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Creation of Reed Cadastres

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Abstract. ***In Latvia the total renewable energy resource volume has not been fully evaluated. Reed exploitation for energy output has not been developed on a large scale. One of the factors for this is the lack of information about to reed resource spread and characteristics. Therefore, there arises the need for a united inventory system – the formation of a reed cadaster. The study contains information on basic principles of reed cadastre creation and research methodologies.***

The reed cadaster is a list of the reed researches which contains information about the reed areas in Latvia, the volume and locations, the legal status, possibilities for exploitation, as well as the biomass qualities, in each specific water reservoir. For each water reservoir, which is included in the reed cadaster, a certificate and chart have been produced. Information about the reed locations in each specific lake have been shown on the cadaster chart; the boundaries of the water reservoir, the boundaries of the reed plants and areas, the natural habitat protected area boundaries, the district boundaries, as well as the access roads. The data for reed characteristics and accessible volumes is compiled in the water reservoir cadaster passport. Development for reed exploitation in the conditions of Latvia is dependent on the location, accessible volumes and existing infrastructure. Reeds are a long term renewable energy resource, with the spread of reeds increasing every year.

Keywords: common reed, reed biomass, renewable energy resource, common reed cadaster.

I. INTRODUCTION

Up to this point in time the energy potential resource of the biomass of water plants has not been taken into account in Latvia. The exploitation of these plants as an energy resource would create new jobs, reduce the use of fossil energy resources, as well as solving a variety of environmental protection problems. One of the plants, which could be made use of in the Latvian conditions for energy purposes, is the reed plant *(Phragmites australis (Cav.) Trin. Ex. Steud.*) growing in natural and artificial water reservoirs. [1,2,3].

Studies carried out by foreign scientists also indicate that reeds can be used as a raw material for fuel generation. [4,5]. Basing on information from the Database of Latvian Lakes, there are 17 lakes and artificial bodies in Latvia whose surface exceeds 1000 ha. [6]. Overall, reeds from more than 2000 Latvian lakes can be used to generate energy. [7]. Latvian lakes have to face eutrophication that has a negative impact on lake biotopes and decreases biological diversity in these lakes; besides, residues of decaying water plants promote emission of gases causing the greenhouse effect. Lake eutrophication is also well-known in other parts of the world. [8]. Reed is one of the most common water plants growing in almost all water bodies in Latvia. Currently, they are being used in small amounts for construction needs, but, due to the increase in prices of fossil energy resources and to the pollution caused by the use of fossil resources, the interest in using local biomass in energy supply is growing. Thus, the issue of rational use of reed resources is becoming more topical.

In Latvia the total renewable energy resource volume has not been fully evaluated, the potential of each energy source and accessability for the long – term in the respective regions. To exploit any of the resources in the long – term in an efficient and justifiable way, it is necessary to evaluate the accessible volumes and qualitative parameters [9].

Thus far, there have not been complex studies on reeds in Latvia, there have only been some studies of specific reed samples to examine their characteristic features and possibilities of biomass pre-treatment. Using reeds for generation of thermal energy in larger volume is not a well-developed practice. One of factors causing this problem is lack of information on distribution of reed resources and their characteristics. Therefore, there is a need to create a unified reed recording system, i.e. reed cadastre. Reed cadastre is a list of reed resources including information on reed-covered areas in Latvia, their volumes and locations, legal status, possibilities of use, as well as characteristics of the biomass in each specific water body. Data included in reed cadastre would allow planning works necessary for reed extraction and forecasting the quantity and quality of the respective raw material. The aim of the research is to study reed distribution and characteristic parameters of this plant, establish criteria for the cadastre of reed resources and create a cadastre of Kvapanu Ponds, as well as to give recommendations for further development of the reed cadastre.

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II. MATERIALS AND METHODS

Cadastre contains the main data related to the use of reed growths. Each water body included in the reed cadastre has its own passport and reed cadastral map. The following aspects are shown in the reed cadastral map: borders of the water body, borders and areas of reed growths, borders of SACs (*Special Areas of Conservation*), borders of administrative areas, and access roads. Reed cadastral passport contains the main parameters and features characterising the respective reed growth. This study analyses the main parameters characterising each reed growth to be included into the reed cadastre and provides methods to establish them.

