FINNISH FOREST RESEARCH INSTITUTE

EFFECTS OF MANAGEMENT ON STAND LEVEL CARBON STOCKS: A SIMULATION STUDY

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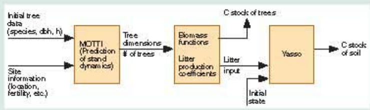

Figure 1. Connection of MOTTI and Yasso for dynamics of stand level carbon stocks.

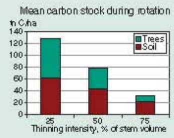

Figure 4. Effect of thinning intensity (three thinnings) on the mean carbon stock during a 100 year rotation in a pine stand on a fresh site in southern Finland analyzed by MOTTI-Yasso.

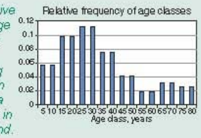

Figure 7. Relative frequency of age classes of pine stands under age 80 growing on fresh sites in Häme-Uusimaa forestry district in southern Finland.

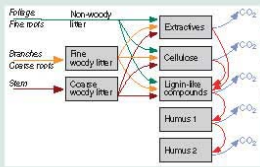

Figure 2. Flow chart of Yasso model. The boxes denote carbon compartments of soil, the arrows carbon fluxes.

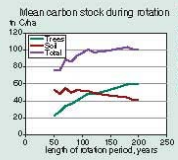

Figure 5. The mean carbon stock of a pine stand in southern Finland on a fresh site as function of rotation lentgth.

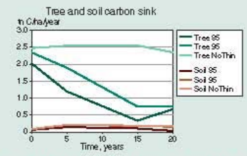

Figure 8. Mean rate of carbon sequestration of pine forest per unit area as a function of time predicted by Motti-Yasso using initial stands with age distribution of Fig. 7. The three management alternatives were: rotation length 85 or 95 years with thinings, and neither thinning nor clear cut: change (increase) in carbon stock of trees (Tree 85, Tree 95, Tree NoThin) and soil (Soil 85, Soil 95 and Soil NoThin).

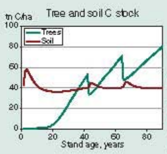

Figure 3. Stocks of carbon in a thinned pine stand in southern Finland simulated by MOTTI-Yasso. Cutting residues from previous rotation were initial litter input.

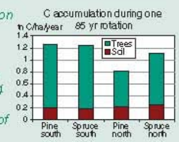

Figure 6. Mean rate accumulation of carbon in thinned pine and spruce stands in 85 years on a fresh site in southern (mean annual temp. 4 C) and northern Finland (mean annual temp. 0.4 C) predicted by MOTTI-Yasso. Soil C concerns that from litter of the present stand.

Background

We have augmented the stand simulator MOTTI with the forest soil carbon model Yasso (Fig. 1). MOTTI employs empirical growth models for the commercial tree species in Finland (the main ones are Scots pine, Norway spruce and birch). The growth models are tree-level, distance-independent, based on extensive data sets, and cover all areas in Finland. Temperature sum and other variables pertaining to geographical location adjust the growth of individual trees to different growing conditions.

Yasso (Fig. 2) takes litter (annual amount, both from trees and understorey vegetation) as input. The parameter values of Yasso (mainly the decomposition parameters) have been adjusted to varying temperature and moisture conditions with litter decomposition data. Yasso uses the chemical composition of litter to divide it to its internal pools of (fractions) of dead organic matter (Fig. 2). This information can be obtained from chemical analyses.

We use tree-level biomass equations for calculation of biomass on the basis tree dimensions that are predicted by MOTTI. Using tree biomass variables we calculate litter input from different tree compartments (e.g. foliage, branches, roots) for Yasso using litter production coefficients. We thus assume that part of the biomasses of the tree compartments turn into litter. We also consider litter from ground vegetation.

As both MOTTI and Yasso and litter production has been adjusted for Finnish conditions, we believe that this hybrid model is a useful tool for analyzing carbon sequestration in Finnish forest stands.

Examples

Thinnigs

Fig. 3 shows a typical course of carbon stocks of trees and soil in a stand thinned according to a commercial schedule simulated by MOTTI-Yasso. The thinning intensity has a clear (and obvious) effect on carbon stocks (Fig. 4). Increasing the length of rotation increases the total carbon stock up to about 100 years in a Scots pine stand (Fig. 5). The effect is coming from increasing tree stock, the soil is showing an opposite trend.

