Reporting the overall climate impact of a forestry corporation - the case of SCA

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February 2019, Final version

This paper was commissioned by SCA and has been subjected to external peer-review.

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Abstract

Forestry and forest products are potentially climate-positive, i.e. can reduce greenhouse gases in the atmosphere. Forestry corporations can therefore combine profitable operations with contributions to climate change mitigation. Achieving this requires clear understanding of carbon flows in forest management, product value chains, energy consumption and production, and product substitution effects (replacing materials and energy with higher climate footprints). Reporting corporate climate impact on an annual basis would provide awareness to stakeholders and facilitate improvements towards enhanced climate benefits.

This paper defines a “forest system” model for calculating the annual overall climate impact of a forestry corporation, using SCA as a case. The model includes three main parameters – forest, value chains and substitution effects. For 2017, the total climate impact of SCA was a reduction of greenhouse gases in the atmosphere corresponding to 8.5 Mt CO_2e. This was a result of carbon stock increase in the forest, a high proportion of bioenergy in industry processes and a substantial substitution effect from delivered wood products, fibre-based products and bioenergy.

1. Introduction

Forestry and forest products are potentially climate-positive, i.e. can reduce greenhouse gases in the atmosphere. Forestry corporations can therefore combine profitable operations with contributions to climate change mitigation. Achieving this requires clear understanding of carbon flows in forest management, product value chains, energy consumption and production, and product substitution effects.

SCA is a Swedish publicly listed forest products company with a net sales of SEK 16.7bn (2017) and 2.6 Mha of forest holdings. Annual forest harvest and additional purchase of timber amount to approximately 10 Mm^3 of renewable raw material which is processed into wood, pulp, paper and bioenergy products. SCA plans to disclose its overall impact on the global climate as one of its key performance indicators within the company’s overall sustainability framework. Reporting corporate climate impact on an annual basis would provide awareness to stakeholders and facilitate improvements towards enhanced climate benefits.

The aim is to calculate present-year climate impact for inclusion in the company’s annual reports. The calculations should be based on the scientific literature and represent current knowledge and understanding of the climate impacts of forest management, forest industry and forest products. They should also be transparent in terms of methodology and input data. Further, and importantly, the approach and results should be presented in ways suitable for communicating to a wider audience.

The following research is then required:

1. Defining a “forest system” model that describe the overall climate impact of a forestry corporation

2. Calculating the individual factors in this model on an annual basis

This paper:
- proposes, drawing from scientific literature, a generic forest system model with respect to climate impact
- reviews results and experiences from studies that have applied a forest system model
- specifically investigates how the substitution effect of forest products has been determined and proposes a conservative approach
- applies the model for SCAs operations in 2017 to calculate the climate impact of the company

2. A forest system model for monitoring overall climate impact

Several studies have analysed the climate impact of the "forest system", defined as the totality of the concerned forest, the management of this forest, the harvesting and processing of forest biomass into forest products and the substitution effect of these products when they replace other products. (Braun et al., 2016; Gustavsson et al., 2017; Kilpeläinen et al., 2016; Knauf et al., 2015; Leskinen et al., 2018; Lundmark et al., 2014; Rüter et al., 2016; Sjolie, Hanne. et al., 2011; Smyth et al., 2017; Soimakallio, S. et al., 2016; Taverna et al., 2007). A common purpose of these studies has been to develop a knowledge base for comparing long-term policy options for forest management, forest harvesting and forest products use in relation to climate change. Such analyses require a different and wider system boundary compared with the United Nations' Framework Convention on Climate Change (UNFCCC) specification of the "forestry sector".

Within the UNFCCC, the "forestry sector" is defined by the concept "Land Use, Land Use Change and Forestry" (LULUCF) (UNFCCC, 2018a), which is also a section of the national greenhouse gas inventory reporting (Naturvårdsverket, 2017; UNFCCC, 2018b). The LULUCF reporting is limited to carbon storage and anthropogenically caused changes in this carbon storage. This is reported for land use categories ("carbon pools"). In addition, there is a pool for Harvested Wood Products (HWP), i.e. carbon that remains in wood products after harvest, which can constitute a substantial carbon sink (Naturvårdsverket, 2017).

LULUCF reporting on changes in carbon storage does not include all carbon sinks from forest growth as part of this growth is considered non-anthropogenic (although the Swedish reports do include all measured forest growth (Naturvårdsverket, 2017)). Emissions resulting from the conversion of forests to other land use sectors (deforestation) are considered to be caused within the forestry sector. One consequence of the way the forestry sector and its carbon fluxes is defined by the UNFCCC is that the sector is globally regarded a major source of emissions, i.e. a big part of the climate change problem. For example, "Forestry and other land use cause 11% of total emissions" according to the Intergovernmental Panel on Climate Change (IPCC, 2014, p.45).

Further, LULUCF reporting does not take into account emissions caused by forest industry processes, nor does it account for the positive effects as forest products are used instead of products with a larger climate footprint. From a UNFCCC perspective, these other climate impacts are accounted for, but within different sectors of the national greenhouse gas inventory reporting.

Obviously, this causes an incomplete and inaccurate representation in UNFCCC reports of the wider climate impact and opportunities of forestry and forest products. When policy is informed about forestry sector emissions and removals as it is defined by UNFCCC, significant climate-positive results are indeed revealed for Nordic countries – results of active forest management over the past 100 years to ensure a high level of wood supply to the forest industry – see e.g. Iordan et al. (2018). Sweden reports net sinks from forest (c. 40 Mt CO_2e/yr) and HWP (c. 5 Mt CO_2e/yr) (Naturvårdsverket, 2017).

However, as the additional positive effects of forest products substitution are omitted from greenhouse gas inventory reporting, there is a tendency to focus on the forest carbon stock as such, rather than the overall dynamic potential to mitigate climate change through the "forest system" including substitution effects, as discussed by e.g. Seppälä et al. (2015). This can lead to misinformed policy as some interest groups and parts of academia formulate arguments to say that it is better for the climate to leave the forest as a carbon storage than to practise forestry, rendering a polarized debate that questions active forest management (e.g. KSLA, 2018). This calls for a systems perspective to better understand the overall impact of forests, forestry and forest products on the global climate.

