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Analysis of Plant-Production-Obtained Biomass in Function of Sustainable Energy

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Abstract: This research analyzed the degree of utilization of the agricultural biomass for energy purposes (combustion), in order to indicate the reasons that limit its use. The biomass potential was studied by means of the methodology of the biomass potential, whereas the factors suggesting a low degree of biomass utilization were identified by means of factor analysis. The research results reveal that there is an enormous potential of the unused agricultural biomass. This dissertation research significantly contributes to the establishment of a genuine mathematical model based on multiple linear regression. The solution obtained by this analysis, in both a mathematical and a scientific manner, conveys the primary reasons for an insufficient utilization of the biomass for energy purposes. Moreover, the paper suggests the measures to be applied for a more substantial use of this renewable source of energy and presents the expected benefits to be gained.

Keywords: biomass; crop residue; crop production; energy purposes; sustainability

1. Introduction

The Republic of Serbia has been estimated to possess around 5,069,000 ha of the agricultural land: 3,298,000 ha (65%) of the arable land and gardens, 239,000 ha (4.72%) of orchards, 50,000 ha (0.99%) of vineyards, 653,000 ha (12.88%) of meadows and 829,000 ha (16.35%) of pastures [1]. The proportion of the agricultural land and the population in the Republic of Serbia is 0.47 ha/person, which is a rather high figure even for the state members of the EU, when compared, for instance, with these proportions in certain countries: Hungary 0.51 ha/person, Denmark 0.50 ha/person, France 0.33 ha/person, Italy 0.20 ha/person, Germany 0.19 ha/person, Holland 0.06 ha/person [2].

The potential of biomass in the Republic of Serbia is estimated at 2.58 Mtoe and consists of agricultural biomass (about 60%) and forest biomass (about 40%) [3,4]. The Republic of Serbia, and especially its northern region (the Autonomous Province of Vojvodina), has a relatively large potential of agricultural biomass, especially in crop production. That is the sole reason why the region of Autonom Province (AP) Vojvodina was selected for the research on the use of plant-production-obtained biomass for energy purposes. The total potential of the biomass in the AP Vojvodina has been estimated at 6.45 Mt per year, out of which, 2 Mt of the harvesting crop residue and around 0.45 Mt of the fruit growing, grape growing and forestry residue could be used for annual energetic purposes [5].

Today, the chief problem of productivity and competitiveness of agricultural production in the Republic of Serbia lies in fragmented agricultural holdings, the average size of which is 5.77 ha [6]. Among other noted barriers that limit agricultural biomass utilization, the following stand out: the non-existence of incentive measures/feed-in tariffs for wider use (thermal energy) [7], limitations and availability of biomass as a source of energy [8], long waiting time for building permits, extremely low purchase price of electricity for non-privileged suppliers, etc.

The goal of this paper was to identify, by way of an analysis of biomass utilization for energy purposes, the chief causes of low biomass utilization in AP Vojvodina. The starting hypothesis in the research was that less than 20% of the biomass technical potential is used for energy purposes.

The research presented in this paper comprises the following chapters: introduction, the problems related to harvesting crop residue, the justification for the utilization of the agricultural biomass for energy purposes, materials and methods, results, discussion and conclusion.

2. The Problems Related to Harvesting Crop Residue

The process of decomposition of organic matter in the soil releases nutrients, which improves soil fertility and increases crop yields [9]. For example, for an average wheat target yield of 4 t/ha per year, each ton of organic carbon (SOC) added to a 15-cm deep plow layer contributed to the formation of 4.75 kg N/ha [10].

Whether, and to what extent, crop residue will be used for plowing and soil erosion prevention and for the increase in soil carbon content, or for energy purposes, depends on several factors. This relationship must be pre-defined and the biomass amounts used for other purposes must be known in advance. This process of primarily harvesting crop residue must be sustainable, because removing too much residue may cause exposure of the soil to excessive erosion, while too little or no residue removal may lead to residue preventing the soil from drying in the spring, which may affect the planting season [11]. The crop residue removal rate depends on several factors, including maintaining the fertility of soil, the availability of mechanization, plant varieties and yield. [12].

