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Modeling of biomass potential from agricultural land for energy utilization using high resolution spatial data with regard to food security scenarios

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ABSTRACT

The paper presents results of modeling biomass potential under different scenarios of agricultural land utilization, which represent strategies of national food security. High resolution spatial data (GIS) including valuation of agricultural land, maps of actual utilization of agricultural land, yields of annual food crops and yield curves of perennial energy crops derived from empirical field data were used. The biomass sources used were residual straw from conventional agriculture crops (cereals, rape) and lignocellulose biomass from perennial energy crops (poplar, willow, Miscanthus, reed canary grass, hybrid sorrel, and other grasses). Biomass potential is modeled using original methods and algorithms that enabled the respecting of several its limitations (nature and soil protection, competition of crops for land, and use of straw for animal production). For the actual modeling—calculating the biomass potential for a given territory—a geographic information system is used (software TopoL©). Results of analyses confirmed that residual of biomass has good potential as source of energy in the Czech Republic (about 121 PJ/year which equals to 6.8% of primary energy sources used in 2012), though the total number is lower than in previous assessments. The current biomass potential can be significantly increased with allocation of energy crops on less fertile land according to food security scenarios. Modeling also showed that biomass potential is non-linearly dependent on land allocated for energy crops. Soil and climate conditions of agricultural land allocated (available) for biomass production and its suitability for new energy crops play the decisive role in the definition of future biomass potential from agriculture land. Practical outputs of the modeling are yield maps of individual and mixed biomass sources as well as databases of biomass potential under different food security scenarios for regions of the Czech Republic, which can be used for planning of sustainable development of bioenergy.

Contents

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1. Introduction

In Directive 2009/28/EC, the European Union set out goals to use renewable energy sources for the year 2020 in the form of the required proportion of RES in covering the final energy consumption. The goal is set both for the EU as a whole and for the individual EU member states. According to Directive 2009/28/EC, the individual member states were obliged to prepare a National Renewable National Action Plan (NREAP) [1], which documents the initial situation (2010) and the method of achieving the (binding) goals in 2020. The highest share in final energy consumption in 2010 for EU as a whole belongs to heating and cooling (48%), followed by electricity consumption (25%) and consumption in transport (27%), assuming that the structure of final energy consumption will remain the same until 2020.

Renewable energy sources currently (2010) contribute about 11.5% of the final energy consumption in the EU and the EU target by 2020 (see Directive 2009/28/EC) requires increasing this to 20%. In the Czech Republic, the share of RES in the final energy consumption is presently (2010) at about 8.4%, and NREAP expects it to rise to 13.5% (2020) [1].

Biomass is currently the most important renewable energy source (RES) in the context of both the Czech Republic and the EU as a whole. Biomass had a 90.9% share in 2010 in the EU RES total contribution in the final energy consumption for heating and cooling and it is expected that a high share of biomass will be retained despite the anticipated rapid development of other renewable energy sources (an increase of other RES about 243% between 2010 and 2020) [1]. According to the NREAPs of the individual EU countries it can be expected that the share of biomass in the final energy consumption from RES for heating and cooling in 2020 will reach about 81%, which means an increase in the amount of biomass in absolute terms by about 46%. According to the NREAPs, in the next decade biomass will remain an important RES in the electricity production in the EU as a whole. In 2010, 17.6% of RES used for production of electricity came from biomass (in all its forms—solid biomass, biogas, and liquid biofuels) and by 2020 this should increase to19.1%. This means 1.87 times increase of power generation using RES and 2.03 times increase of biomass use for electricity production (in absolute values).

The Czech Republic is currently characterized with the high share of solid fuels (namely low quality domestic brown coal) both in the structure of primary energy used (2012 figures: 41% solid fuels including solid biomass, 20.4% liquid fuels, 15.9% gaseous fuels including biogas, 18.5% nuclear, and total RES contribution is 7.8% of total primary energy sources) and in the portfolio of gross power generation (47.3% solid fuels including solid biomass, 34.6% nuclear, 5% gas, 3.4% hydro, and 2.5% PV) [2]. In 2012 RES contributed 8.1 TWh, which is 11.4% of the total inland gross power consumption. Solid biomass currently (2012) contributes 63% to the total RES contribution to primary energy sources [3]. Total utilization of solid biomass was 1.458 mt for power generation and 2.047 mt for heat production in 2012 [3]. Solid (wood) biomass namely in the form of residuals from the wood processing industry and forestry currently plays the most important role (2.7 mt of total 3.5 mt).

Similarly as in the EU, biomass plays an important role in the Czech Republic's energy strategies. In 2010 biomass covered 97% of RES in the final energy consumption for heating and cooling, and the NREAP expects the Czech Republic to maintain this high percentage until 2020. In the Czech Republic (2012) biomass has a 40% share in the total share of RES in gross electricity generation, which according to the NREAP is expected to increase to 53% by 2020, i.e., the production of electricity from renewable energy sources is expected to grow from 8.06 TWh to 11.7 TWh between the years 2012 and 2020.

The EU (e.g., in Energy Road Map 2050 [4]) and Czech Republic (e.g., in State Energy Policy 2012–2040 [5]) documents, dealing with the time period after 2020 count with a further massive increase in the share of RES, where biomass will continue to play a key role in the overall contribution of RES. Such a rapid increase in the expected use of biomass cannot be secured without the use of large areas of agricultural land for the cultivation of biomass for energy purposes. The reason is that the sources of waste and residual biomass to be used for energy purposes have already been largely exhausted. Formulating an effective strategy to meet the defined RES-use goals including using biomass as the main type of RES, requires, inter-alia, determination of the biomass potential in relation to how the agricultural land is used. The key aspect here is how much of agricultural land will be available for targeted cultivation of biomass for energy purposes. This question must be dealt with not only by the Czech Republic, but by all the EU member states.

The development of growing biomass for energy purposes on agricultural land is still in its initial phase. In the last decade, especially classical agricultural crops were grown for the production of liquid biofuels (rapeseed for producing biodiesel, corn and sugar beet for bioethanol production), as input to the biogas plants (maize for green mass). In particular, the support for the production of liquid biofuels has often been criticized in recent years as one of the factors leading to a sharp rise in agricultural commodities between 2004 and 2008 [6,7,8,9]. Many analysts argued that both political targets and economic support of biofuels development (resulting in the massive subsidizing of biofuels production) were one of the crucial factors causing this rise [10,11]. The development of the use of biomass for energy purposes is thus to be understood in direct relation to the food production, and the objectives in the use of biomass should be measured with regard to the potential of biomass corresponding to the area of land that is potentially available for the cultivation of energy crops (while maintaining the required level of food production).

This paper presents a methodology for determining the potential of biomass based on combining information from evaluating soil and climatic conditions of the land with the energy crop yield curves under the conditions of the particular land. When applying the methodology, i.e., calculating the biomass potential for a given territory, geographic information systems are used. This methodology, as is further presented in the paper, enables the user to respect a number of limitations in determining the potential (for example, excluding certain lands from cultivation of biomass for energy purposes, assigning a given crop to the land with an optimum energy yield for the respective climatic and soil