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# Evaluation of the environmental and economic aspects of the use of common reed from eutrophic lakes for energy purposes

**M Niemiec[1,*], Ł Paluch[1], Z Gródek-Szostak[2] , A Szeląg-Sikora[3], J Sikora[3], K Mudryk[3]**

[1] Faculty of Agriculture and Economics, University of Agriculture in Krakow, Poland
[2] Department of Economics and Organization of Enterprises, Cracow University of Economics, Poland
[3] Faculty of Production and Power Engineering, University of Agriculture in Krakow, Poland

E-mail:  marcin1niemiec@gmail.com

**Abstract**. Spatial expansion of reed communities is one of the most frequently identified causes of biodiversity loss in lake ecosystems. Common reed is an expansive species and at high supply of biogens in the environment, it displaces other species from the rush communities. Common reed is a cosmopolitan species. It habitats wetlands, both dry and submerged, as well as periodically submerged. Increasing the area of reed rushes leads to a reduction in breeding area for many species of avifauna, especially in wetland areas. The effect of eutrophication of water reservoirs is the increase in the area occupied by reed rushes. Removing biomass from water reservoirs is one of the methods of their reclamation; it is done by slowing the eutrophication process.

The aim of the study was to evaluate the economic and environmental efficiency of the removal and utilization of common reed from selected lakes of Pojezierze Mazurskie (the Masurian Lake District) for energy purposes. Within the framework of the study objective, in 2016 collected were samples of reeds from 15 selected lakes and the production potential of the studied reed rush communities was estimated. In the collected biomass samples, the calorific value and chemical composition were determined. Based on the calorific value, the potential for using biomass for energy purposes was estimated, and based on the chemical composition, the amount of nutrients removed from the aquatic environment was estimated.

The results of the study show that the average biomass collected from the surface of 1 m$^2$ of reed rushes was 1.053 kg DM. Depending on the habitat from which the samples were collected, significant differences in biomass yield were found. The biomass energy value ranged from 16.4 to 18.1 MJ $\cdot$ kg$^{-1}$ , while the ash content ranged from 8.12 to 10.13%. Based on the results of the study, it was estimated that removing reed from 1 ha of rush would remove, on average, approx. 136 kg of nitrogen, approx. 18 kg of phosphorus, 28 kg of sulphur and 155 kg of potassium. The average of over 170 GJ of energy can be obtained from the removed reed biomass. Ash formed during the combustion process can be used as a soil improvement material due to its high macroelement content and a relatively low content of heavy metals.The results show that the removal of common reed can be an effective treatment process resulting in decreasing the lake trophy at an increased supply of nutrients in the catchment area.

## 1. Introduction

The character of reservoirs in the hydrosphere is related to the constant inflow of biogenic elements from the catchment area. The effect of this process is to increase the trophy of the reservoir, which directly results in the intensification of primary production and the formation of significant amounts of indigenous sediment with significant organic matter content in the bottom area of the reservoir. The process of enrichment in biogenic elements is characteristic of all reservoirs and its intensity depends on the catchment management, the terrain, climate and morphometric features of the reservoir's bottom area [1, 2]. In natural aquatic ecosystems, eutrophication is a slow process, but under intensified anthropogenic activity its intensity is observed to grow significantly. The most important cause of water eutrophication is agriculture and human activities. The use of large quantities of nitrogen and phosphate fertilizers, improper storage of natural fertilizers, and the discharge of untreated sewage into waters are the most frequently identified causes of water eutrophication. The result of trophic expansion of reservoirs of the hydrosphere is the accumulation of significant amounts of organic silt at the bottom, as well as deterioration of oxygen conditions within the entire volume of the reservoir and occurrence of methane and hydrogen sulphide excretion zones [3]. This translates directly into the change in species composition of the fauna and flora of the reservoir, leading to reduced biodiversity[4]. In eutrophic reservoirs, naturally and economically valuable species of fish are observed to disappear, and are replaced by biocoenoses represented by a small number of species. This diminishes the properties of the economic and tourist attractions of water bodies [5]. A characteristic quality of lakes with increased trophy is quantitative and qualitative changes in plant communities. Lakes are hydrosphere reservoirs characterized by a relatively large photic area. These are favorable conditions for the development of submerged soft vegetation. Communities of submerged soft vegetation provide an environment for the reproduction and habitat of many species of fish. They also increase the food base for vertebrate and invertebrate animals and, thanks to photosynthesis, are the source of oxygen in water. The increase in lake trophy results in displacement of soft vegetation communities in favour of emergent plants, most often reed rush. Spatial expansion of reed communities is one of the most frequently identified causes of biodiversity loss in lake ecosystems. Common reed is an expansive species and at high supply of biogens in the environment, it displaces other species from the rush communities. Common reed is a cosmopolitan species [6]. It habitats wetlands, both dry and submerged, as well as periodically submerged. Increasing the area of reed rushes leads to a reduction in breeding area for many species of avifauna, especially in wetlands [7].

