DE GRUYTER OPEN

Environmental & Socio-economic Studies

DOI: 10.1515/environ-2015-0036

Environ. Socio.-econ. Stud., **2014, 2, 2: 38-44**

© 2014 Copyright by University of Silesia

Participation of *Calamagrostis epigejos* (L.) Roth in plant communities of the River Bytomka valley in terms of its biomass use in the power industry

Edyta Sierka, Sylwia Kopczyńska

Department of Botany and Nature Protection, Faculty of Biology and Environmental Protection, University of Silesia, Jagiellońska Str. 28, 40-032 Katowice, Poland
E–mail address (corresponding author): edyta.sierka@us.edu.pl

ABSTRACT

This paper presents an attempt to assess the potential use of *Calamagrostis epigejos* (L.) Roth. as a renewable energy source. Abandonment of human management is often followed by a decrease in species richness in semi-natural grasslands, mainly due to the increased dominance of clonal grasses such as *Calamagrostis epigejos* which were formerly repressed by management. The biomass resource of this, and its accompanying, species, i.e. species of the *Solidago* genus and others e.g. *Cirsium rivulare*, *Deschampsia caespitosa*, *Molinia coerulea* and *Filipendula ulmaria*, was evaluated in the green wastelands of the River Bytomka valley (Upper Silesia, Poland). It was found that approx. 1.2 $t \cdot ha^{-1}$ of dry matter can be obtained from approx. 30% of the average share of *Calamagrostis epigejos* in plant communities of unmown meadows. This is 10 times less than in the case of *Miscanthus giganteus*, a non-native cultivated grass. An increase in the biomass component of *Calamagrostis epigejos* reduced that of *Solidago* sp. (-0.522176, $p< 0.05$) and other species (-0.465806, $p< 0.05$). The calorific value of *Calamagrostis epigejos* biomass is approx. 15.91 $MJ \cdot kg^{-1}$, which is comparable to the calorific value of coal and close to, *inter alia*, that of *Miscanthus sacchariflorus* (19 $MJ \cdot kg^{-1}$) as an energy crop. The presented research is in its preliminary stages and therefore, it is necessary to investigate the reaction of *Calamagrostis epigejos* to regular mowing and to removal of the biomass from the studied areas.

KEY WORDS: *Calamagrostis epigejos* (L.) Roth., grass, plant biomass, renewable energy sources, Silesian Upland

1. Introduction

The necessity to implement the EU energy and climate change policies has resulted in the rapid development of alternative energy sources (STRYJECKI, 2011). Energy from solid biomass has a significant share in the balance of renewable energy in Poland. The combustion of biomass is considered to be beneficial for the environment compared to the use of fossil fuels, as the release of carbon dioxide in the combustion process is compensated by its recent absorption by plants, in the so called closed cycle of CO_2 (KISIEL ET AL., 2006). However, according to some estimates (PATRZAŁEK ET AL., 2011) the production and combustion of biofuels results in worse energy generation and ecological balance than the production and combustion of fossil fuels and is associated with environmental degradation, among others, by increasing the area necessary for cultivation, large consumption of fertilizers, exploitation of forests and the unsustainable management of plant products (PUDEŁKO, 2010). A particularly valuable group to use are the so called energetic plants, which in addition to low soil and climate requirements are capable of significantly increasing their dry matter (DM) during the growing season providing high calorific value.

Native and alien species of grasses, including e.g. *Miscanthus×giganteus*, play an important role among these plants. Undoubtedly, the role of grasses deserves attention if only for the fact that in our climate meadows, where grasses are the most numerous group of plants, are generally considered as the plant communities producing the highest amounts of biomass. Grasses are also the pioneer plants entering spontaneously, or due

to human activities, in areas restored back to nature (MARTYN, 2007). One of these native species, due to its high occurrence, is *Calamagrostis epigejos* (L.) Roth. (bush grass). It is a perennial, widely growing grass occurring in many habitats, such as grasslands, meadows and forests (SIERKA & CHMURA, 2005). It often frequently occurs in altered habitats such as degraded farmlands or waste heaps of the coal industry (PATRZAŁEK ET AL., 2011) and the edges of sand and mineral excavation sites (SIERKA & BABCZYŃSKA-SENDEK, 2013).

