.76	59.27	1,210,301

Table 7 gives data of the total amount of biomass produced during one year. This sum is up to 26.4 million tons each year. The amount of crop biomass is reduced by 20% compared to the situation three decades ago, fruit growing and vine up to 10%, livestock 40% and forest 10% [8-11].

Table 7. Review of produced amount of biomass in Serbia (2003-2009)

No.	Type of biomass	Amount [t]
1	Crop of farming biomass (residue)	9,678,783
2	Orchards and vineyards biomass (cut off)	600,108
3	Cattle breeding biomass (manure)	14,133,717
4	Forestry biomass (residue)	770,500
5	Communal (organic) refuses, 2009	1,210,301
6	Total	26,393,409

Conclusions

The systematic collection of data has revealed that 9.6 million tons of biomass from agricultural production (the rest of the production of grain), 600 thousand tons of fruit growing and wine production (cut off), 14 million tons of livestock production (manure), 770 thousand tons of forest production and processing of wood and 1.2 million tons of municipal (organic) waste are produced in Serbia every year. The annual amount of biomass produced is totally 26.4 million tons. From this quantity of biomass, 30-40% can be used for heating purposes and electricity generation. Other quantities of biomass can be used to increase soil fertility, for vegetable production, producing animal feed, animal bedding, the insulation in building construction, polishing in the metal industry, in the cosmetics industry, and for other purposes. Also, part of the plant production (silage) may be directed to the production of biogas, and on less fertile soils some fast-growing energy crop can be grown.

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