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European forests show no carbon debt, only a long parity effect☆

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ABSTRACT

In the past the use of woody biomass for bioenergy was considered carbon neutral. However, this changed when analyses were made of cases of land use change or old growth forest logging for bioenergy purposes. These analyses showed a significant carbon debt that could take hundreds of years to be compensated by the substitution factor of the bioenergy.

Currently, carbon debt analyses are often carried out: 1) at one hectare scale, or 2) against the hypothetical case of allowing the managed forest to grow to an old-growth state, or 3) in a comparison against short term policy goals. All three are not realistic for European forests. Here we analysed carbon debt and parity of realistically increased harvesting over large forest areas in Europe. We found that under such realistic cases, a carbon debt does not occur. i.e. the large scale average stocks in the forest are not reduced. What does occur is a parity compared to the baseline harvesting levels. The parity effect was eventually also compensated for. However it took long, especially if final fellings were increased for bioenergy; which is a rather hypothetical case. In case of increased thinnings, the parity equality was often reached within 80 years compared to burning coal. Removal of harvesting residues was often compensated within 1 decade. However, parity is a theoretical comparison against a higher baseline C stock in the forest. It is not certain that this higher stocking under the baseline will be sustained, because there is an increasing chance of natural disturbances. Thus the parity may be much shorter than analysed here.

1. Introduction

As part of the climate mitigation effort, the EU launched its new Climate and Energy Framework in 2014 (European Commission COM(2014)15). Part of this EU framework package for climate and energy is an increased share of renewable energy with concrete targets for 2030. 27% of the total energy should come from renewables, of which most likely 50% should be generated from biomass; both from agricultural and forestry primary and secondary residues equally. Comparing this target to current EU energy consumption of 1600 Mtoe, would require some 108 Mtoe[1] from woody biomass. If all of this would have to come from roundwood, it equals 550 million m^3 of roundwood; equal to the current total harvesting of roundwood in the EU. However, much of this will come from primary and secondary residues and post consumer waste wood (Elbersen et al., 2012). Thus the direct pressure on the forest will be much lower, but still very significant.

Using biomass from sustainably managed forests for bioenergy has been considered carbon neutral for a long time because emissions are compensated by a regrowth in the forest afterwards. In most cases in the Northern Hemisphere, the current growth is larger than the harvest and thus the principle of biomass for bioenergy being carbon neutral was not challenged. Also, the European Renewable Energy Policy and its targets for 2020 have been developed on the basis of a political agreement that biomass is carbon neutral and that, therefore, any energy produced from such biomass would deliver a net benefit in terms of climate change mitigation.

The assumption of 'carbon neutrality' is based on the fact that carbon emitted in the process of burning biomass is recaptured when the vegetation regrows, provided the use of the land is not changed after harvest. This basic fact was taken up in national greenhouse gas inventories of the United Nations Framework Convention on Climate Change (UNFCCC) where emissions are counted at the time of harvesting (IPCC, 2006). These emissions should not be counted again at time of burning in the energy sector; hence the CO_2 emissions are set to 0 at the time of burning. Further, burning the biomass for energy replaces a certain amount of fossil fuels that are 'saved': the energy substitution effect.

However, the carbon neutrality assumption became a topic of fierce debate. Essentially, carbon neutrality can only be warranted if the land use does not change after harvesting, i.e. the vegetation is allowed to regrow, or when the area average biomass stock is not significantly reduced due to harvesting. The debate started with analyses for regions where biofuel production caused changes in land use, for example conversion of primary tropical forest to palm oil plantations (Searchinger et

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[1] Mtoe = million tonne oil equivalent. We calculated te required amount of energy from: 1600∗0.27∗0.5∗0.5 = 108. And 1 t oil equivalent equals roughly 5 m^3 of wood.

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al., 2008). In these non-sustainable cases, large emissions occur when land is cleared from the original vegetation, while the pre-harvest biomass will not be reached again by the new crop. It is very unlikely that under these conditions the avoided fossil fuel emissions will compensate for these large biomass carbon emissions. Next, analyses started to investigate the effects of logging of old-growth forests also showing that biomass losses take a long time to compensate, Furthermore, many studies emphasized the stand scale analyses showing large fluctuations of standing biomass in the forest and long recovery times (Mitchell, Harmon, and O'Connell, 2012).

Thus the term 'carbon debt' has been introduced, which implies it can be 'paid off' over time (the payback time). These studies were also initiated by the (high) policy targets for renewable energy and the reduction goals that were set for 2020 or 2030 already. It is this combination of short-term policy targets and the longer-term time dimension of regrowth that stimulated the emphasis of many studies towards short to medium temporal emission effects of woody biomass (Helin, Sokka, Soimakallio, Pingoud, and Pajula, 2013). In addition, wood does not burn as efficiently as e.g. natural gas. Thus, more CO_2 has to be emitted in order to produce the same amount of energy. This CO_2 will be compensated through regrowth, but still that takes time; hence another aspect of carbon debt. In order to deal properly with the carbon debt aspects, Helin et al. (2013) suggests to take into account time aspects, large scales, and make calculations based on a dynamic forest model.