Recultivation of eutrophic lakes is a very difficult process and, in practice, producing hardly satisfactory results. The simplest method of lake reclamation is dredging, i.e. removal of sediment off the lake bottom [8]. Although this is the most effective method, the removal of bottom sediments leads to disturbance of the functioning of the ecosystem, as sediments are an integral part of the aquatic ecosystem. Limiting the supply of biogenes to the tank by rationalizing agricultural production and regulating waste water management is the most environmentally-justified direction of protecting lakes from the over-supply of biogenes [2]. Many authors point out the possibility of removing a part of biogenes introduced into the reservoir together with the plant biomass produced in it [3, 9].This activity is called biomanipulation and seems the right way to manage eutrophic water bodies. Removing plant biomass from reservoirs is an effective method of their phytoremediation, albeit problematic for technological and economic reasons. Therefore a very important aspect of removing emerging vegetation from lakes is the possibility of managing it in such a way as to achieve financial benefits [10].

The aim of the study was to evaluate the economic and environmental efficiency of the removal and utilization of common reed from selected lakes of Pojezierze Mazurskie (the Masurian Lake District) for energy purposes. Fifteen lakes were used for the study, located in the following districts: Giżycki, Węgorzewski, Mrągowski and Olsztyński, in Warmińsko-Mazurskie voivodship.

## 2. Materials and methods

For the examined lakes, the most important parameters are presented in Table 1. Based on the data related to the length of the shoreline of each lake and the overall occurrence of the reed rush, the total surface area of these plant communities in each lake was estimated (Table 1). The width of the reed rush was estimated on the basis of empirical measurements at selected points. The number of measuring points ranged from 8 to 15, depending on the length of the shoreline of the lake. At the same time, at 8 selected research sites estimated was the amount of common reed biomass per unit area and samples for laboratory tests were collected. In biomass, the combustion heat value and calorific value were determined. In addition, the biomass was analyzed for macroelements, microelements and heavy metals. The potential for using biomass for energy purposes was estimated based on the calorific value and combustion heat, and based on the chemical composition, the amount of biogens removed from the aquatic environment was estimated, as well as the usefulness of using ash from the combustion of the studied biomass as a soil improvement agent.