Studies of the "forest system" aimed at policy options for forest management and the subsequent production and utilization of forest products, must then be organized in a way that cuts across the proprietary categories and sectors as defined by the UNFCCC. Several studies have taken this approach (Braun et al., 2016; Gustavsson et al., 2017; Knauf et al., 2015; Lundmark et al., 2014; Rüter et al., 2016; Sjolie, Hanne. et al., 2011; Smyth et al., 2017; Taverna et al., 2007), see also review in the next section.

Building on these a generic model for climate impact of a forestry corporation can be defined as: (see also Figure 1)

(1) $FSCI_y = \Delta FCS_{(y-1,\, y)} - VCE_y + PSE_y$

where:

$FSCI_y$ = Forest System Climate Impact in year *y* [Mt CO_2e]
A positive number means that there is a net removal of greenhouse gases from the atmosphere

$\Delta FCS_{(y,\, y-1)}$ = Change in Forest Carbon Stock from year *y-1* to year *y* [Mt CO_2e]
Expresses the net change in forest carbon stock on company-owned land taking into account biological growth, natural losses, pre-commercial thinning and harvests during the year in question. This is normally measured as part of the continuous monitoring of forest resources for determining forest management goals and sustainable harvesting levels. Results are normally made available on an annual basis.

VCE_y = Value Chain Emissions in year *y* [Mt CO_2e]
Fossil emissions caused by the company's operations throughout the value chain (including, *inter alia,* forest operations, transport and industry processes), noting that large quantities of renewable energy are both produced and used within the forest industry processes, which means that fossil energy use is only a fraction of total energy use. The emissions should include all three "scopes" defined in standards for corporate GHG/emissions reporting (GRI, 2016). The fossil emissions are normally measured as part of corporate monitoring, accounting and reporting and made available on an annual basis.

PSE_y = Products Substitution Effect in year *y* [Mt CO_2e]
Represents avoided fossil emissions when forest products are used for, e.g., construction, packaging or energy supply instead of products with a larger climate footprint. The substitution effect is here calculated for products sold in year *y* although the actual avoided emission may occur at several different points in time. It is unfeasible to directly measure the substitution effect due to complexities and context-specific situations. Instead, approximations must be made, based on analytical research results. This paper reviews research in this field and proposes a conservative approach for the factor.

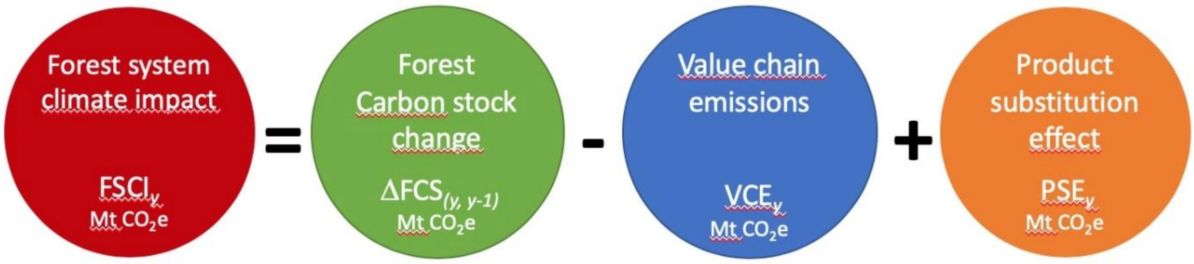

Figure 1. Model used for calculating climate impact of a forestry corporation

The boundary conditions of the model in (1) include, *inter alia,* the following considerations*:*

- The model is defined as a current-year indicator in contrast to multi-year scenarios in most referred studies, in which long-term climate impact of optional forest management approaches were the main focus of the analyses. The scope of climate impact factors used is, however, similar
- The temporary carbon storage in HWP is not considered in the model, as the model does not have a time dimension. From a LULUCF methodology perspective, this is similar to assuming instant oxidation of the products and return of the carbon content to the atmosphere without accounting for the climate benefits of keeping the carbon locked into the products for some time. This corresponds with the approach in the current model to calculate products substitution effect at present time, even if the substitution effects are realized at different points in the future, e.g. when paper products are eventually burned for energy. An alternative approach would be to attempt to account for time dynamics of both HWP storage and the substitution effects, but this was considered unfeasible and unnecessarily detailed for the purpose of this study

- The model focuses on the climate impact of regular value chains for a forestry corporation, i.e. sustainable supply of wood/fibre from managed forests and the processing of wood/fibre into forest products and bioenergy. The model includes fresh fibre-based products following innovation and development, but does not include additional, non-fibre based, business opportunities and developments, such as production of wind energy on land owned by the company. If non-fibre-based business such as wind energy were included, the substitution of fossil energy would increase and improve the overall climate-performance of the company

- Large quantities of wood and fibre may be purchased from other land owners to complement supply from own forests. The climate impact of forest management on this other land is not included. By providing a market for harvested timber in the region, the company creates incentives for other land owners for investing in forest management, with possible additional climate benefits

- Forest carbon stock is calculated by measuring above-ground biomass and extrapolating to include below-ground material based on research findings (Lehtonen et al., 2004; SLU, 2007)

3. Analyses of climate impact of the "forest system"

Studies that have analysed and estimated the overall climate impact of the forest system have focused on administrative geographies, usually countries (Table 1). This appears to be because agreements for emissions accounting and reduction are between nation states and the UNFCCC. Consequently, the design of sector policies that address climate commitments are underway and there is a demand for knowledge to underpin such policies.

The studies listed in Table 1 have all built on long term scenario developments, emphasizing the need to evaluate policy options for forest management, given the inherent multi-decadal and large-area perspectives of the sector. The inclusion of value chains and substitution effects of forest products are made to provide a complete systems analysis, although the conclusions are mainly brought back to how the standing forests should be managed and harvested, with less focus on opportunities to enhance climate benefits later in the value chains.