In all carbon debt studies large scale analyses of sustainably managed forest regions on which a (slightly) higher felling level would be imposed for woody biomass for bioenergy, were never done. Such a case would actually be realistic for European forests from which the current felling level is 73% of the increment (Forest Europe, 2015). Significant volumes of woody biomass from logs of lower quality and primary and secondary residues can be made available while maintaining strict environmental and biodiversity rules (Verkerk et al., 2014, Nabuurs, Van Brusselen, Pussinen, and Schelhaas, 2006, Elbersen et al., 2012). Elbersen et al. (2012) found (under a sustainability scenario) an availability of ~72 Mtoe[2] from additional log harvesting, forest harvesting residues and primary forest industry processing residues together by 2030.

Whether primary (low quality) log sources will be used at large quantities for bioenergy will depend on pulp log price developments, costs of harvesting, collecting, storing, and levels of subsidy and strictness of sustainability criteria applied on bioenergy (e.g. Moiseyev, Solberg, Kallio, and Lindner, 2011, SDE+, 2016). Elbersen et al. (2012) estimated that roughly half of the biomass amounts mentioned above would be available at prices under € 200/Toe.

The question we address here is what are the carbon implications at a large scale if we impose a (10–50%) higher felling level (thinnings and final fellings) on European forests and what are the impacts if we remove 50% of forest residues. Is it legitimate to see biomass as carbon neutral, will a carbon debt develop, and how long does it take to pay back any debt or parity. Further, how significant is the impact on the forest carbon stocks of increased harvest?

2. Concepts: carbon neutrality, carbon debt and carbon parity

In general, carbon neutrality can be seen as the concept that over long time frames and without land use change, carbon emissions and sinks from a (managed) forest ecosystem are in balance. Any violation of the two basic elements of long time frame and no land use change can lead to rejection or questioning of the concept. Land use change can be a conversion of forest to agriculture or biofuel plantations, but also harvesting of old-growth forest. Violating the carbon neutrality can also occur under (strong) changes in management in already managed forest.

[2] 1 Mtoe = Million tonnes oil equivalent. Roughly one tonne oil equivalent translates to 5 m^3 of wood.

In addition, burning of biomass is less efficient than burning fossil fuels and the CO_2-emissions associated with bioenergy generation per unit of energy are generally higher than those of the fossil fuel displaced. Thus, immediately after bioenergy generation, the CO_2 concentration in the atmosphere is higher than immediately after generating the same amount of energy using fossil fuels.

These two together (loss of carbon on land and lower burning efficiency) is called the carbon debt. When the vegetation starts to regrow, carbon is absorbed again and at some point the difference between avoided emissions on the one hand and the actual emissions plus recapture on the other hand, becomes zero – the debt has been paid. This length of period is called the debt payback time. Essential here is the comparison of stocks and emissions with the known stock at the time just before harvest.

If the biomass was not harvested for bioenergy purposes, it probably would have continued to grow for at least some time. At the time of carbon debt payback, there is still a difference between the current carbon stock plus avoided emissions and the carbon stock that would have occurred without harvesting (or baseline harvest). The point in time that this difference reaches zero is called carbon parity and the time it takes to reach this point is the parity payback time. Essential in the calculation of parity is that it is compared to an unknown baseline scenario that evolves over time. Fig. 1 shows the difference between debt and parity at the hectare scale and at large scale.

In general, there is consensus in the studies on what the carbon debt constitutes and that there is a difference between carbon debt and carbon parity. However, not all studies explicitly define the terms carbon debt and/or parity and which of those they are actually studying. Studies that emphasize the lower burning efficiency of wood compared to coal or gas generally are more concerned about the carbon debt, while studies at landscape or national level often compare effects of different scenarios on atmospheric carbon and thus focus on carbon parity (Mitchell et al., 2012, Agostini, Boulamanti, and Giuntoli, 2014). Some studies explicitly take both into account. In fact, landscape-scale analyses often don't show a carbon debt, because the stock of carbon in the whole landscape is still increasing despite the additional, but still

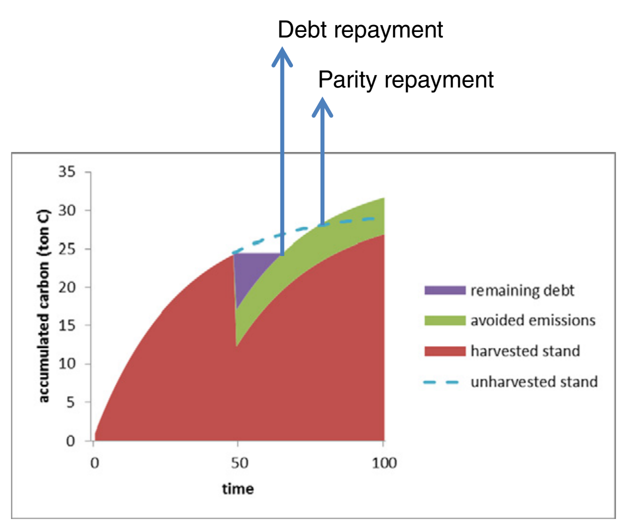

Fig. 1. Conceptual diagram of debt and parity. One stand is planted and left untouched until age 50. Without harvest, it would have continued to accumulate carbon according to the blue dashed line. Now assume one harvest event at age 50 that is entirely used for the generation of bioenergy. The amount of biomass present in the stand is reduced by 50% (12.5 ton C), but avoided fossil fuel emissions are 4.8 ton C. Accordingly, the immediate debt is 7.7 ton C. When the remaining stands is regrowing, the debt is getting smaller, until it is paid at age 64. Parity is reached at age 77, when the amount of carbon in the harvested stand plus the avoided emissions is equal to the carbon that would have accumulated in the same stand without harvesting (and assuming no disturbances in the meanwhile).