The method and the purpose of handling the remaining plant-production-obtained biomass remains a matter of controversy around the globe. Essentially, it is a highly complex problem depending on several variables, including soil quality (the humus content in the soil), the crop rotation plan, and management methods (fertilization and cultivation). Thus, based on the research [13], it has been pointed out that, for the purpose of maintaining the soil fertility, nothing should be removed from the field, or that only 25 to 50% [14,15] may be removed, or 30% to 60% [16], or 33% [17] etc. Research [16] has indicated the existence of a rate of sustainable crop residue removal from agricultural soil regardless of its location, and this rate of sustainable crop residue removal can go up to 40% for wheat, barley, oats and rye, and about 50% for corn, rapeseed, rice and sunflower.

3. The Justification for the Utilization of Agricultural Biomass for Energy Purposes

The use of fossil fuels for energy purposes leads to a constant increase in the concentration of pollutants (CO_2, CO, SO_x, NO_x, and other harmful oxides in the atmosphere) which cause global warming and have other negative impacts, such as acid rain and photochemical smog [18]. The last century was predominantly marked by the use of fossil fuels in energy production [19], but the beginning of the twenty-first century saw enormous efforts made in order to mitigate the effects of global warming caused by CO_2 emissions in the atmosphere [20]. Those were the exact endeavors in which sustainable development was grounded, a development that implies keeping a balance between the use, saving, and renewal of all resources [21], and not their uncontrolled expenditure to the detriment of future generations [22].

Globally, more than 2 Gt of plant residue are burned unreasonably, generating about 18% of total global CO_2 emissions in the process [23]. The production and use of biomass for energy purposes reduces the emission of harmful gases and contributes to the protection of soil and water. With regard to environmental impact, biomass is a highly acceptable fuel as it contains very little, or even no, toxic substances like sulfur and heavy metals, which are usually found in fossil fuels and are emitted into the air through their combustion, posing a danger to human health and natural resources. The main advantage of biomass over fossil fuels lies in its global availability and renewability [24,25]. Calculations show that atmospheric pollution by biomass combustion is negligible, since the amount of CO_2 emitted during biomass combustion is equal to the amount of CO_2 absorbed during plant growth [26,27].

The significant energy production from agricultural biomass can have a negative impact on food supply and prices, soil erosion and biodiversity [28]. On the other hand, agricultural residue can be an environmentally friendly and renewable source of energy [29]. The thermal energy obtained by burning these fuels can be used for heating households, industrial processes, crop drying, etc., and even for electricity production [30].

The traditional method of biomass utilization is mainly present in developing countries, in which this energy source provides between 34% and 40% of the total energy requirements. Modern biomass processing plants, on the other hand, are primarily used in developed countries [31,32], including European, Asian, and North American countries [33].

Globally, the potential for energy production from biomass is quite large, but also insufficient to replace the current energy production sources [34]. Biomass currently secures the largest share of renewable energy with over 50% of global renewable energy consumption [35] (i.e., over 10% of world primary energy consumption) [36]. In the near future, biomass is expected to be the most beneficial of all renewable energy sources [37]. In this context, there is a possibility that there will be a significant increase in agricultural residue globally if the developing countries continue to intensify agricultural production, in which case it is estimated that about 998 million tons of agricultural residue will be generated annually [38]. For example, it is estimated that, by 2030, about 155 million tons of residue will be used in the production of bioenergy in the United States, while not taking into account the formation of additional agricultural properties [39].

4. Materials and Methods

The first step in the process of defining the research hypothesis, i.e., the calculation of the technical potential of biomass for the purpose of satisfying all agricultural activities, was the adoption of the generally accepted scientific assumption prevailing in the Republic of Serbia, according to which, ¼ solid biomass should be used to increase the soil fertility (it is plowed either immediately or in the form of a mulch, after use), ¼ for the production of animal feed, ¼ for industrial processing (in the production of paper, cardboard, packaging, alcohol, cosmetics, etc.), and ¼ used for energy production [40,41].