Conclusions are unanimous in that the forest system provides very large climate benefits. Active forest management with higher levels of harvest are considered most beneficial to the climate over the long term, mainly due to products substitution effects. In the short term, the studies agree on a theoretically higher climate benefit if forest industry is shut down and forests not harvested. However, the sink in forests will then be gradually reduced to zero as natural losses increase and growth decrease in such unmanaged forests, and the forgone substitution effects means that unmanaged forests over the longer term provide considerably less climate benefits.

Table 1. Geographic extent of forest system studies and key results

Reference	Geography	Main focus and results
Knauf et al., 2015	North Rhine Westphalia, Germany	Analyses “the overall contribution to climate protection made by the forest management and wood utilization through CO2-emissions reduction” Concludes “..the net climate protection function of scenarios with varying levels of wood usage is higher than in scenarios without any wood usage.” and also “The short-term evaluation of subsystems can be misleading, rendering long-term evaluations (until 2100, or even longer) more effective. This is also consistent with the inherently long-term perspective of forest management decisions and measures.”
Lundmark et al., 2014	Sweden	Focus on forest management strategies, with LCA perspective on forest products. Main conclusion: “On average about 470 kg of carbon dioxide emissions are avoided for each cubic meter of biomass harvested, after accounting for carbon stock changes, substitution effects and all emissions related to forest management and industrial processes.”
Braun et al., 2016	Austria	“The emissions saved through building up a carbon stock from harvested wood products and through emissions substitution can be as high as »20 years of total annual Austrian emissions in 90 years.”
Rüter et al., 2016	European Union	Analyses ”..carbon sequestration and storage in EU forests, carbon storage in harvested wood products in the EU, substitution of wood products for functionally equivalent materials and substitution of wood for other sources of energy, and displacement of emissions from forests outside the EU”. Conclusion #10: “An optimum combination of the forest protection, cascade and substitution approaches outlined in scenarios II-V, coupled with further progress in energy efficiency and renewable energies (…) might yield additional GHG savings in the 2020-2030 period, and would continue to do so for decades, with sustainable development co-benefits.
Taverna et al., 2007	Switzerland	“The Swiss forestry and timber sector contributes to the reduction of the greenhouse gas effect. This is achieved through the absorption of CO2 in the forest and through the use of wood in wood products and as an energy source.”
Tromborg, E. et al., 2011	Norway	Focus on domestic forest management strategies. Conclusion: overall climate-positive contributions of forestry including substitution effects.
Chen et al., 2018	Ontario, Canada (case study)	LCA of forest products from harvest/forest management to substitution effects. Conclusion: “..harvesting sustainably managed forests in Canada to produce long-lived solid HWP can significantly contribute to GHG mitigation”
Soimakallio, et al., 2016	Finland	Long term scenarios for forest management and products substitution. Main conclusion: Large substitution effects, but lower total climate benefit as a result of long-term reduction of forest carbon stock.

4. Substitution effects of forest products - considerations and numbers

The literature is unanimous in that forest products have a positive climate impact when they are used instead of material such as steel, aluminium, concrete or plastics as these have a higher footprint of fossil emissions. Similarly, forest bioenergy has a positive climate impact when replacing fossil energy from coal, oil or natural gas (Gustavsson et al., 2007, 2006; Gustavsson and Sathre, 2011; Kilpeläinen et al., 2016; Knauf et al., 2015; Leskinen et al., 2018; Perez-Garcia et al., 2007; Petersen and Solberg, 2005; Pingoud et al., 2010; Sathre and O'Connor, 2010; Sjolie, Hanne. et al., 2011; Smyth et al., 2017; Taverna et al., 2007).

Bioenergy has been a controversial theme in politics. Large scale subsidy schemes, that distort markets for land-based products, and use of bioenergy at low conversion rates, such as replacing fossil coal for electricity production, have sometimes been heavily criticized (The Economist, 2013). In some analyses, bioenergy has been considered to have a negative substitution effect, i.e. causing more climate change than fossil fuels (Brack, 2017). Aside of the political perspectives, it appears as these analyses have been based on narrow perspectives that do not incorporate the wider and long-term aspects of forest management or the much higher conversion rates in modern bioenergy production.

As mentioned above, substitution effects are not recognized under the forestry sector in greenhouse gas inventory reports, but instead appear indirectly within the energy sector as lower levels of fossil fuel emissions than would otherwise be the case (as noted by e.g. Knauf et al., 2015). Subsequently, there is no internationally agreed methodology for calculating the substitution effect for forest products. Instead, conversion factors need to be developed based on existing research.

The literature provides a variety of approaches and results for a wide range of forest products. Key variations between studies that need to be considered include:

- Whether emissions caused in the value chain are included or not. In some studies (Lundmark et al., 2014; Sathre and O'Connor, 2010; Soimakallio, S. et al., 2016), also changes in the forest stock are included in the overall substitution effect
- Large variations for specific products occur depending on assumptions of which material or energy source is being substituted. Most studies apply a basket of products and a basket of the materials/energy sources they replace. Results are presented as ranges across the basket or as weighted averages
- For substitution effects that are realised in the future, some studies include all substitution effects throughout the lifetime of the product, while some (e.g. Smyth et al., 2017) do not
- Cascading effects of substitution, i.e. when new substitution occurs after recycling of the first order product, are calculated in different ways
- The measurement unit for substitution effect is different between studies which can make comparisons difficult

For the present study, using the model in equation (1) the following conditions apply:

- Neither forest stock change or value chain emissions should be included in the substitution effect ratio, as per equation (1) where these are accounted for separately
- No further calibration is made between past studies as to the fossil-based materials/energy that the substitution is related to. In other words, the baskets of fossil-based materials/energy in these studies are considered sufficiently accurate for the current analysis
- The model (Equation (1)) is designed for current year reporting. For products sold in the current year, substitution effects are assumed to occur in the same year even if the technical substitutions happen at different points in time during the lifetime, recycling and end-use of the product. This is to emphasize a long-term systems perspective and to avoid overly complicated modelling
- The measurement unit used for the "Substitution Effect Ratio" (SER) is $tC_{fossil}/ tC_{forestproduct}$ for each product, expressing the relative displacement of fossil carbon emissions per unit of carbon content in the forest product. The SER can then be applied to the quantities of product outputs to determine the overall Products Substitution Effect as per Equation (2)

(2) $PSE_y = \sum_{p=1}^{n} SER_p \, Q_{p,y}$

where:

- PSE_y = total Products Substitution Effect for year *y* as per Equation (1), [Mt CO_2e]
- $p_{(1..n)}$ = the set of product categories considered, in this study three items (see below)
- SER_p = Substitution Effect Ratio for product category *p*, [$tC_{fossil}/ tC_{forestproduct}$]
- $Q_{p,y}$ = Quantity sold of product category *p* in year *y* expressed by converting the carbon content to CO_2 equivalents, [Mt CO_2e]

For the current application, products have been grouped into three categories:

- Bioenergy
- Pulp and paper products
- Solid-wood products

While a much finer resolution of product types would be possible, it is not obvious that this would benefit the accuracy or understanding of the overall climate impact model. With a detailed specification of current products, the model could also become more company- and time-specific than desired, making comparisons and further development more challenging.

For each of the three product categories, a conservative substitution effect factor is determined in the following, based on literature (Table 2).

Table 2. Substitution Effect Ratio [tC_{fossil}/ $tC_{forestproduct}$] for Bioenergy, Pulp & paper products and Solid wood products from the literature. Note that factors marked with yellow are not directly compatible with the model proposed in this paper as one or two other model factors are included into integrated estimates

BIOENERGY

Reference	Geography	Substitution effect ratio	Other climate impact factors included		Note
		tC/tC	Change in forest carbon stock (ΔFCS)	Value chain emissions (VCE)	
Knauf et al., 2015	North Rhine Westphalia	0.67	no	no	
Taverna et al., 2007	Switzerland	0.65	no	no	converted from 0.60 tCO_2e/m^3
Rüter et al., 2016	EU	0.70-0.83	no	no	converted from 68-81 gCO_2e/MJ
Soimakallio et al., 2016	Finland	0.80	no	no	
Smyth et al., 2017	Canada	0.47-0.89	no	yes	
Lundmark et al., 2014	Sweden	0.52	yes	yes	average across categories, converted from 0.466 tCO_2e/m^3
Braun et al., 2016	Austria	0.71	yes	yes	average across categories, converted from 0.64 tCO_2e/m^3

PULP AND PAPER PRODUCTS

Reference	Geography	Substitution effect ratio	Other climate impact factors included		Note
		tC/tC	Change in forest carbon stock (ΔFCS)	Value chain emissions (VCE)	
Knauf et al., 2015	North Rhine Westphalia	0.57	no	no	only residual bioenergy included
Soimakallio, S. et al., 2016	Finland	0.8-1.4	no	no	
Lundmark et al., 2014	Sweden	0.52	yes	yes	average across categories, converted from 0.466 tCO_2e/m^3
Braun et al., 2016	Austria	0.71	yes	yes	average across categories, converted from 0.64 tCO_2e/m^3

SOLID WOOD PRODUCTS

Reference	Geography	Substitution effect ratio	Other climate impact factors included		n products considered	Note
		tC/tC	Change in forest carbon stock (ΔFCS)	Value chain emissions (VCE)		
Knauf et al., 2015	North Rhine Westphalia	1.10-2.4 (1.5 used)	no	no	16	
Chen et al., 2018	Canada	2.43	no	no	15	converted from 8.91 tCO_2e/tC
Rüter et al., 2016	EU	ca 1.7	no	no	20	
Soimakallio, S. et al., 2016	Finland	1.30	no	no	1	
Taverna et al., 2007	Switzerland	0.78	no	yes	15	converted from 0.70 tCO_2e/m^3
Smyth et al., 2017	Canada	0.45-0.54	no	yes	6	does not include cascading substitution
Lundmark et al., 2014	Sweden	0.52	yes	yes		average across categories, converted from 0.466 tCO_2e/m^3
Braun et al., 2016	Austria	0.71	yes	yes		average across categories, converted from 0.64 tCO_2e/m^3
Sathre and O'Connor, 2010	meta	2.10	yes	yes	40	forest dynamics included in most cases

Bioenergy

Available research presents fairly similar number for the substitution factor of bioenergy. Variations depend on different levels of conversion efficiency in bioenergy production and different assumptions on the mix of fossil fuel it replaces.

Studies that have included either forest carbon stock changes or emissions in the value chain are not directly compatible with the model proposed in Equation (1) as climate impacts would then be double-counted. The average Substitution Effect Ratio between the four compatible studies is 0.72 tC/tC for bioenergy.

As a result, the Substitution Effect Ratio (SER) for bioenergy is assumed to be 0.7 tC/tC for the purposes of this study.

Pulp and paper products

Only a few studies have attempted to estimate substitution factors for paper and packaging products. While it is clear that there are substitution effects with e.g. plastic-based products, the available research does not offer a clear picture of the rates. Instead the proxy of energy end-use has been used as most of the material is eventually recycled for bioenergy production, noting that recycling levels vary considerably across the geographic regions where SCA's pulp and paper material are eventually used. However, as substitution factors for paper/packaging products are all but missing, a conservative approach would be to use the same substitution effect as for bioenergy as a minimum level for all pulp and paper products.

As a result, the Substitution Effect Ratio (SER) for pulp and paper products is assumed to be 0.7 tC/tC for the purposes of this study.

Solid wood products

The variation between studies of the substitution factors for solid wood products is larger than for bioenergy and pulp/paper products. This is likely because the range of products included also varies between studies, as do assumptions on the use and substitution effects particularly for the construction of buildings. As for bioenergy and pulp/paper products, studies that have included forest carbon stock changes or value chain emissions are not directly compatible with the proposed model. Among the remaining four studies (Table 2), there is a reasonable correspondence with an average Substitution Effect Ratio of 1.73 tC/tC.