**Table 1.** Parameters of lakes used in research.

| No. | Name | Community | Coastline length [m] | Area [ha] | Quantity of reed biomass [kg $\cdot$ m$^{-2}$] | Maximum width [m] | Surface of reed rush [ha] |
|---|---|---|---|---|---|---|---|
| 1 | Lake Okrągłe | Wydminy | 1,950.0 | 31.9 | 0.768 | 450.0 | 3.8 |
| 2 | Lake Czos | Mrągowo | 14,960.0 | 281.3 | 0.935 | 940.0 | 11.1 |
| 3 | Lake Warpuńskie | Skorwity | 3,550.0 | 49.0 | 1.219 | 720.0 | 2.6 |
| 4 | Lake Harsz | Pozedrze | 10,450.0 | 216.2 | 1.370 | 1,020.0 | 11.4 |
| 5 | Lake Sołtmany | Kruklanki | 8,450.0 | 180.0 | 1.600 | 1,040.0 | 5.5 |
| 6 | Lake Gołdopiwo | Pozezdrze | 14,500.0 | 8.6 | 1.162 | 2,730.0 | 11.8 |
| 7 | Lake Dobrzyń | Wydminy | 3,550.0 | 50.3 | 0.761 | 550.0 | 6.8 |
| 8 | Lake Brzeźno | Olsztynek | 3,250.0 | 40.8 | 0.790 | 610.0 | 1.6 |
| 9 | Lake Żywy | Kruklanki | 7,600.0 | 118.8 | 0.622 | 1,330.0 | 6.0 |
| 10 | Lake Łękuk | Wydminy | 5,800.0 | 80.6 | 1.628 | 500.0 | 2.7 |
| 11 | Lake Brożówka | Kruklanki | 3,000.0 | 59.7 | 1.448 | 770.0 | 4.0 |
| 12 | Lake Łaźno | Świętajno | 18,325.0 | 562.4 | 0.761 | 1,800.0 | 5.7 |
| 13 | Lake Zawadzkie | Janowo | 3,500.0 | 82.1 | 0.827 | 850.0 | 4.0 |
| 14 | Lake Rękoty | Stare Juchy | 5,700.0 | 53.4 | 0.622 | 1,060.0 | 2.3 |
| 15 | Lake Babka | Kruklanki | 2,920.0 | 35.9 | 1.273 | 650.0 | 3.5 |

Eight laboratory samples were sampled from each lake, with a total weight of 1 kg fresh weight. The laboratory sample consisted of 10 primary samples. The primary sample consisted of several whole plants without roots. Laboratory samples were dried at 65°C, homogenized and dry under an open system at 450°C and then dissolved in a nitric acid solution. The analytical powder weighed 3g ADT. The concentration of the test elements in the obtained solutions was determined by atomic using the Optima 7600 by Perkin Elmer. The wavelengths used to determine the concentration of the studied

elements and the limits of determination of the methods used are set out in Table 2. The content of nitrogen and organic carbon was determined by elemental analysis in the Vario Max Cube by Elementar. The certified IEA-V-10 reference material was used to check the accuracy of the analyzed elements. Table 2 summarizes the results of the analysis of the reference material and estimates the recovery value, based on the analyzes made in the 4 replicates. In the studied waste samples, the dry matter content of nitrogen and other macroelements were determined, i.e. N, Ca, P, Na, K, and Mg. In addition, the trace element content was determined of Cu, Zn and Fe, Mn.

Table 2.Paremeters of the analysys method

| Parameters | Wavelenghts | Detection limit | Content in certificated material | Measured | Recovery |
|---|---|---|---|---|---|
| | [nm] | [mg·dm$^{-3}$] | [mg·kg$^{-1}$] | [mg·kg$^{-1}$] | [%] |
| Mg | 285.208 | 0.0016 | 1,360 | 1,414.4 | 104 |
| P | 213.617 | 0.076 | 2,300 | 2231 | 97 |
| Ca | 317.933 | 0.01 | 21,600 | 22,896 | 106 |
| Na | 589.592 | 0.069 | 500 | 485 | 97 |
| K | 766.490 | - | 21,000 | 19,740 | 94 |
| Cu | 327.393 | 0.0097 | 9.4 | 10.058 | 107 |
| Fe | 238.204 | 0.0046 | 185 | 179.45 | 97 |
| Zn | 206.200 | 0.0059 | 24 | 23.52 | 98 |

Caloric studies were carried out using an isoperibolic calorimeter C6000 by IKA, according to PN-EN 14918:2010. The ash content was determined according to PN-EN 15403: 2011.