The regional testing criteria were the following:

- The investigations were limited to the locality of AP Vojvodina;
- An equal presence of investigations in all three regions (Srem, Banat, and Bačka);
- The smallest number of represented agricultural properties by district was five, so that properties from all districts (South Bačka, North Bačka, West Bačka, South Banat, North Banat, Central Banat, and Srem) could be examined, Figure 1.

Figure 1. AP Vojvodina with Districts [42].

Basic information on the surveyed properties:

- The activity of the surveyed agricultural farms was plant production;
- The number of samples: 75 agricultural farms;
- The sample size: 25 farms with the size of <100 ha, 25 farms with the size of 100–1000 ha, and 25 farms with the size of >1000 ha;
- The farm selection: by employing the random sampling method.

The total area under crop production on the observed properties was 55,880 ha, Table 1. However, the quantities of biomass (area) that were purposely grown for livestock feed production (hay, alfalfa, and clover), those used in biogas production (silage corn, silage sorghum, etc.), and the residue of other crops that could not be utilized in the combustion process were all excluded from the analysis. The total analyzed areas for calculating the total available biomass in the research amounted to 51,382 ha, Table 2. The average size of the surveyed properties was 745.07 ha, the average number of workers per farm was 27.05, and the average number of workers per ha of cultivated area was 0.041 workers/ha, Table 3.

Table 1. Data related to the size of arable land and the number of workers on the observed agricultural properties.

Property Size	Total Arable Land (ha)	Total Number of Workers (Person/ha)
≤100	1073	61
100–1000	8278	249
>1000	46,529	1719
Σ=	55,880	2029

Table 2. Analyzed crops and cultivated area [43].

Plants					
Farming		Vegetables		Fruits and Grapes	
Analyzed Crops	Cultivated Area (ha)	Analyzed Crops	Cultivated Area (ha)	Analyzed Crops	Cultivated Area (ha)
Wheat	11,059.00	Peas	467.00	Apples	927.00
Triticale	290.00	Green beans	250.00	Pears	359.00
Barley	1881.00	Total=	717.00	Apricots	192.00
Corn	13,282.50			Peaches	375.00
Hybrid seed corn	3605.00			Cherries	422.00
Soya	10,267.50			Plums	102.00
Rapeseed	2587.00			Raspberries	1.00
Sunflower	5123.00			Quince	2.00
Tobacco	25,00			Hazelnuts	8.00
Total=	48,120.00			Walnuts	1.00
				Grapevines	156.00
				Total=	2545.00
		Sum total=	**51,382**		

Table 3. The average data related to the size of arable land and the number of workers on the observed agricultural properties.

Property Size	Average Property Size	Average Number of Workers per Property	Average Number of Workers per Hectare of Arable Land (Person/ha)
≤100	42.92	2.44	0.057
100–1000	331.12	9.96	0.030
>1000	1861.16	68.76	0.037
Σ=	745.07	27.05	0.041

After the results of the utilization of agricultural biomass had been collected, a quantitative assessment of the amount of biomass utilization for energy-related and other purposes was designed. For this assessment, the methodology on biomass potential was used [44] (an Excel application for the development of agricultural biomass balance). The methodology used in this research is identical to other methodologies used in the Republic of Serbia and ountries in the region. It basically calculates the biomass potential based on the determination of the proportion of the total quantity of the crops produced and the residues. Unlike other methodologies that base their estimations on the predicted and expected crop production, this methodology uses the official statistical data on the crops production related to the period in which this research was conducted, i.e., the year of 2018.

The theoretical potential of E_{teo} in this paper was used to present the total amount of biomass in the observed area, i.e., to calculate the technical potential of biomass further, Equation (1)

$$E_{teo} = \sum_{i=1}^{n} P_{polj.(i)} \cdot O_p P_{o(i)} \text{ (t/year)} \quad (1)$$

where:

- $P_{polj.(i)}$—quantity of crops produced (t/year);
- $O_p P_{o(i)}$—mass ratio of basic products—agricultural residue(t/t).