It is important to note that this is a one-time Substitution Effect Ratio of wood as a construction material. It does not include cascading substitution effects when the wood is reused, nor does it include the substitution effect from bioenergy produced at the end-of-life of the wood material.

As a result, the Substitution Effect Ratio for solid wood products is set conservatively to 1.5 tC/tC for the purposes of this study.

Leskinen et al. (2018) presents a recent review of 51 analyses of substitution, corresponding well to the studies included in this paper. One conclusion, similar to this paper, is that the variety in system boundaries and assumptions is large, resulting in wide ranges of estimated substitution effects. They also note that a focus has so far been on wood in construction, with less emphasis on emerging products such as textiles. Their overall average substitution rate is stated at 1.2 tC/tC, but this includes some pulp and paper products and contrary to the current model, this includes fossil emissions in the value-chain as well as end-of-life benefits. For wood products a range of 1.3-1.6 tC/tC is given, which provides some support for the above proposed 1.5 tC/tC.

5. Climate impact of SCA in 2017

Using the above parameters, the "forest system" model can be applied to SCA to estimate the overall climate impact of the company in a given year. Calculations have been made for year 2017 (Figure 2). Data have been drawn from SCAs annual report (SCA, 2017) and corporate management information systems.

Forest carbon stock and material supply

By the end of 2016, SCAs forest had an aboveground stock of 232 Mm^3fo. In 2017 SCAs forest had a biological growth of 9.5 Mm^3fo (tree stem biomass). Out of this, 5.2 Mm^3fo was harvested, 1.3 Mm^3fo lost from natural losses and pre-commercial thinnings leaving 3.0 Mm^3fo of the annual growth in the forest, corresponding to a total net capture of 4.0 Mt CO_2e from the atmosphere (change in Forest Carbon Stock, ΔFCS).

Timber purchases for supply to the industry amounted to 4.2 Mm^3sub. Recycled forest fibre products and other residual biomass (e.g. externally sourced bark) provided an additional 0.3 Mt dry biomass of material supply. It is important to avoid double-counting of the substitution effect from recycled materials. For the current calculation, the recycled material is offset against the higher level of internal use of bioenergy, i.e. from a model perspective the recycled material does not generate another round of substitution effect.

Value chain emissions and energy consumption

The internal value chain generates fossil emissions from transports (0.38 Mt CO_2e), forest operation and industry processes (0.26 Mt CO_2e), inputs (0.21 Mt CO_2e) and other (0.03 Mt CO_2e) for a total fossil emission (Value Chain Emissions, VCE) for SCA of 0.88 Mt CO_2e for 2017.

Large amounts of bioenergy produced from supplied material are used in the industry processes, corresponding approximately to 8 TWh. In addition, other non-fossil energy supply (electricity, heat, parts of fuel) amounted to 2 TWh. In total, c. 95% of the energy used in SCAs industry processes in 2017 was fossil-free, whereas most of the transportation fuel mix was still fossil-based.

Products delivered

From the industry units, a total of 2.1 Mm^3 of solid wood products were delivered in 2017, with a carbon content of 0.53 Mt C. Marketed pulp and paper (2.1 Mt) had a carbon content of 0.78 Mt C. Bioenergy in the form of heat, electricity and biofuels was delivered at a level of 1.7 TWh, corresponding to 0.20 Mt C contents in applicable fossil fuel mix.

Products substitution effect

Applying the Substitution Effect Ratios determined above to the quantities of delivered products and multiplying by 3.67 to convert C to CO_2e, the substitution effects in 2017 were:

- For solid wood products: 0.53 Mt C * 1.5 tC/tC * 3.67 = 2.9 Mt CO_2e
- For pulp and paper products: 0.78 Mt C * 0.7 tC/tC * 3.67 = 2.0 Mt CO_2e
- For bioenergy: 0.20 Mt C * 0.7 tC/tC * 3.67 = 0.5 Mt CO_2e

for a total of 5.4 Mt CO_2e of Products Substitution Effect (PSE), i.e. displacement of fossil emissions.

Total climate impact of SCA in 2017

Applying the model in Equation (1) gives the following result for year 2017:

- change in Forest Carbon Stock, $\Delta FCS_{2016\text{-}2017}$ = 4.0 Mt CO_2e
- Value Chain Emissions, VCE_{2017} = 0.9 Mt CO_2e
- Products Substitution Effect, PSE_{2017} = 5.4 Mt CO_2e
- Forest System Climate Impact, $FSCI_{2017}$
  - $\Rightarrow \Delta FCS_{2016\text{-}2017} - VCE_{2017} + PSE_{2017}$
  - $\Rightarrow 4.0 – 0.9 + 5.4$
  - $\Rightarrow$ 8.5 Mt CO_2e

Conclusively, SCAs overall operations in 2017 reduced greenhouse gases in the atmosphere at an estimated level of 8.5 Mt CO_2e.

