Short term scientific mission: A Comparison of the available models for cambial growth

COST STSM Reference Number: COST-STSM-FP1106-12413

Period: Feb 11–22, 2013

STSM Applicant: Dr. Liisa Kulmala, Finnish Forest Research Institute (Metla), Finland, liisa.kulmala@metla.fi

Host: Dr. Cyrille Rathgeber, INRA Research Center of Nancy, France

Introduction to the purpose of the STSM

Together with the Finnish Forest Research Institute (Metla), University of Helsinki has developed a dynamic intra-annual process model (CASSIA) for the wood formation of Scots pine. The model will be able to quantify cambial growth and xylogenesis at time scales ranging from days to several years, in a whole-tree carbon balance framework. One specific aim of the model is to predict the effects of changing environment, including prolonged drought periods, on wood formation.

The host institute, Centre INRA de Nancy (France) is well-known and merited in the research of wood formation. At the moment, the research team lead by Dr. Cyrille Rathgeber is constructing a model for the cambial activity. In future, the model will be linked with a model of tree water and sugar transport as well as a stand growth model.

The aim of the STSM to INRA was to exchange ideas and experiences about the modeling approaches, extend the existing data sets used for model building and evaluation to cover wider geographical range, as well as to maintain the working relationship between the two institutes.

Evaluation of CASSIA

Boreal forests typically experience a cold and dark winter and a relatively short summer. Boreal conifer trees regulate and control their biological activity such as growth due to these annual changes in the surroundings. The regulation takes place via several functional substances such as hormones which follow the changes in the environment. In boreal forest, especially temperature is in key role in the annual cycle of the biological action of trees. Thus, the sink demands for the growth of roots, needles, shoots and stem of a Scots pine follow the short- and long-term changes in temperature in the model CASSIA (Carbon allocation sink-source interaction analysis). The cambial growth, for example, begins and ends with certain sums of temperature have accumulated. Nevertheless, the modeled carbon balance of the tree determines whether the sink demand for the growth can be fulfilled or not.

The novel model is developed at the University of Helsinki in a co-operation with Finnish Forest Research Institute. At the moment, the model is parameterized using shoot, needle and diameter growth measurements on a middle-aged Scots pine stand at SMEARII (Hari and Kulmala, 2005) in central

Finland in 2008. Using these parameters together with monitored environmental factors, estimated gross primary production (GPP) and modeled respiration, the model is able to roughly predict the onset and cessation of the growth for different years at the same site. In addition, the model runs for a Scots pine stand in Finnish Lapland revealed that the onset and cessation of growth in Northern Finland have similar relationship to the accumulated temperature as in Southern Finland.

The short term scientific mission provided a chance to evaluate CASSIA using the growth measurements at three mixed conifer sites in north-east France in 2007–2009. These managed sites are located on a hillside app. 750, 600 and 350 m above sea level where the mean temperatures in 2007–2009 were 8.6, 9.1 and 10.3 °C, respectively. The sites consist of mature Scots pine, Norway spruce and silver fir.

We estimated the GPP for these sites by PreLES model (Mäkelä et al. 2008) using measured precipitation, temperature, radiation and air humidity (VPD). For the estimation of maintenance respiration, we needed to calculate biomass especially for needles. The task turned out to be challenging since the studied pines were app. 50 cm in diameter and 30 m in height whereas the available biomass models are usually for smaller Scots pines. At the moment, we use the foliage estimation by Marklund (1988) since the size of the trees used to the model derivation are almost as gigantic as the ones at these French sites. Nevertheless, we are still seeking for other possibilities. For example, the models by Socha and Wezyk (2007) and by Jelonek et al. (2011) will be evaluated.

In the current version of CASSIA, the maintenance respiration is calculated from exponential temperature responses for each tree part. The responses are derived from the continuous measurements of flux components at SMEARII. In Finland, the temperature is generally lower than in France and thus, the estimated summer-time respiration rates in France are mainly extrapolated. In addition, trees have the most active period in Finland in lower temperatures than the trees in France. Thus, the Finnish temperature responses (Q_{10}) are most likely too high for French trees and therefore, the subject requires further literature searches. At the moment, we have decreased the Q_{10} values to result in total respiration that is app. half of the yearly GPP, a proportion that is a typical finding in flux sites.

Using the above modifications, site-specific tree characteristics and environmental factors, the model succeeds to some degree to predict the onset of growth at the topmost French site (Figure 1) even if using the same threshold values of accumulated temperature as in Finland. The cambial growth in France ends months later than in Finland and thus, the model requires higher threshold values of accumulated temperature for growth cessation in France compared to Finland. Using modified parameters, the model succeeded to predict the yearly changes in the onset and cessation of growth at the sites. Nevertheless, the evaluation of the model behavior on cambial growth and re-parameterization is still in progress. In addition, the model structure for the different phases of the xylogenesis requires reformulation based on the obtained results on French sites (Cuny et al. 2013) and discussions during the STSM.

Later, we will also evaluate the model prediction of shoot growth. The model behavior will also be evaluated using the detailed knowledge in cell wall thickness and density in the French tree ring profiles.