Level of the lake's overgrowth A_{lake} in %, shows the size of the part of the total area of the respective water body overgrown with reeds:

$$A_{lake} = \frac{S_{reed}}{S_{lake}}, [\%], \quad (1)$$

where S_{reed} is the total area of reeds in each lake;

S_{lake} is the lake surface area.

To detect the reed-covered area (S_{reed}), it is possible to use GPS devices [10], by measuring all reed growths, however it is possible in cases when only small areas are to be measured with high precision, because this process is very labour-intensive. Within this study, the reed-covered area was detected using distance-based probing method in the computer program Arc Map 9.2. This method can be also recommended for further creation and development of the reed cadastre. The measuring method is based on analysis of orthophoto images; orthophoto images were analysed without using specific filters. Orthophoto analysis for detection of plant-covered areas in water bodies has also been used by other researchers [11; 4;5;12; 13; 14]. Borders of reed growths are being digitalised and area of the surface of each reed growth in the specific lake or pond farm is being calculated by using the polygon drawing tool in the computer program Arc Map 9.2. (Fig.1.), digitalisation scale is 1:500. The sum of reed growth areas in each lake constitutes the amount of reeds that can be potentially gathered. Reed-covered areas were detected using orthophotos taken from 2005 to 2010.

Fig. 1. Reed growths in the Southern of Kvapanu Ponds

Long-term changes in the total areas of reed growths are shown by dynamics studies. In the respective water body, reed-covered area is being detected in each of the reference year, which allows assessment of reed growth changes. In order to quantify the reed growth changes over time, the following values were introduced: lake overgrowth intensity $I_{overgrowth}$ and increase in reed growths in the water body I_{wb}.

Reed growth increase in the water reservoir I_{wb} is expressed ha *year $^{-1}$ which shows by how many ha in the time period the reed spread has changed on an annual basis in each specific water reservoir:

$$I_{wb} = \frac{S_e - S_s}{n}, \text{ ha *year}^{-1} \quad (2)$$

Where, S_e – Calculated reed area at the year end;

S_s – Calculated reed area at the year start;

n – The number of years in the period analyzed.

Intensity of the lake overgrowing $I_{overgrowth}$, express changes in the reed area, which happen during the course of time in the water reservoir. The lake overgrowing intensity shows by what percentage annual the reed spread expands or contracts over the total area of the water reservoir.

$$I_{overgrowth} = \frac{(S_e - S_s) * 100}{n * S_{lake}}, \text{ \%*year}^{-1} \quad (3)$$

Where, S_e – Calculated reed area at the year end;

S_s – Calculated reed area at the year start;

n – The number of years in the period analyzed;

S_{lake} – the lake surface area.

Characterisation of field studies. In each of the lakes examined, the author chose four reed growths that, in respect to their characteristic parameters, visually corresponded to the average level in the respective water body. Two sampling plots were examined in each growth. For each of them, the following parameters showing reed productivity were determined: reed density, average diameter of stems and amount of biomass to be gathered. Each year, reed sampling plots were created within the same growth, which allows comparing parameter changes over years. Winter harvesting of reeds on the ice shows a biomass result. With a direct weighing method in situ the amount of reed biomass was established, which can be extracted from lakes and fishfarms from a 1m square reed growth. In the calculations, the reed sections above ice during the winter are included. Reed harvesting and sample weighing were done in 8 sampling plots (four different plant areas with 2 sampling plots in each) in each of the lakes surveyed Sampling plot area 25m square (figure 2). The obtained results were recalculated to the dry condition. Plots were located in places corresponding to the average overgrowth density, and overgrowth density was determined by monitoring the reed bed. This methodology is also recommended for future maintenance and development of the cadastre.

Fig. 2. Sampling plot for reed biomass measurements in Lubana Lake

Characterisation of laboratory studies.

For each of these samples the following heat technology parameters were established – carbon content in the biomass, the relative moisture content, the lowest combustion temperature, the lignin content in the biomass, evaporable matter in the biomass, ash content, as well as the metal content in the biomass for the following – Copper (Cu), Cadmium (Cd), Nickel (Ni), and Lead (Pb).

Samples for the laboratory experiments were prepared according to the standard method CEN/TS 14780.

Moisture content in the reed biomass was established according to the standard method CEN/TS 14774 – 2.

Ash content was determined by applying the standard method CEN/TS 14775.