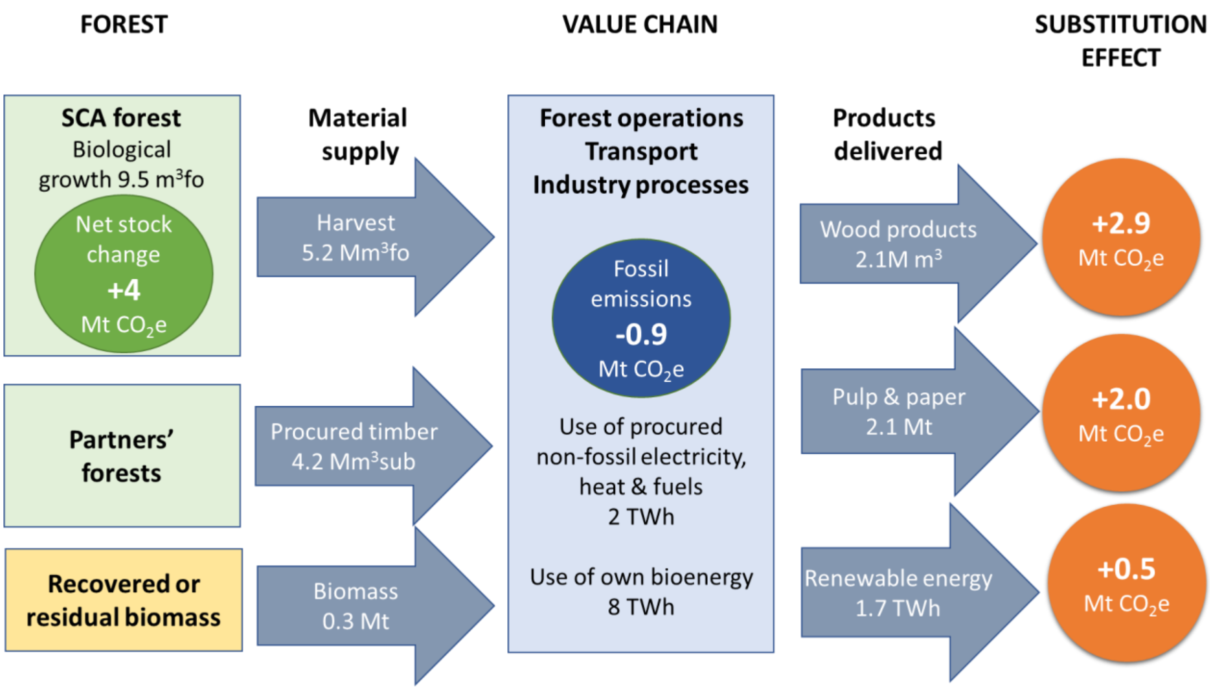

Figure 2. Carbon flows for SCA in 2017 aligned with the Forest System Climate Impact model defined in this paper and using substitution effect factors determined in above review. Circles indicate numerical inputs to the model. The sum of these indicates that SCAs operations reduced greenhouse gases in the earth's atmosphere equivalent to 8.5 Mt CO_2e in the year 2017.

6. Discussion

Model limitation and sensitivity

The proposed model represents the totality of carbon flows for a forestry corporation, albeit on a generalized level. This approach was considered sufficiently accurate for the purpose and for the currently generic set of products delivered from SCA. More specialized corporations, or corporations that have a different balance between forest asset, sawmills, pulp- and paper mills, may require a different level of detail in the analysis. Similarly, if the product mix changes, as a result of innovation or investments in value-adding processing, the model may need to be enhanced.

The knowledge base, experiences and data availability are strong for the factors "Change of Forest Carbon Stock" and "Value Chain Emissions" as these have been subject to reporting for some years, and as they are significant factors also for the economic performance of the company. For the third component, "Product Substitution Effects", there is much less to build on. This is likely because the substitution effect as such has been excluded from GHG inventory reporting, and because the effects are complex and difficult to measure. With rising interest in substituting fossil-based materials and energy, the knowledge base on substitution effects can be expected to grow, which may lead to modifications of the Substitution Effect Ratios.

Choosing an annual reporting cycle for the climate impact will lead to fluctuations that follow economic cycles. If sales volumes go down, so will the overall substitution effects as well as the value chain emissions. At the same time, this will be balanced as more wood will be left in the forest, which increases the net uptake of carbon. And vice versa when sales volumes go up. From this perspective, the overall model results should be relatively stable and not in the short term be strongly influenced by economic down- or upturns.

Conservative estimates of substitution effect rates

Substitution effect rates (SERs) have been conservatively set so as not to unintentionally exaggerate the positive climate effects. As the knowledge base and confidence in findings grow, it is possible that these can be adjusted upwards. For the current study, the following should be noted:

- Bioenergy conversion rates are very high (>90%) at SCA and at the dedicated energy facilities where most of the conversion is done. For some cited studies, lower conversion rates have been used, which suggests that the actual bioenergy SER for SCA can be higher. On the other hand, the recovery of paper-based products for energy is to a large extent done in other countries, with unknown but probably lower conversion rates

- Pulp and paper products to some extent substitute fossil-based products such as plastics, often several times as the material is recycled. However, results from the literature have not been sufficient to allow for quantifying this SER. Instead the SER has been limited to the end-life conversion to energy. This is therefore an underestimation of the overall SER for pulp and paper products. At the same time, not all materials are ultimately used for energy production – some end up in landfills with no substitution effect

- For wood products, only the primary SER has been included, i.e. no substitution for cascading use of wood or the end-life conversion to energy is included. This represents a likely considerable underestimation of the total SER for wood products

Activities not included in model

Two additional major climate-benefits are results of SCA's current operations. Neither of these has been included in the model as they fall outside the direct control of the company and/or are the direct results of other companies' operations. Nevertheless, for these climate-benefits to be realised, partnerships with SCA are required. They can therefore be characterised as "Facilitated climate impacts":

1. Climate impact in forests not owned by SCA, but from which SCA is purchasing wood for its industry. The model accounts for value chain emissions and substitution effects resulting from using this wood. However, the forest impact factor is not

included. It is reasonable to assume that climate-positive forest management is stimulated also on these lands through the possibility to sell timber. The overall forest stock in the four regions where SCA is most active (Norrbotten, Västerbotten, Jämtland and Västernorrland with a total of 11 Mha productive forest land) shows an increase from 97 to 111 m^3fo/ha, or 14%, over the period 2000-2018 based on official Swedish statistics (SLU, 2018, 2000). This indicates that a substantial reduction of CO_2 from the atmosphere happens also on non-SCA land in these regions

2. Wind energy production on SCA land has been expanding considerably over recent years. With the consent of local stakeholders and authorities, substantial amounts electricity can be produced, given that SCAs land area is equal in size to Belgium. In 2017, 2.3 TWh was produced from 301 wind turbines, and decisions made to expand to a capacity of 5 TWh by 2020. The current business model builds on an agreement between SCA and the energy producing company, regulating the conditions for using SCAs property and infrastructure

Other reflections

The suggested model and reporting approach offer opportunities to focus on further innovation and improvements to achieve synergies between business development and increased climate benefits, while taking other sustainability goals into consideration - for example nature conservation. By disaggregating into three main factors, strategies can focus separately on enhancing forest management, reducing value chain emissions, and product values. Further development and verification of the model as well as the underlying calculation of climate impact factors may increase both the accuracy of results as well as acceptance for general use in the forest sector.