The capability of rapid stolon growth (6-7 mm/day), high seed productivity (about 50 million pieces per 1 hectare) (GORZELAK, 2004) and low habitat requirements make *Calamagrostis epigejos* a potential pioneer species (PATRZAŁEK ET AL., 2011). The economic use of bush grass as an energy plant is still poorly recognised. So far, HARKOT (2007), MARTYN (2007), ROGALSKI ET AL. (2008), KOZŁOWSKI & SWĘDRZYŃSKI (2010) and PATRZAŁEK ET AL. (2011) have conducted research on the application of *Calamagrostis epigejos* in the power industry of Poland. The research results are promising and perhaps will contribute to the recognition of bush grass as a species that can meet the requirements of the power industry. However, none of these authors has investigated the share of *Calamagrostis epigejos* in the phytocoenoses of wastelands.

Therefore, the aim of this work is to determine the possible use of bush grass *Calamagrostis epigejos* (L.) Roth as a potential source of biomass for the power industry, by providing information on: the percentage of bush grass in the phytocoenoses of wastelands; the contribution of accompanying species; the biomass of bush grass and an assessment of the suitability of *Calamagrostis epigejos* for the power industry on the basis of existing data and the author's previous research.

2. Study area

The study area (N $50^0$18'37.38"; E $18^0$45'17.69") is located in the Silesian Upland (Southern Poland) within the Bytom Plateau, which is composed of Carboniferous and Triassic rocks. It is characterised by small height differences of 15 to 20 m and a weak erosion cut (RAPORT O STANIE ŚRODOWISKA, 2000). The average annual precipitation ranges from 671 to 718 mm (CZAJA, 1999).

Large areas are covered with wet meadows of *Molinietalia* and fresh meadows of *Arrhenatheretalia*. Wet meadows primarily occupy areas of river valleys where the riparian forests have been cleared. These meadows are characterized by the presence of a lush herb layer with *Cirsium rivulare*, *C. oleraceum* and also: solitary growing *Caltha palustris*, *Deschampsia caespitosa*, *Molinia coerulea* and *Filipendula ulmaria.*

3. Materials and methods

3.1. Characteristics of the study plots

This research was conducted in the River Bytomka valley (Fig. 1), which is channeled and embanked within the studied section and the banks are covered with ruderal vegetation. Research was carried out at three designated plots (Fig. 2), which were selected on the criterion of the presence of *Calamagrostis epigejos*.

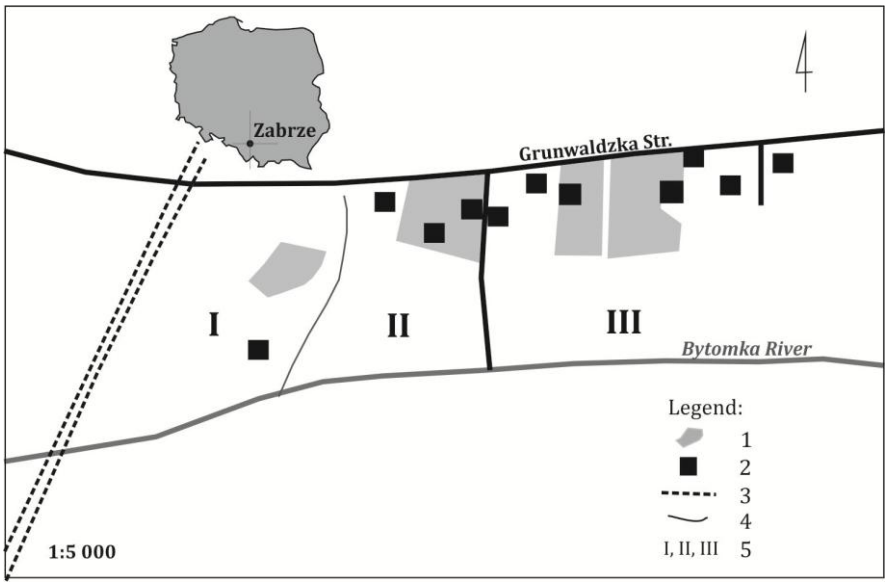


Fig. 1. Location of the study area near the city of Zabrze
1 – area of trees and shrubs; 2 – buildings; 3 – railroad; 4 – drainage ditch; 5 – study plots



Fig. 2. Research area with occurrences of *Calamagrostis epigejos*: plots I – 30%, II – 15%, III – 5% (*S. Kopczyńska*, 2011)

Plot I (N: 50°18'35.4"; E: 18°45'8.8") is located within unmown meadow and pasture and *Phragmites australis* (Cav.) Trin. ex Steud. dominates the land-surface in the southern part. The southern boundary of the plot is delineated by a railway embankment with clusters of woody species, including *Populus nigra* L. *'Italica'*, *Aesculus hippocastanum* L., *Salix alba* L., *Acer platanoides* L. and *Sambucus nigra*, and the embankments themselves are covered with *Crataegus monogyna*.