Carbon content in the biomass was established with the carbon/sulphur analyzer ELTRA CS – 2000 which works on the principles of chromatographic analysis. The reed biomass thermal capacity was established with a colorimetric thermometer Paar 6772, for a natural moisture content of 10 – 12%.

Lignin content in the reed biomass established by the Classon method [15].

Evaporable matter content established by the following methodology: First weigh the crucible, then the sample for analysis with a mass of 1± 0,1g, the crucibles are covered with a lid and placed in a furnace with tongs with a preset temperature of 600C.

After 7 minutes the crucibles are removed and left to cool in the air. The lids are removed and the crucibles placed in an escalator where the samples cool to room temperature, the crucibles are weighed and the non – evaporable remainder removed. The relevant calculations are made.

To determine the **heavy metal content in the biomass** the mineralization of the samples was carried out using the relevant methodology. The reed biomass was reduced in size by a milling process which produced bits <150 um, which were weighed as a 1,5g dry biomass sample. Then 15ml concentrated $HN0_3$ was added, the sample heated to 95 degrees C over 2hours. The cooled sample was filtered, the filter having been washed with 0,5% $HN0_3$ and diluted with deionized water up to 65ml. The metal content in the solution was established with an optical plasma spectrometer Perkin Elmer optima 2100 DV.

Concentration (C) of heavy metals per 1 kg of reed ashes is calculated using equation 4:

$$C = \frac{C_{el} * V_{sample} * 1000}{m_b}, \text{ mg*kg}^{-1} \quad (4)$$

where C_{el} is concentration of the element, mg*l^{-1};

V_{sample} is volume of the sample after mineralisation, l;

m_b is ash weighting, g.

Content of heavy metals in ash is used to determine maximum five-year doses of ash incorporation into the soil. Maximum acceptable doses of reed ash to be incorporated into one unit of soil area were assessed taking into account sewage sludge incorporation into the soil. Limiting doses were established in line with the requirements of Cabinet Regulation No. 362 of November 1, 2008 "On Utilisation, Monitoring and Control of Sewage Sludge and the Compost thereof" (Table 1).

Table 1
Limit Values Of Annual Heavy Metal Emission Intoagricultural Soils

Nº	Limiting element	Average for a five-year period (g*ha^{-1} per year)	
		sand, loamy sand	loam, clay
1	Cadmium (Cd)	30	35
2	Cooper (Cu)	1000	1200
3	Nickel (Ni)	250	300
4	Lead (Pb)	300	350

All laboratory studies were repeated thrice, the respective error calculations were also carried out, therefore these values are indicated in the reed passport data as an interval. Descriptive statistics and dispersion analysis methods were used for data processing [16; 17]. Images were used to visualise data and correlations.

The amount of the mass obtained was determined at a natural moisture content. Reeds were cut above the ice using a scythe. Reeds, after being cut, were gathered, tied and weighted. The amount of the biomass obtained from the respective sampling plot was recalculated to t*ha^{-1}. For studies of characteristic features, the results obtained were recalculated to a dry state $\mathbf{M_{dry}}$.

Reed height $\mathbf{H_{reed}}$ was established with a tape measure in situ. In each of the water reservoir sampling plots the harvested reeds were measured and the mean height established for a 1m square area.

Reed diameter $\mathbf{D_{niedru}}$ was established with a slide gauge in situ. In each sampling plot the reed diameter was measured for a 1m square area, when harvested for the biomass result. The diameter was measured 10 cm above the ice. The results were analyzed to calculate the mean reed diameter in each sampling plot.

Reed density was established in each water reservoir sampling plot with a count of reed stalks for a 1m square area, which were harvested to establish the biomass result. From each sampling plot about 1kg of reed biomass was taken, which was used to establish the parameters of reed heat engineering under laboratory conditions.

Previous studies have revealed that reed stems and leaves have different features and different capacity to accumulate heavy metals. [18]. In our research, reed stems were not separated from leaves, because, when gathering reeds for fuel generation, such separation is complicated and energy intensive, which would make reed procession more expensive. Reed samples gathered from eight sampling plots in each lake were joined together to create the averaged sample. Reed samples were placed in a shelter for storage, no additional drying was performed. Reeds were shredded, and 1 kg of the shredded averaged sample was taken for laboratory studies.