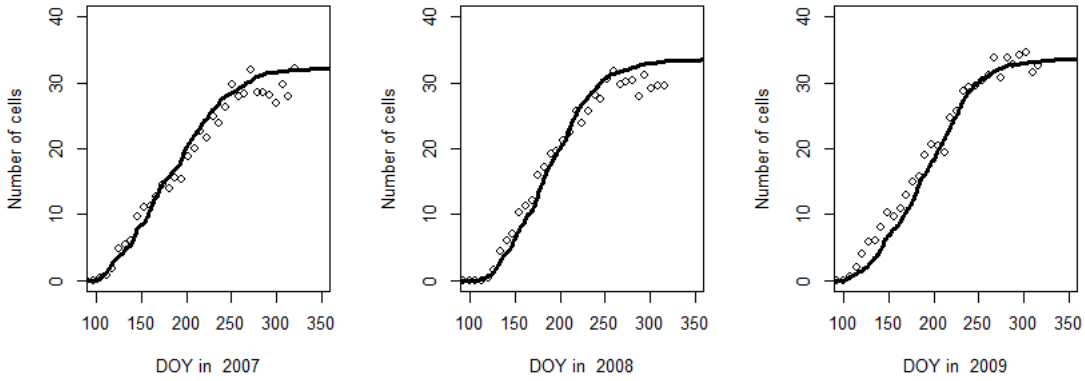

Figure 1: The measured (circles) and modeled (lines) total number of cells in a radial cell row at the highest French site (750 m a.s.l.) in 2007, 2008 and 2009

Other main results of the mission

Turgor pressure and cambial growth

The initial idea at University of Helsinki and Metla was to include turgor pressure as the force for cell elongation in CASSIA in order to study more closely the effects of prolonged droughts and the internal water balance on the tree growth. During the STSM, the subject was widely discussed and the assumptions were evaluated. As a result, we will build a common model for the division, enlargement and wall forming of cells using turgor pressure as the driving factor for the cell enlargement. This will lead to a common publication in the end of the year 2013.

Data-processing and analysis with CAVIAR

The methods for producing microcore data varies among study or groups and, therefore, most studies are difficult to compare with each other. Cyrille Rathgeber and his group has developed CAVIAR package for R for unifying the definitions of the main phenological events i.e. the onset and cessation of the cell enlargement, cell wall formation, and mature stages. During the STSM Cyrille Rathgeber demonstrated the use of CAVIAR package to analyze microcore measurements for later co-operation and comparability of the results at both institutes.

Xylogenesis and environmental factors

The research group at the host institute is working on a manuscript that observes the relationship between carbon flows and carbon allocation and also the connections between rates of different stages of xylogenesis and environmental factors. During the STSM, we discussed on the subject and decided to later work on it together for a join publication.

Contribution to the Action aims

Currently, University of Helsinki, Metla, and INRA Nancy develop models for cambial growth. The model at INRA is theoretical detailed view on xylogenesis whereas CASSIA predicts the growth in the framework of the carbon balance of the whole tree. The mission enabled evaluation of CASSIA in extend temperature environment using the local measurements. Yet, the available models are not in a stage where they can be truly compared and verified but the mission allowed for the first discussions on the strengths and weaknesses of the models in addition to the possibility to create a common examination on the role of turgor pressure on cell enlargement. The achieved contacts between the institutions facilitate future co-operation in model verification and comparison and will enable 2 common publications already in 2013.

This report may be posted on the Action website.

Confirmation by the host institution of the successful execution of the STSM can be found on the last page of the report.

References

Cuny, H., Rathgeber, C., Senga Kiesse T., Hartmann F., Barbeito, I., Fournier, M. (2013) Generalized additive models reveal the intrinsic complexity of wood formation dynamics (accepted Journal of Experimental Botany)

Hari, P. & Kulmala, M. (2005) Station for Measuring Ecosystem–Atmosphere Relations (SMEAR II). Boreal Env. Res. 10: 315–322

Mäkelä A, Pulkkinen M, Kolari P, Lagergren F, Berbigier P, Lindroth A, Loustau D, Nikinmaa E, Vesala T, Hari P. (2008). Developing an empirical model of stand GPP with the LUE approach: analysis of eddy covariance data at five contrasting conifer sites in Europe. Global Change Biology 14: 92–108.

Marklund, L.G. (1988). Biomass functions for pine, spruce and birch in Sweden. Dep. of Forest Surveying, Swedish Univ. of Agric. Sciences, Umeå, Report 45, 73 pp.

Socha J., Wężyk P. (2007). Allometric equations for estimating the foliage biomass of Scots pine. European Journal of Forest Research. 126: 263–270.

Jelonek T., Pazdrowski W., Walkowiak R., Arasimowicz-Jelonek M., Tomczak A. (2011) Allometric models for foliage biomass in Scots pine. Polish J. of Environ. Stud. 20: 355–364.

MINISTERE DE L'AGRICULTURE ET DE LA PECHE
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR ET DE LA RECHERCHE

Cyrille Rathgeber
Equipe croissance, production et qualité des bois
Laboratoire d'Etude des Ressources FOrêt-Bois
Unité Mixte de Recherches INRA-ENGREF 1092
Centre INRA de Nancy - Lorraine
54 280, Champenoux

Champenoux, 20 March 2013

Letter of Short Term Scientific Mission (STSM) execution for Liisa Kulmala

I – undersigned Cyrille Rathgeber – have been very happy to host Liisa Kulmala for two weeks (from the 11/02/13 to the 23/02/13) at the LERFoB (INRA Research Center of Nancy-Lorraine, France) in order to work with her on intra-annual wood formation modelling.
Liisa's STSM was successfully executed. I am very happy with the work she did during her stay, and I found the report very informative. We plan to write to joined publications on the subject and we are currently discussing further collaborations.

Sincerely,

Cyrille Rathgeber
Laboratory of Forest and Wood Ressource Studies (LERFoB)
INRA Research Center of Nancy-Lorraine
F-54280 Champenoux, France
Tel.: +33 3 83 39 40 64
Fax : +33 3 83 39 40 69
Email : cyrille.rathgeber@nancy.inra.fr