Forest biomass production potential and its implications for total carbon balance: a case from Sweden

Abstract

The increasing atmospheric carbon dioxide concentration level has been a global concern for the scientific society in recent past. Several strategies are suggested to attempt to reduce carbon emissions for reversing the trend. One of the important strategies is a forest management practice that increases biomass growth and subsequently product harvest. This will increase carbon sink and the potential of product use to substitute carbon intensive products. It is also important to consider the soil carbon stock which is an integral part of ecosystem carbon stock. The Swedish boreal forest landscape has been to a large extent actively managed for the last 100 years. Throughout the 20th century the growth in Swedish forests has been larger than the annual use of forest raw material. For this reason the forest standing stock and therefore the amount of carbon stored in the forest ecosystem have increased as an effect of active management of forest resources. However, the standing biomass, soil carbon stock, harvested products and the substitution carbon benefits may differ according to the forest management system and the product use. Harvested forest products may not only be used within Sweden but also exported into other countries thus is not known how it will effect on carbon balance. Thus the estimation of total carbon balance of a forest biomass production and use system needs to consider different variables. This presentation aims to explain how different forest management systems and management scenarios affect the standing biomass carbon stock, soil carbon stock, product harvest, substitution carbon benefit and the product carbon stock as total carbon balance of whole system. In addition, it explains how the carbon balances within and outside Sweden differs with different forest management scenarios. This presentation is an abstract form of four journal papers.

An integrated methodological approach is used to analyze the forest biomass production potential in Sweden and its use to reduce carbon emissions. Forest biomass production, product harvest, and product use are analyzed in a system perspective considering the entire resource flow chain. The total carbon emissions as well as avoided emissions are quantified for the resource flow chain activities of forest biomass production, harvest, use and substitution of non-biomass materials and fossil fuels. Different forest management scenarios with climate change effect, intensive forestry practice effect, two different forest management systems i.e. clear-cut and continuous-cover forestry effect, forest product use effect such as building construction, pulp and paper production, and bioenergy production are considered in the study. Forest product use as stem-wood only and whole tree are also considered.

Process based plant biomass production model, empirical forest growth model, soil decomposition model, substitution model, wood flow model based on long range historical data are used in the study. The analysis is divided into four main parts. In the first part, forest biomass production is estimated using principles of plant-physiological processes and soil-water dynamics. Biomass production in different forest management scenarios are compared, some of which include the potential effects of climate change and intensive forestry practices. In the second part, forest harvest potentials are estimated based on plant biomass production data and Swedish national forest inventory data for different forest management alternatives. In the third part, soil carbon stock is estimated for different litter input levels from standing biomass and forest residues left in the forest during the harvest operations. The fourth part estimates carbon emissions reduction due to the substitution of fossil fuels and carbon-intensive materials by the use of forest biomass.

We assume that wood products replace more energy-intensive consumer products resulting in material substitution. Forest residues and stumps as well as industrial forest based residuals result in direct substitution of fossil fuels–i.e. energy substitution. The emission and substitution factors for the pulp and paper cycle have been derived from SimaPro ecoinvent

2.0 database. The product carbon stock is calculated by means of dynamic modeling using different lifetime of the products. Due to the long residence time for solid wood in constructions the calculations start in the year 1900. The consumption and foreign trade figures from 1900 to 2005 were taken from various statistical sources. In order to show the long term effects of current or future wood use, the stock developments are considered over a period of at least 100 years after the last change in consumption. The total carbon balance is calculated after summing up the carbon stock changes in the standing biomass, carbon stock changes in the forest soil, forest product carbon stock changes, and the substitution effects. Fossil carbon emissions from forest operational activities are calculated and deducted from total carbon balance to calculate the net total carbon balance.

The results showed that the climate change effect most likely will increase forest biomass production compared to unchanged climate. The annual forest biomass production and harvest can be further increased by the application of more intensive forestry practices compared to practices currently in use. As an effect of increased biomass production, there is a possibility to increase the harvest. Intensive forestry practices such as application of pre-commercial thinning, balanced fertilization, and introduction of fast growing species to replace slow growing pine stands increased forest growth thus the standing biomass carbon stock appeared to be greater compared to the reference scenario. Soil carbon stock increase was higher when only stem-wood biomass is used, compared to whole-tree biomass use. The total carbon balance was greater when climate change effect and intensive forestry practices were included. When forest management systems were compared, the clear-cut forestry had greater total carbon balance than the continuous-cover forestry. However, the ecosystem carbon stock (standing biomass carbon stock and soil carbon stock) was greater in continuous-cover system while the substitution carbon benefit and product carbon stock was greater in clear-cut system. The harvest and use of biomass residues and stumps in clear-cut forestry did not significantly contribute the carbon benefits compared to the standing biomass and soil carbon stock in continuous-cover forestry. Forest products exported outside Sweden contributed larger substitution effect compared to the products used within Sweden. The result showed that the increase of carbon stocks in wood products depends largely on magnitude of harvest and for what the wood is used. In general, the substitution benefits were the largest contributor to the total carbon balance. The ecosystem carbon stock is dominant when the forest is managed under continuous-cover forestry.

This study shows that production forestry can be a good alternative to balance biomass growth and harvest in the long run. Semi-natural forest can be managed as continuous-cover forestry which may not provide large amount of forest products but stores more ecosystem carbon and also provides ecosystem services. If the current Swedish forestry model is continued, the long-term effect will correspond to more than 60 million tonnes of CO_2 emissions reduction annually when carbon stock changes, substitution effects and all emission related to forest management and industrial processes are accounted for. Due to Sweden's large export share of forest based products, the CO_2 emissions reduction effect is larger abroad than within the country. Results also show that the forestry's contribution to reduce carbon emissions could be significantly increased if management of the boreal forest were oriented towards increased production and wood use towards substitution of fossil fuels and energy-intensive construction materials.

Keywords: forest growth; harvest; soil carbon, substitution; carbon dioxide; abroad.