The forest system model offers a perspective on forest and forest management that goes beyond what UNFCCC related reports, or studies that apply the sector boundaries as defined by the UNFCCC. This is important as the focus has often been on preserving the forest carbon stock as such, not considering the long-term dynamics of forest management or the product substitution effects, leading to an underestimation of the climate-benefits of forestry.

Financial benefits of climate performance (such as carbon credit trading or tax incentives) has not been a topic for this study, however the results could be used for further analyses in these areas.

Similarly, the results could be used to analyse the climate effects of restrictions on forest management, as well as opportunities from more intensive forest management and/or increased external wood supply.

As elaborated above, the substitution effect rates used in this study do not include effects of fibre products (paper, packaging, textiles, etc.) as they replace more fossil-based materials such as plastic or synthetic fibre. Further, wood fibre products are recyclable and can therefore cause such substitution effects repeated times. In addition, the neither the effects of recycling wood products, nor the end-use bioenergy effect when the wood is ultimately burnt, are included. The substitution effects calculated in this study are therefore conservative, or even incomplete. With improved knowledge, standardised methods of calculating effects and more experience of monitoring and reporting, current substitution effects can be expected to be at a considerably higher level.

Over the longer term, the product substitution effect ratios are likely to change (as noted also by Leskinen et al. (2018)) as a result of changing overall energy supply to society as well as innovations both in the forest sector and in other sectors (such as steel and cement production and more efficient use of such products). New forest products or more efficient use of wood and wood fibre may achieve even higher substitution rates. It is also possible that the substitution effect will go down as the reliance on fossil fuels diminishes, although this development is still unpredictable at the international level. Similarly, the substitution effect will go down if the climate footprint of using alternative materials is reduced. These developments towards a fossil-free world would be desirable for society. Instead of a "substitution effect" we may gradually have to refer to benefits of renewable forest products and energy as integral parts of a circular economy where human welfare depends on efficient and sustainable management of the biological production systems.

References

Braun, M., Fritz, D., Weiss, P., Braschel, N., Büchsenmeister, R., Freudenschuß, A., Gschwantner, T., Jandl, R., Ledermann, T., Neumann, M., Pölz, W., Schadauer, K., Schmid, C., Schwarzbauer, P., Stern, T., 2016. A holistic assessment of greenhouse gas dynamics from forests to the effects of wood products use in Austria. Carbon Manag. 7, 271–283. https://doi.org/10.1080/17583004.2016.1230990

Chen, J., Ter-Mikaelian, M.T., Yang, H., Colombo, S.J., 2018. Assessing the greenhouse gas effects of harvested wood products manufactured from managed forests in Canada. For. Int. J. For. Res. 91, 193–205. https://doi.org/10.1093/forestry/cpx056

Duncan Brack, 2017. The Impacts of the Demand for Woody Biomass for Power and Heat on Climate and Forests [WWW Document]. Chatham House. URL https://www.chathamhouse.org/sites/default/files/publications/research/2017-02-23-impacts-demand-woody-biomass-climate-forests-brack-final.pdf (accessed 11.22.18).

GRI, 2016. GRI 305: Emissions [WWW Document]. URL https://www.globalreporting.org/standards/gri-standards-download-center/ (accessed 11.20.18).

Gustavsson, L., Haus, S., Lundblad, M., Lundström, A., Ortiz, C.A., Sathre, R., Truong, N.L., Wikberg, P.-E., 2017. Climate change effects of forestry and substitution of carbon-intensive materials and fossil fuels. Renew. Sustain. Energy Rev. 67, 612–624. https://doi.org/10.1016/j.rser.2016.09.056

Gustavsson, L., Holmberg, J., Dornburg, V., Sathre, R., Eggers, T., Mahapatra, K., Marland, G., 2007. Using biomass for climate change mitigation and oil use reduction. Energy Policy 35, 5671–5691. https://doi.org/10.1016/j.enpol.2007.05.023

Gustavsson, L., Madlener, R., Hoen, H.-F., Jungmeier, G., Karjalainen, T., KlÖhn, S., Mahapatra, K., Pohjola, J., Solberg, B., Spelter, H., 2006. The Role of Wood Material for Greenhouse Gas Mitigation. Mitig. Adapt. Strateg. Glob. Change 11, 1097–1127. https://doi.org/10.1007/s11027-006-9035-8

Gustavsson, L., Sathre, R., 2011. Energy and CO2 analysis of wood substitution in construction. Clim. Change 105, 129–153. https://doi.org/10.1007/s10584-010-9876-8

Iordan, C.-M., Hu, X., Arvesen, A., Kauppi, P., Cherubini, F., 2018. Contribution of forest wood products to negative emissions: historical comparative analysis from 1960 to 2015 in Norway, Sweden and Finland. Carbon Balance Manag. 13. https://doi.org/10.1186/s13021-018-0101-9

IPCC, 2014. Climate Change 2014 Synthesis Report [WWW Document]. URL http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf

Kilpeläinen, A., Torssonen, P., Strandman, H., Kellomäki, S., Asikainen, A., Peltola, H., 2016. Net climate impacts of forest biomass production and utilization in managed boreal forests. GCB Bioenergy 8, 307–316. https://doi.org/10.1111/gcbb.12243

Knauf, M., Köhl, M., Mues, V., Olschofsky, K., Frühwald, A., 2015. Modeling the CO2-effects of forest management and wood usage on a regional basis. Carbon Balance Manag. 10, 13. https://doi.org/10.1186/s13021-015-0024-7

KSLA, 2018. Forests and the climate – manage for maximum wood production or leave the forest as a carbon sink? [WWW Document]. URL http://www.ksla.se/aktivitet/forests-and-the-climate/ (accessed 11.22.18).