III. RESULTS AND DISCUSSION

The reed cadastre was created as a summary of results of the main researches related to reed growths, which allows using it in further management and studies of reed growths. Each water body included in the reed cadastre needs to have a passport and reed cadastral map. The study resulted in a reed cadastre for 11 biggest reed gathering sites in Latgale region. Studies of reed growths were carried out in Lubana Lake, Gumelis Lake, Raznas lake, Feimanu Lake, Sivera Lake, Luknas Lake, Kvapanu Ponds and Naglu Ponds, as well as in Rusonas Lake, Birzkalna Lake and Cirisa Lake.

Information on reed locations in each specific lake is shown in the reed cadastral map where visualisation of borders of the water body, borders and areas of reed growths, borders of the special area of conservation, borders of regions and access roads (Fig. 3), can help in finding solutions for better logistics of reed use.

Data to be included into the reed cadastral passport were divided into two parts: geographical data of the water body and characteristic parameters of reeds. Geographical data of the water body are the following: CWMD (*Classifier of Water Management Districts*) code and surface area of the water body, as well as average depth and legal status of the water body defined basing on data from the Database of Latvian Lakes. [6]

Characteristic parameters of reeds include calculated reed-covered area, average amount of reed cut above ice in wintertime, potential amount of biomass and amount of biomass actually harvested. (Fig.4).

Areas overgrown with bushes were not added to the total reed areas, while areas covered with cane were taken into account.

Studies carried out by other authors have shown that it is not recommended to cut 100% of all reed-covered areas each year, because it causes changes in the structure of reed growths and may affect negatively populations of organisms living therein [5;19]. Therefore, the amount of reed biomass to be actually obtained is lower than the potential amount of reed biomass that could be theoretically obtained. Besides, to avoid any adverse impact on reed growths and organisms living therein, the maximum amount to be obtained should not exceed 50% of the total amount. [2]. Thus, the biomass amount to be actually obtained was calculated as 50% of the reed amount found in each water body. Total amount of reed biomass to be actually obtained was calculated by multiplying the area covered with reed to be actually used by the amount of biomass obtained from one surface unit in each specific water body.