Plot II (N: 50°18'36.7"; E: 18°45'18.83"), covered an area of irregularly mown meadow, which was covered mainly by grasses such as *Arrhenatherum elatius*, *Phleum pratense* and *Dactylis glomerata*. There are numerous depressions and waste dumpslocated in this area, with rubble next to them. The whole area is covered with low bushes of *Sambucus nigra*.

Plot III (N: 50°18'37.16"; E: 18°45'33.75"), is located in an irregularly mown meadow, which has been burnt in spring in some places. The area is dominated by grasses such as *Elymus repens*, *Agrostis capillaris* and *Arrhenatherum elatius*.

3.2. Fieldwork

The fieldworkwas conducted between May and October 2011. In total 60 floristic inventories (20 at each of the 3 plots) covering an area of 25 m^2 were conducted in order to determine the floristic composition of the area where *Calamagrostis epigejos* occurred. Frequency and percentage occurrence were determined for each species. Due to the fact that *Calamagrostis epigejos* coverage was the highest in Plot I, 25 biomass samples were collected from this plot for further analyses (0.25m^2 each). All plants were cut about 5 cm above the soil level. This was followed by the separation of each sampleand pooling of *Calamagrostis epigejos*, *Solidago* spp., and each of the other species.

3.3. Laboratory analysis

Each sample was weighed, dried for 5 weeks at 25^{0}C and then weighed again. The WPS RADWAG 600C type of scale was applied to determine the amount of biomass of each of the investigated species with an accuracy to 10 milligrams. The names of plant species and communities were given after MIREK ET AL. (2002) and MATUSZKIEWICZ (2001). An assessment for each plot was made of: percentage share of *Calamagrostis epigejos* in each of the 20 floristic inventories, average cover (%) of *Calamagrostis epigejos*, *Solidago* spp., and all other species. Furthermore, the significance of the relationship between *Calamagrostis epigejos* biomass and the biomass of the other species in the studied communities were verified by the Spearman's non-parametric correlation test.

4. Results

4.1. Plant species associated with *Calamagrostis epigejos* in the study area of the River Bytomka valley

The number of species recorded on the research plots was similar and was as follows: Plot I - 35, II - 34, III - 24. On all three study plots 16 plant species co-occurred, simultaneously with a relatively high frequency. Table 1 shows the full list of recorded species. Average occurrence [%] of *Calamagrostis epigejos* for each plotw as: I – 33%, II – 18%, III – 4%.

4.2. *Calamagrostis epigejos* biomass

Following three weeks of drying, the average weight of the biomass was 34 grams (fresh biomass 41 g) for *Calamagrostis epigejos*, 79 grams for *Solidago* spp. (fresh biomass 102 g), and 22 grams for other species (fresh biomass 36 g) (Fig. 3).

The biomass moisture content of *Calamagrostis epigejos* was 17.1%; *Solidago* spp. – 22.5%; other species – 39%. A slight but statistically significant correlation was found between the increase in *Calamagrostis epigejos* biomass and the biomass of the other species (Tab. 2). An increase in *Calamagrostis epigejos* biomass resulted in a decrease of the biomass of *Solidago* spp. and the other accompanying species.

Table 1. Frequency of plant species occurring together with *Calamagrostis epigejos* (without *C. epigeios*) (author's own research). Bold indicates maximum frequency species in each plot

