A GIS-model to estimate a sustainable potential for forest fuel for energy generation in the municipality of Växjö, Sweden

Gunnar Wohletz, Jürgen Knies

Jade University of Applied Sciences Wilhelmshaven/Oldenburg/Elsfleth
Institute of Applied Photogrammetry and Geoinformatics
Ofener Str. 16/19
D-26121 Oldenburg
gunnarwohletz@me.com
juergen.knies@jade-hs.de

Abstract: Since the 1980s the municipality of Växjö in Southern Sweden has been increasingly focusing on using wood, primarily forest wood, to produce heat and electricity. A permanent and sustainable supply of forest wood (so-called *forest fuel*) is therefore indispensable for the future operation of the energy generation process. The objective of this project was to develop a model to estimate a sustainable potential of the forest fuel supply until the year 2050 for the municipality of Växjö. The model for the spatial and temporal analysis was implemented in a *Geographical Information System* (GIS). The GIS-model follows a top-down approach of three sequential modeling steps to narrow down the biomass potential estimations: a *theoretical*, t*echnical* and *reduced technical* potential. It hereby includes topographic features, resource competition or other factors to narrow down the final forest fuel potential. The result shows that the municipality of Växjö should be able to satisfy its demand for energy wood from harvested forest fuel alone until around the year 2035, but might have shortages after that until the year 2050.

1. Introduction

Worldwide the importance of renewable energies for a sustainable and clean energy future has been recognized by most countries. In Europe the European Union already has passed several directives to this topic, including the so-called “20-20-20” directive which declared each EU member state to create and implement a “National Renewable Energy Action Plan” (NREAP) to reach their energy goals. The Swedish NREAP aims to extend renewable energy sources to make out 50% of the total nationally provided energy by 2020. Växjö, a municipality located in the province of Kronoberg in Southern Sweden, even wants to surpass those goals and create a fossil fuel free city until 2030. The city once has been awarded the title “The Greenest City in Europe” by the British BBC back in 2007, because of the city’s efforts focusing on building a renewable energy future since the 1970’s, including the establishment of a district heating system for the city in the 1980's. The heating system is run by a combined heat-and-power plant (CHP), which produces heat and electricity and almost is powered by wood alone.

The *North Sea Sustainable Energy Energy Planning* (North Sea SEP) project, which this study was embedded in, is supported by the European Regional Development Fund (ERDF) and is part of the North Sea Region Programme (Interreg IV B) and runs from 2009 to 2012. 26 project partners in 6 countries in the North Sea region, including Energikontor Sydost in Växjö, are involved.

The aim of the study was to find out if the municipality of Växjö would be able to be self-sustainable by only relying on the wood from within its own municipal borders until the year 2050. A geographic information system (GIS) would be used to set up a model using spatial and temporal factors for an analysis.

2. Data and Methodology

2.1 Background Research and Preparation

In this study the term *forest fuel*, which was the goal of this biomass potential analysis, described *primarily forest fuel*, which describes forest wood that is directly obtained from the forest for its usage a biofuel.

The Research Studios Austria (RSA) in Salzburg developed an approach about how to generally model the biomass potential in a top-down strategy: the *theoretical potential* (sustainable biomass potential without any disturbing factors), the *technical potential* (introduing technical limitation) and a *reduced technical potential* (modeling losses during the energy conversion process) [BD08].

About how much biomass single tree components contained an extensive study has been carried out, including taking hundreds of tree samples, dividing and weighing the trees' components and setting up biomass functions for each tree component [Ma87] [Ma88]. In 2006 some of those functions have been revised [PS06].

2.2 Data

The most fundamental dataset for this study was a digital, geograpical forest coverage dataset called kNN-Sweden from 2005, which included estimated forest parameters, such as total wood volume, wood volume by tree species, stand age, and above-ground tree biomass [Re03]. Field plot data obtained by the Swedish *National Forest Inventory* (NFI), by the help of satellite images and topographic maps, were therefore interpolated by using the k- Nearest Neighbor.

Also digital topographical maps (provided by the Swedish mapping, cadastral and land registration authority *Lantmäteriet*) were used in the project. The energy balance for the municipality of Växjö (delivered by the North Sea SEP project partner Energikontor

Sydost) delivered extensive numerical energy data for the years of 1993 until 2009.The orgin forest data had a spatial resolution of 25 x 25 meters. This resolution was the base for the modeling process.