The technical potential of biomass E_{teh} obtained during the research was calculated on the basis of the calculated theoretical potential E_{teo} and the sustainability factor F_o. The technical potential is basically the part of the theoretical potential that can be used in practice, and thus can be employed in the process of the practical use of energy. The technical potential of the agricultural residue utilization is significantly lower than the theoretical potential. A certain amount of harvest residue must be left in the soil and plowed in order to preserve the soil productivity, or it must be returned to the soil by way of the biomass intended for food and mulch

$$E_{teh} = \sum_{i=1}^{n} E_{teo(i)} \cdot F_{o(i)} \text{ (t/year)} \quad (2)$$

where:

- $F_{o(i)}$—the sustainability factor (%).

The technical potential of biomass presented in this manner in the research results was compared with the actually used biomass energy potential.

Due to the need to maintain the fertility of agricultural soil in the course of research, it was adopted/calculated that $\frac{1}{4}$ or 25% (F_o = 0.25) can be removed from the fields in field and vegetable production. On the other hand, in the calculation of the residue of prune kernels in fruit and vineyard production of seed corn cobs and sunflower husk, the value of F_o = 1 was adopted.

The energy potential of biomass E_{pot} is part of the technical potential, in which case the available biomass amount is shown in relation to energy, Equation (3)

$$E_{pot} = \sum_{i=1}^{n} E_{teh(i)} \cdot H_{d(i)} \text{ (GJ/year)} \quad (3)$$

where:

- $Hd_{(i)}$—the lower thermal power (MJ/kg).

The factor analysis was used to identify the main factors contributing to a low degree of the utilization of biomass for energy purposes in the AP Vojvodina. Primary data related to the identification of the key factors were collected by means of a specially designed initial questionnaire.

The questionnaire was constructed using the rational method and comprised 60 questions concerned with the economic, social, educational and technological aspects of the use of biomass for energy purposes. It is important to emphasize that the respondents who participated in the validation of the questionnaire were not involved in collecting the data related to the influence of the identified factors on the degree of biomass utilization. Thus, partial responses were avoided. A total of 600 respondents participated in the validation of the questionnaire. The *Kaiser–Meyer–Okin* (KMO) test was used for testing the adequacy of the sample size.

The factor analysis was conducted on the basis of the results obtained from the initial questionnaire. It was based on the supposition that the data were interval data, thus satisfying the assumption of normal distribution. For the purpose of identifying the key factors, the *Promax* rotation (with the *Kaiser* normalization) was used, which rotates the orthogonally rotated solution again in order to enable the correlations among the factors. Based on this rotation, 18 key factors were identified which determined the degree of use of biomass for energy purposes.

The obtained results were used in the model of multiple linear regression of Equation (4) to examine the influence and significance of individual factors on the degree of biomass utilization for energy purposes, where the energy purposes are expressed through the percentage of biomass utilization for energy purposes—y (%)

$$y = \alpha + \sum_{i=1}^{n} \beta_i x_i \quad (4)$$

where:

- α—the section coefficient within the model;
- β_i—the regression coefficient with the i^{th} independent variable;
- x_i—the independent variable of the i^{th} factor influencing the degree of biomass utilization.

The data related to the degree of biomass utilization were collected from 75 agricultural properties, which were divided into three groups according to the size of the area from which biomass was collected. The least square method (*Ordinal Least Square*) was used for the model evaluation.

5. Results

5.1. The Analysis of Plant-Production-Obtained Biomass Utilization Results in AP Vojvodina

Based on the presented calculation analysis, it was concluded that at the observed location the total theoretical potential of biomass was 481,326.90 t/year, the technical potential of biomass 152,318.49 t/year, and the energy potential 2,201,389.03 GJ/year (Table 4). In addition to the fact that 25% of biomass from field and vegetable production could be used for energy purposes, the analysis also includes the biomass potentials that can be fully utilized, as is the case with crops in fruit and wine production, seed corn cobs, and sunflower, walnut and hazelnut husks.