Species	Frequency [%]		
	I	II	III
Achillea millefolium L.	40	-	-
Aegopodium podagraria L.	25	**80**	-
Agrostis capillaris L.	45	30	85
Arctium tomentosum Mill.	-	50	50
Arrhenatherum elatius (L.)	75	35	65
Artemisia vulgaris L.	40	25	-
Calystegia sepium (L.) R. Br.	50	55	75
Carex hirta L.	40	25	75
Centaurea jacea L.	25	-	-
Chenopodium album L.	25	-	-
Cirsium arvense (L.) Scop.	**85**	55	25
Convolvulus arvensis L.	25	60	25
Crataegus monogyna Jacq.		25	
Dactylis glomerata L.	40	25	30
Elymus repens (L.) Gould.	55	**80**	95
Equisetum arvense L.	-	50	40
Festuca pratensis Huds.	-	50	-
Festuca rubra L. S. Str.	-	75	-
Galeopsis pubescens Besser.	25	35	25
Galium mollugo L. s. str.	80	75	55
Heracleum sosnowskyi Manden.	50	-	55
Hypericum perforatum L.	25	-	-
Linaria vulgaris Mill.	50	-	25
Melandrium album (Mill.) Garcke	25	25	-
Phleum pratense L.	75	50	80
Pimpinella saxifraga L.	60	-	-
Plantago lanceolata L.	50	25	-
Poa pratensis L. s. str.	50	30	25
Poa trivialis L.	25	25	**100**
Potentilla reptans L.	80	-	50
Rumex acetosa L.	50	50	25
Rumex acetosa L.	-	35	-
Sambucus nigra L.	-	25	-
Solidago canadensis L.	35	25	-
Solidago gigantea Aiton.	35	25	25
Tanacetum vulgare L.	60	-	-
Tragopogon pratensis L.	75	25	-
Trifolium repens L.	-	-	50
Urtica dioica L.	25	55	45
Vicia cracca L.	25	50	25
Verbascum densiflorum Bertol.	25	-	-
Veronica chamaedrys L.	50	-	-
Vicia cracca L.	25	-	25
Viola tricolor L.	-	25	-
Total number of species	**35**	**34**	**24**

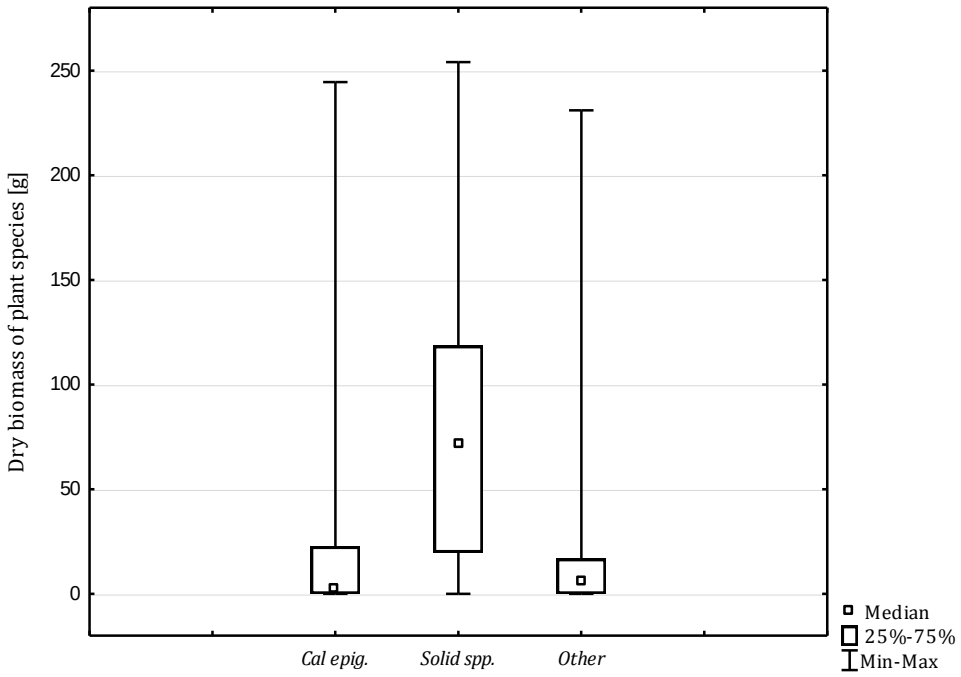


Fig. 3. Average biomass of species after drying (author's own research)

Table 2. Relationship between percentage occurrence of the species (author's own research)
(Spearman rank test, *statistically significant results p< 0,05)

	Mean of fresh biomass [g]	Standard deviation (SD)	*Calamagrostis epigejos*	*Solidago* spp.	Other species
Calamagrostis epigejos	40.92	77.43	1.00	-0.52*	-0.09
Solidago spp.	102.04	84.58	-	-	-0.46*
Other species	36.29	65.56	-	-	-