2.3 Modeling Process

The modeling process was divided into five steps:

First the forest was classified into three different forest types, namely coniferous, mixed and deciduous forest according to a threshold value.

The *second* step was to model the forest growth until the desired date that should be modeled. The growth function for each forest type was hereby determined by a regression function which was created based on assumptions mainly using the age and biomass variable from the kNN-Sweden forest dataset to perform a regression anaylsis.

The *third* step marked the first of the biomass potential models called the "theoretical potential". A default forestry style was defined here, so that it could be determined how much forest fuel could be theoretically obtained in a particular year. This forestry style already has to be sustainable.

The *fourth* step marked the "technical potential". In this step all technical parameters which would affect the forest fuel outcome are applied. Those included topographic features (slopes, distances to forest access roads and the exclusion of natural habitats), competition factors (timber and paper industry), as well as the optional harvest of stumps and roots.

In the *fifth* and last step, the "reduced technical potential", the *primary energy* (the theoretical energy before the energy conversion process) was transformed into *final energy* (the usable energy that arrives the customer). This included modeling the losses that occur during energy conversion and transportation.

3. Results and Discussion

The main result of the study, beside the created tool itself, is a line chart which depicts the forest fuel potentials between the years 2010 to 2050 for the Växjö municipality. The modelled years include 2010, 2015, 2020, 2035 and 2050. The continuous green line represents the actual energy supply for Växjö between 1993 until 2009. Several plots have been included, which show the results for the different forest fuel potentials (continuous lines) and results for the technical potential assuming altered technical factors (dashed lines). They all show great differences according to their absolute numbers, but all follow the same trend: While the supply of forest fuel until around the year 2035 should be guaranteed, shortages might occur afterwards until the year 2050. The fact that the forest data which has been used during the project might not take the effects of the tremendous storm ‘Gudrun’ from 2005 into account, emphasizes the steady need to repeat the modeling by using updated forest data to predict more accurate results.

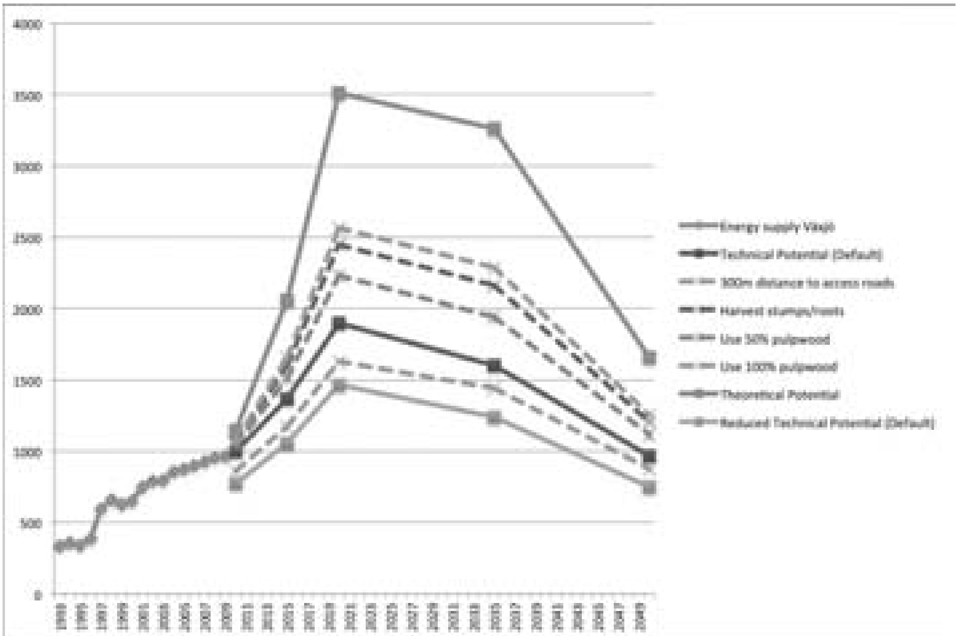

Figure 1: Final results of forest fuel potential modeling from 2010 to 2050.

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