Table 4. The potentials of biomass [43].

Plant Production	E_{teo} (t/Year)	E_{teh} (t/Year)	E_{pot} (GJ/Year)
For field production	466,259.87	139,205.21	2,000,486.81
For vegetable production	2605.00	651.25	9117.50
For fruit and vineyard production	12,462.03	12,462.03	191,784.72
Total=	**481,326.90**	**152,318.49**	**2,201,389.03**

Research has shown that of the total (theoretical) potential of 481,326.90 t/year, 15,149.42 t/year was used for energy purposes direct combustion), 13,252.90 t/year for livestock, 440,208.68 t/year for mulching and plowing, and 12,715.90 t/year was burned on site, Table 5. The study did not record the amount of biomass that could be used for industrial purposes.

Table 5. The analysis of the utilized potentials of solid biomass [43].

Plant Cultures	Total Biomass Available (t/Year)				
	Total Available Potentials	Energy Utilized	Used to Feed Livestock	Used for Mulching and Plowing	Burned in the Field
For field production	466,259.87	14,813.69	13,252.90	437,603.68	589.60
For vegetable production	2605.00	0.00	0.00	2605.00	0.00
For fruit and vineyard prod.	12,462.03	335.73	0.00	0.00	12,126.30
Total=	**481,326.90**	**15,149.42**	**13,252.90**	**440,208.68**	**12,715.90**

Of the total amount of biomass utilization for various purposes, 3.15% was used for energy purposes (direct combustion), 91.46% for mulching and plowing, 2.75% for livestock feeding, and 2.64% was burned in the field, Figure 2. If, in the course of analysis, the amounts of biomass that were combusted/burned on any basis are combined, and if the industrial utilization is included, the following data are obtained: 0.00% of biomass is used for industrial purposes, 2.75% for livestock feed, 91.46% for mulching and plowing, and 5.79% was burned, Figure 3.

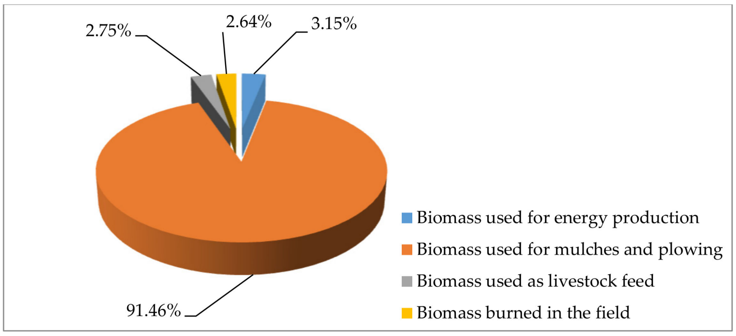

Figure 2. The actual utilization of multipurpose biomass—a separate display of burned biomass (thermal energy production and on-site burning) [43].

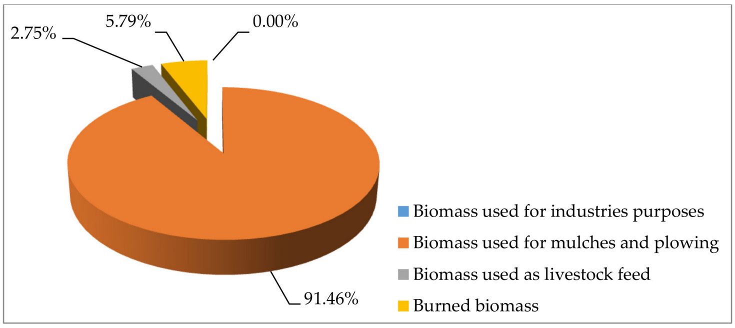

Figure 3. The utilization of multipurpose biomass the summary of burned biomass (thermal energy production and on-site burning).