## 3. Results and discussion

One of the most important elements of sustainable development is the rationalization of the use of available resources, as well as the search for methods to reduce dissipation of elements in the environment and energy losses in processes [11]. With regard to energy sourcing, sustainable development activities are aimed at finding renewable sources. In the field of element management, the most important element of rationalization is to reduce their dissipation in the environment by increasing the efficiency of fertilization and reusability of the elements by introducing waste to the soil [12, 13]. Biogens emitted to the environment from agriculture, industry and human life are discharged along with basin drainage waters to reservoirs of the hydrosphere causing their eutrophication. The most sensitive to eutrophication are shallow lakes with intensively managed catchments, and especially in the case of degraded development with unregulated sewage management and intensive agriculture. Under such conditions intensive lakes degradation processes are associated with their overgrowth, shallowing and the quantitative and qualitative changes of biocenosis. These processes lead to creation of new habitat types, impeding the economic and environmental functions of lakes. Under intensive eutrophication processes, it seems appropriate to implement activities aimed at removing biogenes from the lake area. Removal of reed rushes can be an effective method of limiting the trophy of lakes and can have positive effects in reducing the spread of these emerging plant communities, which are not ecologically sound [14]. Allocating the harvested biomass for energy purposes can improve the economic efficiency of such operations. The use of ash obtained in the combustion process as a soil improvement agent will allow the biogenes to be recycled into agro-ecosystems [7]. Risén et al. [3] states that using reeds for energy purposes is economically justified. The share of non-renewable energy used to harvest and process biomass is approx. 40%. In addition, due to the physical form of the material, it can be used in many ways, both for direct combustion and as a raw material for the production of other energy materials [9,10,14].

**Table 3.** Calorific value of the tested reed biomass samples.

| Sample | Ash content [%] | Humidity [%] | $q_{gr\,d}$ [J/g] /dry combustion heat | $q_{gr\,d}$ [J/g] /working combustion heat | $q_{n\,d}$ [J/g] / dry fuel value | $q_{n\,d}$ [J/g] / working fuel value |
|---|---|---|---|---|---|---|
| 1 | 10.609 | 7.294 | 18,920 | 17,540 | 17,710 | 16,240 |
| 2 | 10.500 | 7.294 | 18,950 | 17,570 | 17,740 | 16,270 |
| 3 | 8.123 | 7.561 | 19,090 | 17,650 | 17,850 | 16,320 |
| 4 | 8.120 | 7.561 | 19,130 | 17,690 | 17,890 | 16,350 |
| 5 | 9.551 | 7.674 | 19,120 | 17,660 | 17,900 | 16,340 |
| 6 | 9.595 | 7.674 | 19,140 | 17,670 | 17,920 | 16,350 |
| 7 | 10.097 | 6.986 | 18,880 | 17,560 | 17,660 | 16,260 |
| 8 | 10.168 | 6.986 | 18,910 | 17,590 | 17,697 | 16,670 |
| 9 | 9.256 | 7.524 | 18,920 | 17,540 | 17,710 | 16,240 |
| 10 | 8.595 | 6.985 | 18,950 | 17,570 | 17,740 | 16,270 |
| 11 | 10.23 | 7.523 | 19,090 | 17,650 | 17,850 | 16,320 |
| 12 | 10.52 | 7.524 | 19,130 | 17,690 | 17,890 | 16,350 |
| 13 | 9.112 | 6.852 | 19,120 | 17,660 | 17,900 | 16,340 |
| 14 | 8.563 | 7.421 | 19,140 | 17,670 | 17,920 | 16,350 |
| 15 | 9.526 | 7.152 | 18,880 | 17,560 | 17,660 | 16,260 |