Lehtonen, A., Mäkipää, R., Heikkinen, J., Sievänen, R., Liski, J., 2004. Biomass expansion factors (BEFs) for Scots pine, Norway spruce and birch according to stand age for boreal forests. For. Ecol. Manag. 188, 211–224. https://doi.org/10.1016/j.foreco.2003.07.008

Leskinen, P., Cardellini, G., González-García, S., Hurmekoski, E., Sathre, R., Seppälä, J., Smyth, C., Stern, T., Verkerk, P.J., 2018. Substitution effects of wood-based products in climate change mitigation (No. 7), From Science to Policy.

Lundmark, T., Bergh, J., Hofer, P., Lundström, A., Nordin, A., Poudel, B., Sathre, R., Taverna, R., Werner, F., Lundmark, T., Bergh, J., Hofer, P., Lundström, A., Nordin, A., Poudel, B.C., Sathre, R., Taverna, R., Werner, F., 2014. Potential Roles of Swedish Forestry in the Context of Climate Change Mitigation. Forests 5, 557–578. https://doi.org/10.3390/f5040557

Naturvårdsverket, 2017. National Inventory Report Sweden 2017 - Greenhouse Gas Emission Inventories 1990-2015 [WWW Document]. URL https://www.naturvardsverket.se/upload/sa-mar-miljon/statistik-a-till-o/vaxthusgaser/2016/data-metoder/nir-se-submission-2017.pdf (accessed 11.9.18).

Perez-Garcia, J., Lippke, B., Comnick, J., Manriquez, C., 2007. An Assessment of Carbon Pools, Storage, and Wood Products Market Substitution Using Life-Cycle Analysis Results. Wood Fiber Sci. 37, 140–148.

Petersen, A.K., Solberg, B., 2005. Environmental and economic impacts of substitution between wood products and alternative materials: a review of micro-level analyses from Norway and Sweden. For. Policy Econ. 7, 249–259. https://doi.org/10.1016/S1389-9341(03)00063-7

Pingoud, K., Pohjola, J., Valsta, L., 2010. Assessing the integrated climatic impacts of forestry and wood products. Silva Fenn. 44. https://doi.org/10.14214/sf.166

Rüter, S., Werner, F., Forsell, N., Prins, Christopher, Vial, Estelle, Levet, Anne-Laure, 2016. Climate benefits of material substitution by forest biomass and harvested wood products: Perspective 2030 - Final Report (No. 42), Thünen Report. Johann Heinrich von Thünen-Institut, Germany.

Sathre, R., O'Connor, J., 2010. Meta-analysis of greenhouse gas displacement factors of wood product substitution. Environ. Sci. Policy 13, 104–114. https://doi.org/10.1016/j.envsci.2009.12.005

SCA, 2017. SCA Annual and Sustainability Report 2017 [WWW Document]. URL https://www.sca.com/globalassets/sca-engelska/investors/annual-reports/annual-and-sustainability-report-2017.pdf

Seppälä, J., Kanninen, M., Vesala, T., Uusivuori, J., Kalliokoski, T., Lintunen, J., Saikku, L., Korhonen, R., Repo, A., 2015. Climate impacts of forest use and Crbon sink development (No. 3), The Finnish Climate Change Panel.

Sjolie, Hanne., Latta, Greg, Gobakken, Terje, Solberg, Birger, 2011. Norfor - A forest sector model of Norway (No. 18), INA fagrapport. Norwegian University of Life Sciences.

SLU, 2018. Skogsdata 2018 - Aktuella uppgifter om de svenska skogarna från Riksskogstaxeringen [WWW Document]. URL https://www.slu.se/globalassets/ew/org/centrb/rt/dokument/skogsdata/skogsdata_2018_webb.pdf (accessed 11.20.18).

SLU, 2007. Kolet, klimatet och skogen - Så funkar det [WWW Document]. URL https://www.mistra.org/wp-content/uploads/2017/10/LUSTRASa%CC%8AFunkarDet2007.pdf

SLU, 2000. Skogsdata 2000 [WWW Document]. URL https://www.slu.se/globalassets/ew/org/centrb/rt/dokument/skogsdata/skogsdata2000_webb.pdf

Smyth, C., Rampley, G., Lemprière, T.C., Schwab, O., Kurz, W.A., 2017. Estimating product and energy substitution benefits in national-scale mitigation analyses for Canada. GCB Bioenergy 9, 1071–1084. https://doi.org/10.1111/gcbb.12389

Soimakallio, S., Saikku, L., Valsta, L., Pingoud, K., 2016. Climate Change Mitigation Challenge for Wood Utilization—The Case of Finland. Environ. Sci. Technol. 50, 5127–5134.
Taverna, Hofer, P., Werner, F., Kaufmann, E., Thürig, E., 2007. The CO2 effects of the swiss forestry and timber industry (No. 0739), Environmental Studies. Federal Office for the Environment, Bern.
The Economist, 2013. The fuel of the future - Environmental lunacy in Europe. The Economist.
Tromborg, E., Sjolie, H., Bergseng, E., Bolkesjo, T., Hofstad, O., Rorstad, P., Solberg, B., Sundhe, K., 2011. if19.Carbon cycle effects of different strategies for utilisation of forest resources - a review (No. 19), INA fagrapport. Norwegian University of Life Sciences.
UNFCCC, 2018a. Land Use, Land-Use Change and Forestry (LULUCF) [WWW Document]. URL https://unfccc.int/topics/land-use/workstreams/land-use--land-use-change-and-forestry-lulucf (accessed 11.1.18).
UNFCCC, 2018b. National Inventory Submissions 2017 [WWW Document]. URL https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/submissions/national-inventory-submissions-2017 (accessed 11.1.18).