The problems related to crop residue burning have been noted on smaller farms, because sometimes farmers burn the residue in order to get rid of huge amounts of biomass before the basic tillage. The remains from the fruit and vineyard production are also burned because there is no technological process of pruning collection and utilization.

The ratio of biomass for energy purposes and biomass for other purposes—the investigated state and the assumed state—is shown in Figure 4. The technical potential of biomass intended for energy purposes was 26.94% (mark 1) in relation to the theoretical biomass potential, while 73.06% of biomass could be used for other purposes. The results of the research showed that the usable energy potential was 3.15% (mark 1) in relation to the theoretical biomass potential, while 96.85% of biomass was used for other purposes.

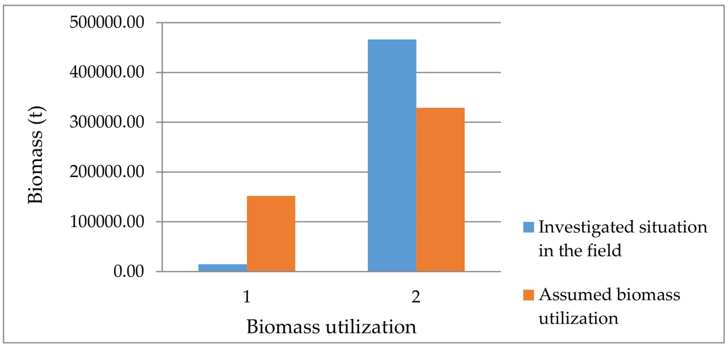

Figure 4. Biomass utilization, the investigated state—the assumed state [43].

Biomass used for energy purposes was 15,149.42 t/year, while an additional 137,169.07 t/year could be used without affecting the sustainability of the agricultural production. These results indicate that the hypothesis is confirmed.

5.2. The Investigation of Key Factors of the Utilization of Biomass for Energy Purposes

The Factor Analysis Identified 18 Factors with their particular values higher than 1, Table 6. The analysis confirmed that these 18 identified factors explained 59% of the variation.

Table 6. Identified factors.

Factor	List of Factors
Q1	Lack of economic justification for the use of biomass for energy purposes;
Q2	Emergence of problems related to technical equipment and technology applied in the production, manipulation and storing of biomass;
Q3	Economic justification for the production of biomass for energy purposes is debatable;
Q4	Lack of precise government measures that might considerably initiate the use of the agricultural biomass for energy purposes;
Q5	Official educational system has not yet recognized the necessity of educating professionals to occupy themselves with the agricultural biomass;
Q6	Investing in agricultural machinery, equipment and energy manufacture is expensive;
Q7	Agricultural biomass is characterized by limiting factors in comparison to other renewable energy sources;
Q8	Biomass power generation (biomass used for combustion) is short-term without the presence of manpower;
Q9	There is no active free market of biomass;
Q10	There is a shortage of either national or international projects that might support the construction of manufacture operating on biomass;
Q11	Shortage of workers t obe employed in the biomass sector;
Q12	The low price of electricity in the Republic of Serbia is a limiting factor that affects the use of biomass;
Q13	The need for the plants that use biomass and produce thermal energy is limited;
Q14	Certain interest groups are not in favor of the use of agricultural biomass for energy purposes;
Q15	Biomass transport is costly, which greatly determines the criteria for defining the economic justification of this type of production;
Q16	The problem of a continuous placement of energy in the course of the year;
Q17	Problems related to the sale of the produced biomass are rather pronounced;
Q18	Stimulating tariffs for the production of energy from the agricultural biomass are hard to get.

In order to identify the main causes of low biomass utilization, Table 7 shows the estimates of the model parameters according to Equation (4), while taking into account the importance of the size of the agricultural property at which biomass for energy purposes is generated.