The results of the research show a slight variation in the calorific value of the tested reed biomass samples. The working combustion heat value ranged from 17,540 to 17,690 J · kg^{-1} while the working calorific value ranged from 16,240 to 16,670 J · kg^{-1} (Table 3). Values for reed biomass similar to those obtained in the study was noted by Važić et.al [15]. The obtained results indicate that the energy potential of the tested materials is significant and comparable with the so called biomass raw materials, e.g. willow, miscanthus or cereal straw [16]. The average of over 170 GJ of energy can be obtained from the removed reed biomass. Based on estimates by Spinelli et al. [17] on the costs of acquiring the biomass studied, it can be estimated that the energy yield from reed can be as high as 50%. The mineral content of the samples tested is significant. Raw materials most frequently used for the production of solid biofuels contain up to 2% ash for wood biomass and up to 6% for herbaceous biomass [18]. Increased ash content (over 6%) does not disqualify the sedimentary biomass as a raw material for biofuel production, however it will not be possible to obtain a high quality product in the light of current quality standards included in the package of PN-EN ISO 17225 standards, which set the level of minerals at less than 2%. Važić et al [15] emphasize the usefulness of reed biomass as a component for fuel production. The authors stated the ash content of the reed biomass from the Serbian area of Danube tributaries at 2.1 to 4.4%. The production of biomass in areas which, due to unfavourable habitat conditions, can't be used for energy purposes is very important as energy production in such areas does not compete with food production [10, 19- 21]. The development of fuel crops involves the need to increase the area of land used for their cultivation, which can contribute to the global food deficit, and to the conversion of natural areas into heavily-used agricultural land [22]. Organization of biomass production in coastal areas can be an element of renewable energy production with a limited impact on the natural environment. The amount of biomass obtained from water and mud areas depends on the availability of nutrients in sediments, especially phosphorus and nitrogen [23].The results of the study show that the average biomass collected from the surface of 1 m$^2$ of reed rushes was 1.053 kg DM and ranged from 0.662 to 1.628 kg DM · m$^{-2}$ of reed rush. Depending on the habitat from which the samples were collected, significant differences in biomass yield were found. The largest amount of biomass was found in the Łękuk, Sołtmany and Brożówka lakes, respectively 1,628; 1,600 and 1,448 kg DM · m$^{-2}$(Tab. 1). The smallest amount of reed biomass was observed in Lake Rękoty. In natural wetland ecosystems, reed biomass can be up to 2 kg of dry matter · kg$^{-1}$ · year$^-$

[15]. Rycewicz-Borecki et al. [24] obtained similar research results of the production of reed biomass under experimental conditions.

The mean nitrogen content of the cane biomass collected from the examined lakes was 1.254 and ranged from 0.875 to 1.625%, while the phosphorus concentration ranged from 0.115 to 0.248% and the mean value was 0.159%. The highest nitrogen content in plant biomass was found in Babka, Sołtmany and Łękuk lakes. The highest phosphorus content was found in reed biomass obtained from Sołtmany, Harsz and Brożówka lakes (Table 4). Zhuo et al. [25] report the average content of these elements in bulrush, at 0.935% N and 0.64% P. On the other hand, [24] found that the amount of nitrogen in reed biomass was 0.5%, while the amount of phosphorus was 0.175%. Water plants are generally characterized by high concentrations of macroelements, and are therefore often used as food or feed [26]. The amount of nitrogen in reed biomass found