5. Discussion

This research was undertaken to determine the occurrence (%) and biomass of *Calamagrostis epigejos* in meadow communities. The results show a negative correlation between the increased occurrence of *Calamagrostis epigejos* and a reduction in the number of meadow species and associated diversity of plant communities. For alluvial meadow (*Cnidion dubi*) noted to reduce the number of species by 44% (KRYSZAK ET AL., 2006). In a study on the occurrence of *Calamagrostis epigejos* conducted in the Przemyskie Foothills (BARABASZ-KRASNY, 2011) the number of species in the relevés varied from 20 to 46, which indicated a floristic instability in these communities. According to BARABASZ-KRASNY (2011) the dominant plant in the community was *Calamagrostis epigejos* accompanied by, as in the case of the studied area: *Cirsium arvense, Equisetum arvense, Galium mollugo, Stellaria graminea* L., *Trifolium medium* L., *Urtica dioica, Veronica chamaedrys* and *Vicia cracca*. The first and second plots are slightly different in terms of species composition and frequency of the individual species. The largest differences were observed in the third plot, where therewere only 24 species recorded with a significant predominance of *Elymus repens*.

The particular plots in this study differ in the degree of *Calamagrostis epigejos* coverage. The first plot was covered with the highest number of bush grass patches. Its presence was recorded in all 20 floristic inventories at this plot. The patches of this species covered areas located closer to the River Bytomka and the steep slopes of its embankments. Research by KRYSZAK ET AL. (2006) on the occurrence of bush grass in the grassland communities of river valleys in Wielkopolska showed that *Calamagrostis epigejos* was the most common species in the river valleys, where it inhabited local elevations and steep slopes on the edges of valleys and levees. The analysis of the share of bush grass in each of the floristic inventories revealed that its coverage ranged between 5 and 80%. FALKOWSKI (1982) described *Calamagrostis epigejos*, as a heliophilous species, which would explain the differences in the degree of coverage at particular plots. The highest

coverage occurred in open areas devoid of trees. The low *Calamagrostis epigejos* cover on the second and third plots was probably related to the recent use of this part of the area and its regular burning, the traces of which were clearly visible during the site inspection.

The results of the study show that the average percent coverage of *Calamagrostis epigejos* on the test sites of all three research plots is lower than with other herbaceous species, but higher than the average percentage cover of *Solidago* spp. When assessing the percentage cover of the plots, it should be taken into account, that the floristic inventories and evaluation of species cover were performed in June and July, and as reported by FALKOWSKI (1982) *Calamagrostis epigejos* flowers between June and August. Therefore, it might be expected that in August, after reaching maximum size, its cover might be at its highest.

Calamagrostis epigejos biomass was 1.220016 t·ha^{-1} of dry mass (DM). For comparison, according to KUŚ & MATYKA (2009), dry matter yield of *Salix viminalis* L. planted at an amount of 40 000 individuals ha^{-1}, *Miscanthus* ×*giganteus* 15 000 individuals ha^{-1} and *Sida hermaphrodita* (L.) Rusby 20 000 individuals ha^{-1}, collected on an annual basis, depending on the type of soil was as follows in the first year of research: for *S. viminalis*: from 10.1 t·ha^{-1} on sandy soil to 12.8 t·ha^{-1} of DM on heavy soil; *M.*×*giganteus*: from 19. t·ha^{-1} on heavy soil to 20.7 t·ha^{-1} of DM on medium soil; *S. hermaphrodita*: from 20.5 t·ha^{-1} on sandy soil to 20.8 t·ha^{-1}of DM on heavy soil.

The yield of *Calamagrostis epigejos* dry matter, in this study, is from 10 to 20 times lower than crops of energy species. However, it has to be emphasised that *Calamagrostis epigejos* is a wild growing plant, which does not reach 100% cover. In addition, *Calamagrostis epigejos* dry matter samples were collected from a small area and therefore, may not reflect the phenomenon in full on the big areas of wasteland.

The largest biomass amount within the investigated area was recorded in samples of two species of goldenrod (*Solidago canadensis* and *S. gigantea*), which according to PATRZAŁEK ET AL. (2011) dominate on meadows that have not been used for many years. It would be reasonable to investigate the possibility of incinerating *Calamagrostis epigejos* together with the addition of *Solidago* spp. Patches of *Calamagrostis epigejos* and *Solidago* spp. in the Bytomka valley are numerous and are either adjacent or overlapping. The calculated correlations showed that, the increase in biomass of one species reduced the biomass of other species.