The results of the model parameter evaluation show that, in the case of agricultural producers who cultivate up to 100 ha, two factors affecting the utilization of biomass for energy purposes are important. Those are factor 6, related to high investment costs for agricultural machinery, equipment, and modern power plants, and factor 14, related to the influence and activities of certain interest groups (decision-makers, lobbyists, etc.) which are not in favor of the utilization of agricultural biomass that could be used for energy production during the combustion process.

Table 7. The results of model evaluation depending on the size of the agricultural property [43].

Variables	Coefficient	Standard Error	T-Test Value	*p*-Value
		Up to 100 ha		
Constant	0.719	0.151	4.763	0.000
F6	−0.132	0.049	−2.702	0.013
F14	−0.056	0.024	−2.276	0.033
R^2	0.399			
		Over 1000 ha		
Constant	−0.003	0.045	−0.071	0.944
F16	−0.037	0.011	−3.297	0.004
F1	0.019	0.008	2.504	0.021
R^2	0.403			

In the case of farmers cultivating lands of a size between 100 and 1000 ha, the parameter evaluation factors showed that the factors identified using the PCA analysis had no significance for them.

In the case of agricultural producers cultivating lands of over 1000 ha, the analysis indicated that two factors were significant: factor 1, related to a lack of economic justification for the utilization of biomass for energy purposes, and factor 16, related to technical problems, or more precisely to continuous energy placement within a year. A lack of economic justification is related not only to the non-existence of a free market for biomass, guaranteed purchase prices for the sale of biomass, and guaranteed purchase prices for privileged energy producers, but also to the fact that increasing biomass utilization requires additional labor force, which would incur costs higher than the benefits of increasing biomass utilization. In order for such processing plants to be economically justified as soon as possible, it is necessary for them to operate as many days as possible during the year.

6. Discussion

The results of the analysis of the utilization of biomass for various purposes in AP Vojvodina showed that 3.15% was used for energy purposes, 91.46% for mulching and plowing, 2.75% for livestock feed, and 2.64% was burned on site. It is very interesting to compare those results with the countries that are leaders in the utilization of agricultural biomass for energy purposes, for example with the results in Sweden and Denmark. In 2012, Scott Bentsen, N. et al., 2016, analyzed the utilization of straw biomass in Sweden. Their research showed that straw was collected on 40% of the total area planted with crops, i.e., ~1.02 million ha, where 73% was used for mulching/plowing, 13% for livestock feeding, while 9% was used for heating energy requirements (i.e., 3.6% of the total area or 36,000 ha) [45]. Ericsson and Nilsson, 2006, state that in Denmark, 20–40% of crop residue from agricultural production is used for the production of energy [46].

Research has shown that the average used biomass for energy purposes (direct combustion) was 3.15% in AP Vojvodina. Those results are similar to the results of the biomass potential utilization in the Republic of Serbia presented in the *Strategy, 2015*, according to which the utilization of agricultural biomass is merely 2% [47].

Research has shown that 2.64% of crop residue was burned in the field. Problems related to crop residue burning have been noted on smaller farms because farmers sometimes burn the residue in order to get rid of huge amounts of biomass before basic tillage. Burning crop residue in fields is a problem in many countries worldwide. In China, 20.5% of crop residue is discarded or uncontrollably burned on site, 37.5% are used for energy purposes (of which 37% of crop residue are directly burned by farmers, and 0.5% is used for biogas), 23% is used for animal feed, 15% is lost during the process of collection, 4% for industrial substances [48]. In India, the share of burned crop residue ranges from 8 to 80% [49,50], with the crop residues most frequently burned coming from rice (43%), wheat (about 21%), sugar cane (about 19%), and oilseeds (about 5%) [50,51]. In Europe, specifically in Greece, it has been recorded that the remaining amounts of biomass in the fields are burned [52].