in this study is high, however, during winter reed harvest, when the harvesting is most justified from the fuel sourcing point of view, the amount of this element can be considerably smaller. Važić et al. [15] report the nitrogen content of reed biomass collected after the growing season at about 0.3%. In our own research, the average amount of nitrogen and phosphorus removed with reed biomass was 13.67 and 1.751 g $\cdot$ m$^{-2}$, respectively. There were significant differences in the amount of phosphorus and nitrogen removed, depending on the research object (Table 4). Similar to the results obtained in own study was the amount of biogens in common reed reported by Hansson and Fredriksson [7]. In turn, Zhou et al. [25] state that the amount of nitrogen and phosphorus removed from the surface of 1 m$^2$ of bulrush may be 23.4 and 1.59 g $\cdot$ m$^{-2}$, respectively. These authors point out the great potential of reed removal as lake recultivation and rationalization of the use of biogens in agriculture. The results of our own research indicate that very high amounts of potassium and calcium can be removed from the aquatic ecosystem. The average amount of elements removed together with 1 m$^2$ of the the reed biomass amounted to 1.53 and 10.81 g $\cdot$ m$^{-2}$ (Tab. 4). The amount of magnesium absorbed by the studied plants ranged from 0.927 g $\cdot$ m$^{-2}$ in the Łaźno Lake biomass to 8,274 g $\cdot$ m$^{-2}$ in the Sołtmany Lake biomass (Table 4). The amount of sulphur accumulated by the reed rush ranged from 0.906 to 6.82 g S $\cdot$ m$^{-2}$. The highest sulphur absorption was found in the biomass of Lake Żywy, while the largest accumulation of this element was noted in the plants from Lake Harsz. There were large differences in the amount of elements accumulated by reed biomass depending on the object studied. The amount of accumulated elements was more dependent on the amount of biomass produced than on the content of elements in the biomass of sampled plants. From the point of view of managing the eutrophication of reservoirs, the removal of potassium, calcium, magnesium and sulphur is insignificant. However, the use of ashes from the combustion of reed biomass for farming allows recycling these elements into the bio-circulation, which may be an important element of rational management of non-renewable resources. The elements accumulated in reservoir sediments are immobilized and inaccessible to living organisms. Utilization of ash from 1 ha of reed rush for fertilization would approx. 18 kg of phosphorus, 23 kg of magnesium and over 100 kg of potassium 28 kg of sulphur and about 120 kg of calcium to the soil.Removal of reed rush biomass can be an effective method for the purification of aquatic ecosystems from assimilable forms of toxic trace elements, as pointed out by other authors [27,28,6]. The high content of macroelements in the studied reed rush biomass makes its removal from wetlands an effective method of reducing the wetland trophy. Moreover, the ash obtained from the biomass combustion can be used as a soil improvement agent. Hansson and Fredriksson [7] note, however, that common reed retracts most of the nitrogen to the rhizome in the winter, so at the winter harvest of reeds, the effectiveness of biogene removal from the lake ecosystem may be limited. Common reed has a large ability to bioaccumulate trace elements, which in particular circumstances can disqualify its use as a soil improvement agent. The contents of copper, zinc and iron in biomass from the studied lakes are low and are characteristic for unpolluted aquatic environments. The content of zinc, lead and copper in reed biomass from rainwater tanks was several dozen times higher than that obtained in own research [29]. These authors point out the possibilities of using common reed for remediation of heavy metal pollution of reservoirs.