5.1. *Calamagrostis epigejos* as a fuel

Research by HARKOT ET AL. (2007) on the grasslands in south-eastern Poland determined combustion heat for *Calamagrostis epigejos* at 18.4 MJ·kg^{-1}. Thus, as reported by the author, combustion heat of the investigated species was similar to that of *Salix* sp., for which it varied between 18.6 and 19.6 MJ·kg^{-1} of DM. The same parameter for bush grass has been assessed by PATRZAŁEK ET AL. (2011) at 17.19 MJ·kg^{-1}.

The authors present different calorific values for bush grass, which according to HARKOT ET AL. (2007) was 17.3 MJ·kg^{-1}, whereas PATRZAŁEK ET AL. (2011) presents values of about 15.91 MJ·kg^{-1} in air-dry conditions and 18.58-18.88 MJ·kg^{-1} in dry, ash-free conditions. HARKOT ET AL. (2007) likens the calorific value of bush grass to the calorific values of species such as *Miscanthus sacchariflorus* (Maxim.) Hack. (19 MJ·kg^{-1}) and *Spartina pectinata* Link. (16.8 MJ·kg^{-1}).

Another parameter - ash content remaining after combustion of *Calamagrostis epigejos* according to HARKOT ET AL. (2007) is 5.5%. A higher ash content was presented by PATRZAŁEK ET AL. (2011) amounting to 6.6%. For comparison, the ash content from the combustion of *Salix viminalis* is 1.6%, and 4.4% of *Miscanthus sacchariflorus* (PATRZAŁEK ET AL., 2011).

Additionally, HARKOT ET AL. (2007) defines other parameters for bush grass, such as the total sulfur content, which was 0.16%. It is one of the lowest values, since the sulphur content in grasses ranges from 0.2 to 0.8%. Among the species of grasses investigated by HARKOT ET AL. (2007), bush grass had the lowest chlorine content (0.23%), which is very important in assessing the energy value of its biomass. The chlorine content is an important parameter, since it affects the use of heating systems, accelerating the corrosion of furnaces.

ROGALSKI ET AL. (2008) regarded *Calamagrostis epigejos* as a potential source of biofuel showing that 318-459 litres of ethanol can be produced from 1 ha of this species. Moreover, KOZŁOWSKI ET AL. (2010) emphasized that the chemical composition of *Calamagrostis epigejos* makes this species an interesting source of heating biomass, and to a lesser extent for the production of biogas. The results of their studies showed that *Calamagrostis epigejos*is rich in carbon and is characterised by a high calorific value, exceeding

even 21 MJ from 1 kg of DM. The authors also remarked that the calorific value of grass biomass, and in particular the biomass of *Phalaris arundinacea* L. and *Calamagrostis epigejos*, is similar to the calorific value of coal (16,7-29,3 MJ·kg^{-1}) (PATRZAŁEK ET AL., 2011). A limitation of the use of the investigated species as an energy plant, according to KOZŁOWSKI ET AL. (2010), is its relatively low above ground mass. The mass of stolons located at a depth of 30 cm is five times larger than the mass of stems above the ground.

Taking into account the possibility of harvesting bush grass as an energetic plant from a given area, the most suitable area for this purpose would be the first study plot, where the investigated species occurred with the highest cover. In the case of obtaining the investigated species from areas located in the River Bytomka valley, it should also be taken into account that *Calamagrostis epigejos* does not form dense swards. In addition, although the structure of the inflorescence contains a lot of grains, they exhibit very low (12%) germination capability, which indicates their lesser role in the spread of *Calamagrostis epigejos* (KOZŁOWSKI ET AL., 2010). It should be pointed out that the presented research is only preliminary and it is necessary to investigate the impact of regular mowing and biomass export on *Calamagrostis epigejos*and on the associated impact on the community composition if cutting will be continued.

Actually, chances of using the biomass of *Calamagrostis epigeios* as a fuel in power generation are low.

6. Conclusions

1) The proportion of *Calamagrostis epigejos* in plant communities is variable and is influenced by: recent land use, landform and the presence of tree stands.
2) The biomass value of *Calamagrostis epigejos* is 1.220016 t·ha^{-1}.
3) The values of parameters such as combustion heat, calorific value, and the chlorine content of *Calamagrostis epigejos* have been determined by various authors and indicate, that interest in this species as a potential energy source is justified.
4) *Calamagrostis epigejos* can become a potential source of renewable energy, however, it is necessary to conduct further research.