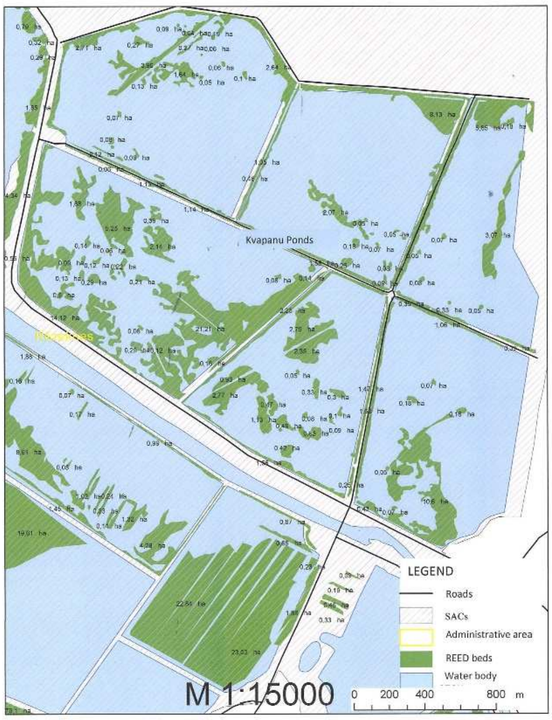

Fig. 3. Cadastral map of reed growths in Kvapanu Ponds

Kvapanu Ponds	
Geographical data of the water body	
CWMD (*Classifier of Water Management Districts*) code	No
Surface area, $\mathbf{S_{lake}}$, [ha]	610
Average depth of the lake, $\mathbf{H_{lake}}$ [m]	0.5
Legal status	Private
Area of conservation	Nature reserve "Wetland of Lubana Lake", territory of Natura 2000.
Characteristic parameters of reeds	
Calculated reed area, $\mathbf{S_{reed}}$,[ha] (in 2008)	160
Distribution of reed areas by administrative territories, %	100 % Rezekne region
Reed-covered area located in Special Areas of Conservation, [ha]	16
Average amount of reeds cut above ice in wintertime, $\mathbf{M_{reed}}$ [t*ha^{-1}] (in 2010-2012)	8.16-8.66
Potential amount biomass (when cutting reed above ice in wintertime), $\mathbf{M_{total}}$,[t] (in 2010-2012)	1305-1385
Amount of biomass actually harvested (when cutting reed above ice in wintertime), $\mathbf{M_{real}}$, [t] (in 2010-2012)	650-690
Overgrowth level in the water body, A_{lake}, [%], (in 2008)	26.2
Increase in reed growths in the water body I_{wb},[ha* year^{-1}], (in 1997-2008)	7.8
Overgrowth intensity in the water body, $I_{overgrowth}$, [%*year^{-1}], (in 1997-2008)	1.3
Average heigh of reeds, H_{reed}, [m] (in 2010-2012)	2.18-2.28
Average diameter of reeds, D_{reed}, [mm]; (in 2010-2012)	7.84-8.24
Average density of reeds, B_{reed}, [stems * m^{-2}]; (in 2010-2012)	55-60
Average ash content, A_d, [%]; (in 2010-2012)	4.3
Average relative humidity, M_{rel},[%] (in 2010-2012)	15.6-17.0
Average lowest heat of combustion, [MJ*kg^{-1}], (in circumstances of natural moisture content) (in 2010-2012)	14.11-14.39
Average carbon content, [%] (in 2010-2012)	40.6-42.8
Average lignin content in biomass, [%] (in 2010-2012)	25-25.67
Average content of volatile substances in biomass, [%] (in 2010-2012)	68.1-68.8
Maximum acceptable five-year dose of reed ash distribution t*ha^{-1}.	Sand, loamy sand – 10.4 Sandy loam, clay – 12.5

Fig.4. Cadastral passport of reeds in Kvapanu Ponds

In Latvia, there is no system performing reed growth monitoring, therefore there are no data on long-term availability of reed resources. Cadastral passport also contains information on the overgrowth level in the water body and increase in reed growths in the water body. The latter shows intensity of reed invasion. These values allow assessing the amounts of reeds as renewable energy sources and their development trends, which helps us foresee their amounts in future. Studies of reed dynamics reveal that every year reed-covered areas in Latvian lakes increase. Thus, it can be concluded that reed is a sustainable resource. To quantify this increase, the cadastral passport contains information on overgrowth intensity in the water body expressed as %*year^{-1}. It can be seen from the Figure 4 that in Kvapanu Ponds this increase amounts to 1.3%*year$^{-1 f}$ from the total surface area of the water body.

Furthermore, passport data include information on characteristic features of reed growths: average height of reeds, average diameter of reed stems and reed density, which allows conclusions to be drawn as to the overall state of the respective reed growth and which is also necessary in the process of reed harvesting and when choosing and designing technical equipment for primary-processing.

Research results show that average height of reed growths on sampling plots varied between 1.55 and 2.35 m. Average height of reed growths in Kvapanu Ponds amounted to 2.18-2.28 m. Average diameter of reed stems in growths varied from 5.25 to 8.35mm, while in Kvapanu Ponds the average diameter was 7.84-8.24 mm, which is above the average level. Average density of reed growths amounted to 55-60 stems per one m^2 of reed growth.

Reed suitability for energy production is characterised by their thermal features. Reed cadastral passport contains the following features: lowest heat of combustion, carbon content in the biomass, ash content in the reed biomass, relative moisture content, content of volatile substances in the biomass and lignin content in the biomass. The main indicator to be included into the reed cadastral passport is heat of combustion. For the analysed samples of reed biomass, the lowest heat of combustion varied from 13.57 to 14.70 $MJ*kg^{-1}$. For reeds growing in Kvapanu Ponds, this value was 14.11-14.39 $MJ*kg^{-1}$.

Main factors that can affect the heat of combustion are the content of combustible elements and content of moisture and ash in the biomass. Ash content in the respective samples varies from 2 to 8%. On the average, reeds contain approximately 5% of ash, which is five times more than in wood and is equal to the ash content in straw or canary seed. Ash content depends on individual reed growing conditions in each water body. Ash content in reed biomass is stable within one water body. Main factor affecting the ash content might be the content of various elements in water and silt absorbed by reeds.