Tree species

Pine and spruce sequester carbon equally in southern Finland; in the north spruce dominates (Fig. 6). Increase of soil C stock is greater in the north due to slower decomposition rate.

Forest

When a forest consisting of Scots pine stands that have the initial age distribution according to Fig. 7 is managed with different alternatives (Fig. 8), the outcome depends in the short term on both the schedule and the initial age distribution. The forest is a sink of carbon with all management alternatives during the first 20 years (Fig. 8); this is because most of the stands will not reach the clear cut age in this period (Fig. 7). Sequestration by the trees is much larger than by soil (Fig. 8). Even if the rotation age is increased by 10 years (85 → 95) the carbon gain decreases during the first 20 years. This is since many stands are coming to thinning stage (Fig. 7). Only abandoning cuttings keeps the C sequestration at the same level. As regards attaining Kyoto targets in the first or later commitment periods, both effects of management on stand level (e.g. Fig. 5) and the initial age distribution of the forest should be considered.

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About Yasso:
www.efi.fi/projects/yasso

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References

MOTTI

Hynynen, J., Ahtikoski, A., Siitonen, J., Sievänen, R. & Liski, J. 2005. Applying the MOTTI simulator to analyse the effect of alternative management schedules on timber and non-timber production. Forest Ecology and Management 207: 5-18.

Matala, J., Hynynen, J., Miina, J., Ojansuu, R., Peltola, H., Sievänen, R., Väisänen, H. & Kellomäki, S. 2003. Comparison of a physiological model and a statistical model for prediction of growth and yield in boreal forests. Ecological Modelling 161(1-2): 95-116.

Yasso

Liski, J., Palosuo, T., Peltoniemi, M. & Sievänen, R., 2005. Carbon and decomposition model Yasso for forest soils. Ecological Modelling (In Press) doi:10.1016/j.ecolmodel.2005.03.005.

Liski, J., Nissinen, A., Erhard, M. & Taskinen, O. 2003. Climatic effects on litter decomposition from arctic tundra to tropical rainforest. Global Change Biology 9(4): 575-584

Palosuo, T., Liski, J.A. Trofymow & B.D. Titus. 2005. Litter decomposition affected by climate and litter quality—Testing the Yasso model with litterbag data from the Canadian intersite decomposition experiment. Ecological Modelling (In Press)

Peltoniemi, M., Mäkipää, R., Liski, J. & Tamminen, P. 2004. Changes in soil carbon with stand age - an evaluation of a modelling method with empirical data. Global Change Biology 10(12): 2078-2091.

www.efi.fi/projects/yasso

Biomass equations

Marklund, L.G., 1988. Biomassfunktioner för tall, gran och björk I Sverige. Report 45. Department of Forest Survey, Swedish University of Agricultural Sciences, 73 pp. (in Swedish).

Laitakari, E., 1935. The root system of birch (Betula verrucosa and odorata). Acta For. Fenn. 41, 216 pp. (in Finnish with English Summary).

Vanninen, P., Ylitalo, H., Sievänen, R., Mäkelä, A., 1996. Effects of age and site quality on the distribution of biomass in Scots pine (Pinus sylvestris L.). Trees 10, 231–238.

Litter production

Lehtonen, A., Sievänen, R., Mäkelä, A., Mäkipää, R., Korhonen, K.T. & Hokkanen, T. 2004. Potential litterfall of Scots pine branches in southern Finland. Ecological Modelling 180(2-3): 305-315.

Muukkonen, P. 2005. Needle biomass turnover rates of Scots pine (Pinus sylvestris L.) derived from the needle-shed dynamics. Trees - Structure and Function 19(3): 273-279.

Muukkonen, P. & Lehtonen. A. 2004. Needle and branch biomass turnover rates of Norway spruce (Picea abies). Canadian Journal of Forest Research 34(12): 2517-2527.

Starr, M., A. Saarsalmi, T. Hokkanen, P. Merila, and H.-S. Helmisaari. 2005. Models of litterfall production for Scots pine (Pinus sylvestris L.) in Finland using stand, site and climate factors. Forest Ecology and Management 205:215.