References

Barabasz-Krasny B. 2011. *Zróżnicowanie roślinności i sukcesja wtórna na odłogach wielkopowierzchniowych Pogórza Przemyskiego*. Wyd. IB im. W. Szafera PAN, p. 180, Kraków.

Czaja S. 1999. *Zmiana stosunków wodnych w warunkach silnej antropopresji: (na przykładzie konurbacji katowickiej)*. Wyd. Uniw. Śląskiego, Katowice.

Falkowski M.1982. *Trawy polskie*. PWRiL, Warszawa.

Gorzelak A. 2004. *Trzcinniki biologia i zwalczanie*. Centrum Inform. Lasów Państ., Warszawa.

Harkot W., Warda M., Sawicki J., Lipińska H., Wyłupek T., Czarnecki Z., Kulik M. 2007. Możliwości wykorzystania runi łąkowej do celów energetycznych. *Łąkarstwo w Polsce*, 50: 58-67.

Kisiel R., Stolarski M., Szczukowski S., Tworkowski J. 2006. Biomasa pozyskiwana z gruntów rolniczych źródłem energii. *Zagad. Ekon. Rolnej*, 100: 90-101.

Kondracki J. 2002. *Geografia regionalna Polski*. Wyd. Nauk. PWN, Warszawa.

Kozłowski S., Swędrzyński A. 2010. Możliwości wykorzystania trzcinnika piaskowego w kontekście jego biologicznych, chemicznych i fizycznych właściwości. *Łąkarstwo w Polsce*, 65: 117-136.

Kryszak A., Kryszak J., Grynia M. 2006. Występowanie *Calamagrostis epigejos* w zbiorowiskach trawiastych Wielkopolski. *Łąkarstwo w Polsce,* 9: 113-121.

Kuś J., Matyka M. 2009 Wydajność wybranych gatunków roślin odnawialnych na cele energetyczne w zależności od jakości gleby. *Fragm. Agronomika,* 26(4) 103-110.

Martyn W., Wyłupek T., Czerwiński A., 2007 Zawartość wybranych makroskładników w glebie i roślinach energetycznych nawożonych osadami ściekowymi, *Łąkarstwo w Polsce*, 50: 149-158.

Matuszkiewicz W. 2001. *Przewodnik do oznaczania zbiorowisk roślinnych Polski*. Wyd. Nauk. PWN, Warszawa.

Mirek Z., Piękoś – Mirkowa H., Zając A., Zając M. 2002. *Flowering plants and pteridophytes of Poland a checklist*. Inst. Bot. im. W. Szafera. Pol. Akad. Nauk. Kraków.

Patrzałek A., Kozłowski S., Swędrzyński A., Trąba Cz. 2011. *Trzcinnik piaskowy jako potencjalna „roślina energetyczna"*, Wyd. Polit. Śląskiej Gliwice.

Pudełko R., Faber A. 2010. *Dobór roślin energetycznych dostosowanych do uprawy w wybranych rejonach kraju. Nowoczesne technologie pozyskiwania i energetycznego wykorzystania biomas.* Inst. Energetyki, Warszawa: 50-68.

Raport o stanie środowiska 1999 opracowany przez Ośrodek Badań i Kontroli środowiska, Zabrze, 2000.

Rogalski M., Wieczorek A., Szenejko M., Kamińska A., Miłek E. 2008. Możliwości wykorzystania ekstensywnie użytkowanych łąk nadmorskich do celów energetycznych. *Łąkarstwo w Polsce*, 55: 174-177.

Sierka E., Babczyńska-Sendek B. 2013. Participation of grasses (Poaceae) in spontaneous development of plant cover on the edges of gravel excavation. *Fragm. Flor. Geobot. Polon*., 100(50): 285-301.

Sierka E., Chmura D. 2005. Role of *Calamagrostis epigejos* in forest communities of Silesian Upland (S Poland). [in:] Frey L. (ed.) *Biology of grasses*. W. Szafer Inst. of Bot., Polish Acad. of Sci., Kraków: 343-352.

Stryjecki M., Mielniczuk K., 2011. *Wytyczne w zakresie prognozowania oddziaływań na środowisko farm wiatrowych*. Gen. Dyr. Ochr. Środ., Warszawa.