UNIVERSITY OF SOPRON
Roth Gyula Doctoral School of Forestry and Wildlife Management Science
Forest Technology Program

THESES OF DOCTORAL (PHD) DISSERTATION

PRODUCTION AND UTILIZATION OF DENDROMASS FOR ENERGY PURPOSES AND POSSIBLE ROLE IN THE BASE MATERIAL SUPPLY OF LIGNOCELLULOSE BIOFUEL PLANT

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IMPORTANCE AND ACTUALITY OF THE RESEARCH TOPIC

Millions of years ago fixed carbon have been continuously emitting due to the increased use of fossil fuels in the last centuries. Therefore, the carbon dioxide concentration of the atmosphere has increased from the pre-industrial level of 300 ppm to over 400 ppm by now.

Biofuels are of the utmost importance to slow down climate change caused by greenhouse gases. On the other hand, using first generation biofuels removes more and more agricultural land from food production. This tendency leads to changing of the land use structure. In addition, growing population and transforming structure of consumption are expected in the 21st century.

The satisfaction of a multifaceted demand is a growing problem, because of decreasing yields of crops due to the climate change. An alternative solution can be the large amount of biofuel production based on industrial, forestry and agricultural by-products, which is justified in the near future. At the same time, the shift from the linear economic to the biomass-based economy model requires a scientifically planned development in the crop production systems.

The dendromass cultivation to this system is ecologically well-adapted, especially with short carbon cycle.

AIMS OF RESEARCH

One of the main limiting factors of lignocellulose biofuel production is the high investment cost of the plants. On the other hand, the main advantage of the second generation biofuels are the wide variety of usable base materials. At the same time, it needs to be considered that the change-over to bio-products within the framework of circular economy also increases the scope of concurrent users. Therefore, one of the aims of the research is to carry out the estimation of forest and agricultural by-products potential for lignocellulose biofuel production in Hungary. The by-products are showing a different territorial intensity. Minimizing their collection and transport distances is an important task both ecologically and economically. Consequently, it is essential aim to compare the required collection areas of different base materials and to extend them to the real condition.

The short rotation woody biomass as alternative base material was also evaluated. The coppicing technology generates thin wood, which has different properties compared to the wood material delivered by forestry production. It is necessary to examine its usability for biofuel production by determining the energetic parameters.

According to literary sources, the role of the foliage of plantations in soil repair and carbon capture from atmosphere is significant. In Hungary, there are no examples to examination of foliage mass, so measuring them and completed with data of root and wood mass gives the opportunity to determine the amount of carbon capture by the plantation. Considering the CO_2 emissions of the used machines, during cultivation, transport and biofuel processing, it is also possible to determine the amount of carbon emission for the whole life cycle of liquefied biofuels. However, the latest legislation primarily encourage the use of electric drive, so the comparison of energy efficiency of the dendromass use for different purposes is important.

MATERIAL AND METHODS

The research was carried out with the analysis of international and Hungarian literature, with the evaluation of the data of statistical offices and with measurements on the experimental plantation and in the energy laboratory.

The estimation of the base material potential of lignocellulose biofuels was realized by the following main methods:

- estimation of the generated and collectable potential of woody by-products, such as forest residues, grape cuttings and orchards pruning in Hungary by counties;
- detection of the free usable potential, taking into account the base material needs of the currently operation and in the future expected major utilizer,
- comparison of the energy content of the collectable dendromass and of the high lignocellulose containing herbaceous by-products.

The base material footprint under theoretically conditions for one unit of biofuel energy was carried out on three countries, on five types of biofuels, on four main agricultural products and on three high lignocellulose containing woody and herbaceous by-products. The impact of climate change on the size of the collection area was qualified considering the fluctuation of the biomass yield. In the case of corn and corn stalk the extension for the real condition was used the GIS method within two 50 km radius area of Hungary. In the case of the forest residues, was taken into account the total area of one of the choosen forestry company.

The usability of energy plantations for biofuel production and the role of carbon sequestration was examined on the ERTI Bajti Experimental plantation with the selecting of the following species/clones:

- *Populus x euramericana* 'I-214',
- *Populus x euramericana* 'Koltay',
- *Robinia pseudoacacia*,
- *Salix alba* 'Drávamenti'

During the research the following parameters were measured on one, two and three years plant:

- the number of shoots per plant,
- the wet weight of the shoots,
- the diameter of shoots ($d_{0.1}$ and $d_{1.3)}$,
- the height of shoots,
- the mass of foliage and
- the foliage area belonging to shoots.

The energetic parameters were analysed in laboratory of the Institute of Forest- and Environmental Techniques and of the content of elements was measured in the Institute of the Environment and Earth Science at the University of Sopron. The following parameters were determined for the samples:

- the moisture content of the wood with bark, of the bark and of the leaf,
- weighing bark and wood separately,
- the calorific value of the wood with bark, and only of bark
- the ash content of the wood with bark and only of bark
- the element content on the foliage.

By evaluating the obtained data were determined the leaf to wood mass ratio, the area of the foliage belonging to the shoots, the bark to wood ratio and the wood density depending on the cutting cycle.

SUMMARY OF RESEARCH RESULTS, USABILITY IN THE PRACTICE

Hungary has already significant capacities in the production of conventional biofuels. However, the European Union regulations will encourage the production of non-crop-based biofuels in the future. Installing lignocellulose biofuel plants can be only achieved with the help of central funding sources or large industrial investors due to their extremely large investment needs. It requires well-founded decision-making, which is one of the main pillars of the right base material supply. The research covers the estimation of the potential of dendromass by-products and the expected method of they utilization. The potential estimation will help in choosing of installation place and technology of future plants.