**Table 4**. The content of macroelements in common reed biomass and the amount of elements removed with the biomass.

| | Ca | K | Mg | P | N | S | Cu | Fe | Zn |
|---|---|---|---|---|---|---|---|---|---|
| | % | | | | | | $mg \cdot kg^{-1}$ | | |
| 1 | 1.332 | 1.045 | 0.272 | 0.122 | 0.956 | 0.141 | 3.236 | 93.02 | 15.47 |
| 2 | 0.888 | 1.011 | 0.147 | 0.121 | 0.875 | 0.319 | 1.767 | 61.82 | 11.72 |
| 3 | 0.542 | 1.596 | 0.119 | 0.179 | 1.203 | 0.199 | 4.983 | 89.07 | 26.02 |
| 4 | 0.912 | 1.910 | 0.202 | 0.207 | 1.327 | 0.412 | 3.256 | 99.32 | 20.58 |
| 5 | 2.077 | 2.213 | 0.517 | 0.248 | 1.606 | 0.070 | 2.327 | 242.50 | 15.95 |
| 6 | 1.064 | 1.665 | 0.199 | 0.173 | 1.124 | 0.285 | 1.165 | 90.27 | 13.27 |
| 7 | 0.698 | 0.889 | 0.220 | 0.131 | 1.099 | 0.192 | 1.317 | 85.37 | 10.97 |
| 8 | 0.949 | 0.751 | 0.186 | 0.116 | 0.923 | 0.299 | 0.717 | 73.72 | 11.40 |
| 9 | 1.241 | 1.043 | 0.242 | 0.115 | 0.899 | 0.146 | 2.967 | 116.4 | 25.40 |
| 10 | 0.978 | 1.054 | 0.159 | 0.132 | 1.456 | 0.381 | 1.767 | 93.28 | 12.17 |
| 11 | 0.971 | 2.017 | 0.211 | 0.205 | 1.489 | 0.474 | 2.917 | 161.3 | 37.07 |
| 12 | 0.564 | 1.747 | 0.122 | 0.183 | 1.523 | 0.201 | 4.900 | 88.37 | 26.20 |
| 13 | 0.863 | 1.537 | 0.201 | 0.132 | 1.125 | 0.194 | 2.300 | 115.2 | 19.67 |
| 14 | 0.977 | 1.651 | 0.185 | 0.161 | 1.589 | 0.257 | 1.300 | 84.75 | 10.10 |
| 15 | 0.858 | 1.043 | 0.266 | 0.155 | 1.625 | 0.229 | 1.350 | 83.62 | 11.23 |
| Mean | 0.994 | 1.411 | 0.216 | 0.159 | 1.254 | 0.253 | 2.42 | 105.2 | 17.81 |
| Standard deviation | 0.367 | 0.459 | 0.095 | 0.040 | 0.277 | 0.110 | 1.298 | 44.29 | 7.867 |
| %* | 36.91 | 32.50 | 43.83 | 25.21 | 22.09 | 43.40 | 53.70 | 42.11 | 44.16 |
| | $g \cdot m^{-2} \cdot year^{-1}$ | | | | | | $mg \cdot m^{-2} \cdot year^{-1}$ | | |
| 1 | 10.23 | 8.029 | 2.087 | 0.940 | 7.346 | 1.086 | 2.486 | 71.46 | 11.88 |
| 2 | 8.296 | 9.450 | 1.375 | 1.130 | 8.177 | 2.978 | 1.651 | 57.77 | 10.95 |
| 3 | 6.610 | 19.46 | 1.447 | 2.178 | 14.66 | 2.430 | 6.076 | 108.6 | 31.72 |
| 4 | 12.49 | 26.17 | 2.770 | 2.841 | 18.17 | 5.645 | 4.461 | 136.1 | 28.20 |
| 5 | 33.22 | 35.41 | 8.274 | 3.973 | 25.69 | 1.113 | 3.722 | 388.0 | 25.52 |
| 6 | 12.36 | 19.34 | 2.312 | 2.014 | 13.05 | 3.307 | 1.354 | 104.9 | 15.41 |
| 7 | 5.315 | 6.768 | 1.672 | 0.994 | 8.367 | 1.459 | 1.002 | 64.99 | 8.349 |
| 8 | 7.502 | 5.935 | 1.469 | 0.919 | 7.296 | 2.365 | 0.567 | 58.27 | 9.012 |
| 9 | 7.724 | 6.489 | 1.504 | 0.717 | 5.596 | 0.906 | 1.847 | 72.42 | 15.81 |
| 10 | 15.92 | 17.17 | 2.586 | 2.148 | 23.71 | 6.201 | 2.876 | 151.9 | 19.81 |
| 11 | 14.05 | 29.20 | 3.051 | 2.961 | 21.56 | 6.862 | 4.224 | 233.6 | 53.68 |
| 12 | 4.295 | 13.30 | 0.927 | 1.389 | 11.60 | 1.530 | 3.731 | 67.28 | 19.95 |
| 13 | 7.143 | 12.71 | 1.662 | 1.088 | 9.308 | 1.601 | 1.903 | 95.30 | 16.27 |
| 14 | 6.073 | 10.26 | 1.150 | 1.001 | 9.877 | 1.599 | 0.808 | 52.68 | 6.278 |
| 15 | 10.92 | 13.28 | 3.387 | 1.968 | 20.69 | 2.916 | 1.719 | 106.5 | 14.30 |
| Mean | 10.81 | 15.53 | 2.378 | 1.751 | 13.67 | 2.800 | 2.562 | 118.0 | 19.14 |
| Standard deviation | 7.058 | 8.934 | 1.785 | 0.947 | 6.656 | 1.935 | 1.580 | 88.53 | 12.06 |
| %* | 65.29 | 57.52 | 75.06 | 54.09 | 48.68 | 69.13 | 61.69 | 75.04 | 62.99 |

* Relative standard deviation

## 4. Conclusion

1. The energy potential of reed biomass is significant, comparable with the so called biomass raw materials, i.e. willow, miscanthus or cereal straw.
2. The amount of reed canebiomass obtained from 1 m$^2$ of reed cane ranged from 0.622 to 1.628 kg DM · m$^{-2}$.
3. There were large differences in the amount of elements removed with the reed biomass in the studied lakes of the Masurian Lake District.
4. The amount of elements removed with the reed rush biomass depends to a greater extent on the volume of biomass produced than on its chemical composition.
5. Removal of reeds from lakes can be an effective way of reducing water eutrophication.
6. The use of ashes from the burning of reed biomass for agricultural purposes is justified from an economic and environmental point of view.

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