MS-E2177 - Seminar on Case Studies in Operations Research

Team UPM Carbon

System Dynamics Modelling of Forests as Carbon Sources and Sinks

Interim Report

Cosmo Jenytin
Sonja Kokkonen
Roni Sihvonen (Project Manager)
Joanna Simms

April 17, 2020

Aalto University
School of Science

Project Status

We started our work on the model by creating our "First proof of concept" (first PoC) that demonstrated the ability of our chosen software, Simulink. The first PoC was a simple model, with only the atmosphere and forest as CO2 stocks and with forest industry products' production and waste handling (i.e. burning). The model mostly had dummy data and parameter values, but the forest growth dynamics were somewhat grounded in reality and had parameter values based on literature.

The CO2 sequestering in Finnish forests was even in this first, rudimentary model modeled according to the biological cycle of CO2 in the forest biosphere, with different types of respiration and disturbances in the forest taken into account. On the other hand, the forest's annual growth was static.

We continued building upon this first PoC to create our "Improved PoC" by adding more stocks and dynamics: we added recycling, to allow products to go back into the supply by being recycled; we added a dynamic demand that maximizes the production of a forest based product type, but if the demand is not met, increases the demand of a (non-renewable) substitute product; and lastly added the production, recycling, and waste handling of substitute products. A crucial part of the model in the making is modelling the growth of forests while taking into account their age structure and logging. There are lots of growth functions that could be used and historical data from Finnish forests, but modelling the growth of all forests is complex and needs simplifications.

Now we are starting to work on "Building the simulation tool", which in our case means creating a user-friendly graphical user interface (GUI), in a best case scenario a compiled executable MATLAB/Simulink application. This tool is aimed at e.g. customers of UPM who want to explore the climate impact of using their forest for forestry products instead of letting the existing demand be fulfilled by non-renewable substitutes; this means the GUI/application should be simple enough for a layman to use. In addition, we will also try to implement an "advanced user mode", where one can see more of the inner workings of the model, e.g. by showing and possibly allowing the editing of most or all the parameters and variables which were initialised based on our assumptions and literature sources.

Our most important next step for the model is adding more realism to it through more realistic parameters and data. In terms of the data collection for this model, we have consulted a lot of different sources to achieve a good understanding and to produce a nearly complete set of data for a successful

model. Although the varied sources gives room for error, especially with company secrecy about the manufacturing cost in atmospheric CO2, it also permits constant validation of the data we are gathering to produce the most accurate results that are possible with open data. By choosing to focus on the Finnish forest industry, rather than the worldwide industry, we can set a clearer picture from "cradle to cradle" or "cradle to grave" data from overlaps between Luke, VTT, Tilastokeskus and UPM open data. In addition, our UPM mentors are working with us to provide us with sensible end landscapes and predictions. When considering the data it is important to remember that the model is intended primarily as a learning tool instead of a scientific instrument, meaning that only aggregate data is required for the success of the project.

Life-cycle CO2 emissions have been calculated for the stages of a products life which are considered as parameters in our model (growing of trees, manufacture and recycling). Currently we are considering the demands, production shares and recycling in more detail. These are the parameters which will ultimately define the business competitiveness of each product against each other, after the affect of the CO2 sequestered by trees. Towards this end, we have historical production, recycling and consumption data for the last 60 years and are using time-series analysis and nonlinear-regression models to analyse patterns. This will provide a better picture of the next century, as well as adding an element of uncertainty that can later be used in sensitivity analysis. A portion of the historical data will also be used to test the model for accuracy.

Overall, to facilitate the development of our model, we have had regular meetings with our client UPM, with most of the project organisation from UPM present during each meeting. We have received support and guidance from UPM, but right from the start it has been clear that the project goals are developing together with the model and project, and there can be no definitive requirements on the model or answers to many questions. Thus we have worked iteratively, with each version giving more insights for the client and allowing them to come up with new interesting ideas and define a clearer direction for the project. The approach to this project is iterative not just in terms of modelling, but also in revealing what new data parameters need to be added to the model. This continuous process of incremental data analysis gives the model a strong theoretical basis as we are always referring and responding to the relevant literature.