The forest residues represent a significant proportion of the examined by-products; however, they need the largest collection area for production unit of biofuel. According to the investigation, the short rotation coppices are a possible alternative solution to the base material supply of increasing biofuel requirements. Significant installation of plantations can be achieved by developing and providing the appropriate support system. They offer high biomass output per hectare, while improves the organic content of low-quality

agricultural soils due to the intensive foliage and root production. All in all they can play an important role of the atmospheric CO_2 sequestration in the future. During the research developed method allows to estimate the weight of the foliage in the case of known shoots diameter ($d_{0.1}$) or weight. With help this data it can be calculated to transported amount of carbon nutrients into the soil.

The carbon life cycle of the biofuels based on the short rotation woody biomass production is low, thanks to the short carbon cycle of the dendromass production. High bark content is disadvantageous from a technological point of view; therefore, it is suggested to mix it with barkless sawdust during pyrolytic biooil production. However, it can be used alone to supply combined heat and power plants with high efficiency. The latter will in the near future a benefit in Hungary because the reliable technology is available and the investment risk is low.

THESES, NEW RESEARCH RESULTS

The author provide the following theses in connection with her research:

1. Based on the potential assessment in Hungary for biofuel base materials about 1 million tons of dendromass by-products are generated annually in forestry and in agriculture. Considering both ecological and technological aspects, about 700,000 tons of wet biomass can be collected, which is slightly more than 8% of the energy content of collectable herbaceous by-products. Currently operating power and heating plants are tying of these by-products in the event of collection and about 100-150 thousand tons of free potential appears in the south-east part of the country.

2. A new measuring system has been introduced as a base material footprint, which shows the required collection area for a unit energy content of biofuel, examined under theoretical and real condition. The collection area of forest residues in Hungary is approximately 0.1-0.5 ha under theoretical condition and 6.3-39.5 ha under real condition for the production of 10 GJ biooil, depending on the logging practice. Compared with agricultural main and by-products, the collecting area of forest residues is smaller under theoretical conditions, while under real condition required larger collection area for producing the same energy containing biofuels.

3. The conversion of base material from short rotation coppices to biofuels by thermochemical process is firstly made by its high bark ratio difficult. The 6% to 18% bark ratio of base material results an ash content of 2-3%, the value depends on the tree species and on the cultivation technology. It is advisable to apply the maximal applicable rotation harvest technology on

the plantation, but at least two years, in the case of willow three years. Furthermore, in case of each species it is suggested the mixing of the base material with barkless sawdust during thermochemical utilization, which generated as wood processing by-product.

4. The carbon sequestration in the foliage of the woody energy crops on the examined plantation with applying three years rotation harvest technology is about 8-46 t/ha depending on the tree species, during the 20-years lifetime period. This value decreases by 17% in the case of two years harvest rotation technology, and by 48% with a yearly harvest. *Populus X euramericana* 'Koltay' showed the most favorable properties for degradation characteristics on the examined area, examining on the aspects of ecology, quantity and C/N content. The role of roots in carbon sequestration is similar to the foliage.

5. A method has been developed to estimate the weight of foliage of short rotation coppice. The practice of non-destructive measurements requires the annual estimation of the amount of foliage by steam diameter in cutting height ($d_{0,1}$) during vegetation period. The tendency of the relationship between steam diameter and foliage weight is best described with the Avrami equation. Using this in the case of known diameter ($d_{0,1}$), the weight of foliage belonging to steam (Lm) can be estimated. The goodness of fit (R) and the equation for the four examined species are the following:

Species	**Goodness of fit (R)** **Equation**
Populus x euramericana 'Koltay'	R = 0,98 $Lm = (6318{,}5) * (1 - \exp(-1 * (((0{,}00500066) * d_{0,1})\text{^}(2{,}1322)))) + (2{,}91295)$
Populus x euramericana 'I-214'	R = 0,97 $Lm = (365{,}606) * (1 - \exp(-1 * (((0{,}0250635) * d_{0,1})\text{^}(3{,}51832)))) + (11{,}1053)$
Salix alba 'Drávamenti'	R= 0,95 $Lm = (1416{,}74) * (1 - \exp(-1 * (((0{,}00830169) * d_{0,1})\text{^}(2{,}56758)))) + (8{,}92634)$
Robinia pseudoacacia	R= 0,95 $Lm = (0{,}719686) * (1 - \exp(-1 * (((0{,}0235838) * d_{0,1})\text{^}(3{,}30563)))) + (0{,}00702737)$

6. It is approximately 54 g of C is emitted during the cultivation of base material from short rotation plantation with the average yield of 10 t/ha/yr dry mass, the biofuel production, the refining and the product utilization process of 1MJ biooil. During the calculation, it was considered that waste energy generated during biooil production is used for drying the base material and for the plant's own energy consumption. Approximately 6.5% of the emitted carbon comes from fossil fuels during the biofuel life cycle and the rest are neutral due to the short carbon cycle base material cultivation. Considering the high carbon emissions of fertilizer production, an additional 1 g of C is emitted during the life cycle of each MJ biofuel, of which comes from more than 9% fossil sources.

7. In Hungary, from the energy efficiency point of view the use of dendromass based electricity in the road transport is more favorable than liquid biofuel produced by pyrolysis. In latter case using 1 ton of dendromass, 38 km distance can be achieved with average fuel consumption and 39-45 km distance with electric car depending on the efficiency of the power plant. During the potential estimation detected ca. 100,000 t free dendromass by-product could satisfy for 0.6-0.7% of the energy need of total fuel consumption in Hungary, and in the case of the collection of the total 700,000 tons, more than 4% could be achieved depending on the technology, applied the RED II. multipliers.

LIST OF PUBLICATION ON THE RESEARCH TOPIC

Journal and Conference Publication

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