Relative moisture content in the respective samples varied from 14.5 to 19.2%. Average moisture content in samples of reed biomass was approximately 16.8%, which shows that reeds may be successfully combusted without previous drying. Almost the same moisture content was found by Estonian researchers: reeds with moisture content not exceeding 20% may be harvested in spring-winter period [5].

Lignin content in plants varies depending upon their type. For wood, it is 19-30%, in fibres of other plants 8-22 %. Lignin content was established using Klasons method [20]. Our study revealed that lignin content was equal to the wood biomass and was higher than in fibres of other plants, which shows that reeds are suitable for granulation and briquetting without adding additional binding agents, therefore this parameter should be included into the reed growth passport.

Content of volatile substances characterises combustion capacity. In the respective samples the content of such substances was high and varied from 64.4-72.8%, which may indicate that reed biomass is a highly flammable fuel.

Studies on canary seed reveal that the time of harvest also affects significantly thermal characteristics of the biomass [21], however harvest time for reeds is limited. Taking into account current technical harvesting equipment, industrial reed gathering requires a thick layer of ice. In order to avoid causing significant changes in reed growths, it is usually possible to harvest reeds only starting from the beginning of February to the end of March, which is also the time when reeds have the best thermal characteristics. Therefore, the impact of the time of harvesting on reed characteristics was not analysed and the recommended time of harvesting was not included into the cadastral passport as an indicator.

Using reeds as a fuel, reed combustion results in ash that can be considered to be a hazardous waste because it contains heavy metals. Studies on possibilities of reed ash utilisation by incorporating it into the soil have helped to determine the maximum acceptable five-year dispersion doses $t*ha^{-1}$ that have been included into the cadastral passport data. For reeds obtained from the Kvapanu Ponds, this value was 10.4 $t*ha^{-1}$ of ash in sand and in loamy sand soils, and 12.5 $t*ha^{-1}$ of ash in sandy loam and clay soils. Although a high level of ash content is typical for reeds, which often causes problems during combustion in wood combustion devices, adapting furnaces to reed combustion would allow successful converting them into energy. Reeds should be used as an additional energy resource, by using it in various technological processes of fuel procession and energy generation, which, in case of necessity, would create a possibility to replace the reed by other types of biomass, e.g. wood, because there are several high risk factors related to the use of reeds: floods in winter, storms and freezing of water bodies during floods, as well as blizzards may seriously damage the reed growths, or, in case of untypically warm winters, ice layer may not be sufficiently thick to ensure industrial harvesting of reeds.

Reeds in the water bodies of Latgale region should be harvested in winter time, by cutting them above ice, because permanent provision of this raw material, by cutting it in summer period, is not possible.

Harvesting of reeds in winter time, i.e. from the beginning of December to the end of April, is the best time to use them for fuel generation, because then the reeds have the best qualities as fuels. During this period, reeds contain the lowest level of chlorine and alkali metals undesirable in combustion devices. Besides, harvesting reeds in winter time reduces emission of CH_4 into the atmosphere. Cutting prevents reed-covered areas from overgrowing, raises reed viability and capacity to absorb nutrients during the next season. Reeds cut in the winter are easy to be converted into energy and they regrow by the next harvesting season [22].

IV. CONCLUSION

Reeds may be used for fuel generation. In Latvia there are more than 2000 lakes and pond farms that can be used to obtain reeds.

Criteria have been drawn up and a cadastre has been created containing information on reed resources in the most important reed harvesting sites in Latgale region. A cadastral map and reed growth passport have been created for each water body.

Cadastral map visualises borders of reed growths, borders of water bodies, areas of growths, borders of administrative territories, access roads and borders of special areas of conservation.

Reed cadastral passport contains geographical data of the water body and characteristic parameters of reeds. Geographical data included in the reed cadastral passport are the following: CWMD (*Classifier of Water Management Districts*) code, name of the water body, surface area of the water body, average depth and legal status.

Characteristic parameters of reeds are the following: reed-covered area, distribution by administrative territories, amount of reeds cut above ice in winter, potential and actual amount of biomass to be obtained, overgrowth level of the water body, reed height, density and average diameter. Besides, reed thermal features were also included: moisture and ash content, heat of combustion, content of lignin and volatile substances, as well as maximum five-year doses of reed ash distribution.

Reed cadastre should be developed and maintained, it can serve as a basis for creation of enterprises related to reed harvesting and processing.

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