Changes to the initial project plan

All the completed tasks were taken in time according to our initial project schedule. However, the schedule was not very detailed making it flexible. The more detailed schedule for the remainder of the project is shown in Figure 1.

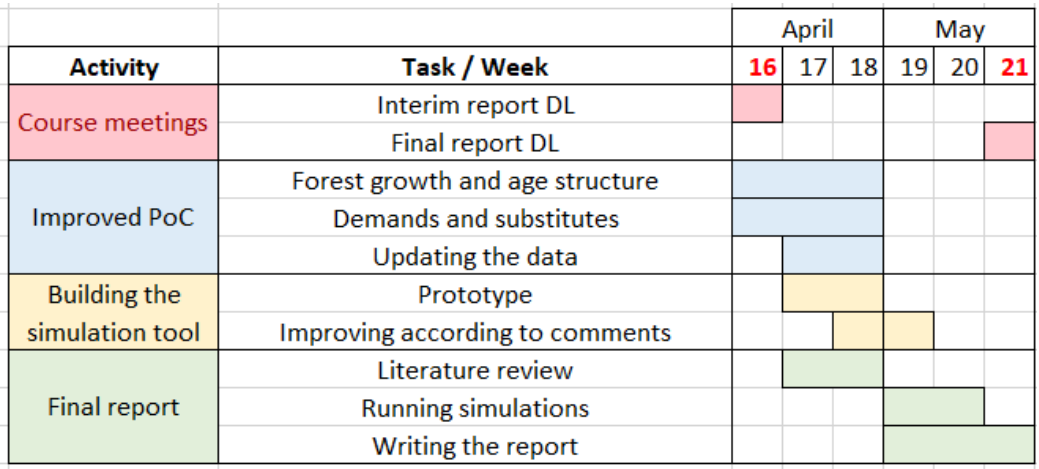

Figure 1: Gantt chart of the schedule for the remainder of the project.

The main tasks have not changed from the project plan. While the project has progressed, it has been possible to list subtasks and schedule them in more detail. As for the programming languages and the final product, one of our initial goals was to change to an open source option to make it easier for everyone to access. However, this is not anymore in the scope of the project, as we found Simulink satisfactory and changing to an open source option would require too much time.

Risks

There have been few changes to the original risk assessment. However, the coronavirus pandemic has changed ways of working and caused some additional risks. The updated risks are listed in Table 1.

Table 1: Updated table of risks.

Risk	**Likelihood**	**Effect**	**Impact**	**How to avoid**
Overly complex model	Medium	Workload too large, lack of motivation & time, mistakes	High	Sufficient project plan & realistic schedule
Overly simple model	Low	Model is not useful	Low	Research, managing expectations, allow future developments
Unreliable or non-realistic model	Medium	Overconfidence, false conclusions	High	Sensitivity analysis, critical thinking, avoid oversimplifications, use reliable data
Incomplete data	High	Difficulties in creating the model, mistakes	Medium	Research, scoping
Insufficient team work, team member inactive	Low	Uneven workload, inefficiency, project delayed	Medium	Good communication, project managing
Risks related to the coronavirus	Medium	Communication difficulties, technical issues with Internet and tools	Medium	Maintaining good communication, finding alternatives and backup plans to overcome technical problems

The updated table of risks considers the coronavirus. Because many people have switched into remote working, including the entire Aalto university, there are new changes and risks related to the situation. Since all communication takes place remotely, the quality of communication is inevitably weaker. In addition, not being able to use the university resources can increase the risk of technical problems, such as a poor Internet connection or difficulties with tools and applications. We have already encountered some of these difficulties. However, having plenty of alternative tools for working and communicating remotely has helped to change the working methods with

only few problems.

As for model-related risks, overly complex model, non-realistic model and incomplete data are the most current risks at this stage of the project. Modelling the growth of Finnish forests can be very complex, and simplifying it can make then model non-realistic. Even though plenty of data can be and has been found, converting it into a form that fits the model can lead to rounding inaccuracies and mistakes. As the development of the model progresses, it is important to keep in mind what dynamics are relevant and which are not. When we are getting closer to the end of the project, time management becomes particularly important. However, the model is in a good phase already, which indicates that our risk management has been sufficient to date.