While bearing in mind the obtained results, and especially the high values of the determining factor (R^2), it is possible to propose recommendations which could contribute to the utilization of biomass for energy purposes to a significant degree, and those would include the following:

1. Providing farmers with financial incentives for the purchase of machinery and equipment and the construction of energy plants, and for investing in the education of agricultural producers;
2. The introduction of guaranteed quotas for the purchase of produced energy through legislation would eliminate the influence of certain interest groups that disfavor this type of energy;
3. Securing a free biomass market, providing guaranteed biomass purchase prices, guaranteed energy purchase prices for privilege energy producers, etc. The opening of a free biomass market (more regional biomass purchase centers) would allow more people to benefit from biomass utilization (biomass producers, traders, distributors, end users, etc.);
4. Securing heat consumption for the produced energy throughout the year would solve the problems of continuous energy placement and justification of this type of energy production. Using thus produced thermal energy to help heat cities and municipalities could significantly reduce the use of fossil fuels on the one hand, while, on the other, locally available energy sources would be used. That type of thermal energy placement is fully justified, due to the fact that local self-government bodies could provide thermal energy producers with incentive feed-in tariffs for heat production.

With all recommended measures applied, the following benefits are expected to be gained in the forthcoming period: the production of considerable quantities of energy; diversification of the national energy market, revival of rural settlements [53]; creation of reduced dependence on fossil fuels and alleviation of shortages thereof on the market [54]; placement of the produced thermal energy as support in heating cities and municipalities; gaining profit; options for biomass export; considerable number of citizens will benefit from the use of biomass (producers of biomass, businessmen, logistics employees, end users, etc.) and protection of natural resources (water, air, soil, fauna, etc.).

Justification of the conducted research fits into the current needs and goals of the Republic of Serbia in terms of new sources of energy. The needs for energy in the Republic of Serbia are enormous —on the one hand, imported fossil fuels are used, and on the other, locally available renewable resources, such as crop residue, are almost not used at all. The needs for heat energy in the sector of agriculture alone (hothouses, greenhouses, smokehouses etc.) are 420,851.8 toe [55]. The increased usability level of crop residue for the needs of energy production fits into the planned goals of the Republic of Serbia by the end of 2020, with the construction of new power plants that are supposed to achieve energy production in the amount of 209 ktoe (of which, 75 ktoe is from the production of electrical energy and 134 ktoe from the production of energy in the heating and cooling sector) being expected in the biomass sector alone [56]. In addition, the Republic of Serbia, as a European Union candidate, is expected to invest a certain amount of effort in order to close Chapter 27 as referring to "the environment and climate change". Using a considerable amount of the technical potential of agricultural biomass would significantly reduce the level of SO2 emission (which, at this point, is 4 to 16 times higher than the permitted level in the sector of thermal energy [57]), given that biomass usually contains small amounts of sulfur in comparison with other solid fuels [58,59].

7. Conclusions

The results of the research indicate that there is a huge potential in unused agricultural biomass for energy purposes in AP Vojvodina. Considering the surveyed 75 agricultural properties, the total technical potential of biomass was 152,318.49 t/year, while only 15,149.42 t/year was used for energy purposes. A significant part of biomass is burned in the fields instead of being used for energy purposes. The negative consequences of burning crop residue in the fields certainly include the destruction of flora and fauna, the negative impact on the state of the environment, and the reduction in organic matter in the soil.

The use of this source of energy can be improved in the future by conducting research into the economic advantages of the biomass production, reasons for the field burning of agricultural residues, technology, equipment and plants for biomass production, benefits of the use of biomass in comparison to the use of other fossil fuels, etc.

A greater use of the agricultural biomass resources for energy purposes of the thermal energy production is accorded with the goals established by the Republic of Serbia. Being the official candidate country to become a member state of the European Union, the Republic of Serbia is required to activate the mechanisms for a faster implementation of the projects pertaining to the use of renewable energy sources and environmental protection in the future. Considering that the production of thermal energy in the Republic of Serbia is under the jurisdiction of local self-government bodies, and that the legislation enables them to provide incentive feed-in tariffs for the production of thermal energy, it is realistic to expect that agricultural biomass (harvest residue) in the near future will secure a share in the production of thermal energy for heating certain cities and municipalities in the Republic of Serbia.

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