Second generation biofuels from short rotation plantations are less efficient in climate-change mitigation than reforestation within reasonable timeframes

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Motivation

Second generation biofuels (2G biofuels) produced from lignocellulosic biomass are often considered as integral part of a future sustainable transport system. Provided that substantial areas of agricultural land can be diverted from food and feed production without impairing food security, energy plantations managed in short rotation (e.g. willow or eucalyptus plantations) appear as a promising option for supplying large amounts of biomass feedstock. In contrast to raising wood removals from forests, growing biomass specifically for energy does not interfere with forest carbon (C) stocks and can therefore be perceived to be truly C-neutral within short timeframes. However, instead of using agricultural land for energy plantations, it could also be reforested, thereby acting as a long-term C sink that also results in climate benefits.

This paper provides a systematic comparison of the long-term C benefits from 2G biofuels produced from plantation biomass with the C sink strength of natural succession on arable land (see Fig. 1). In case of reforestation (here modeled as natural succession), climate benefits originate from C stock increases, i.e. sequestration of C from the atmosphere. Establishment of energy plantations also results in net C sequestration relative to conventional cropland use, but this effect is significantly lower because plantations are periodically harvested. The main C benefit results from the substitution of fossil fuels with 2G biofuels.

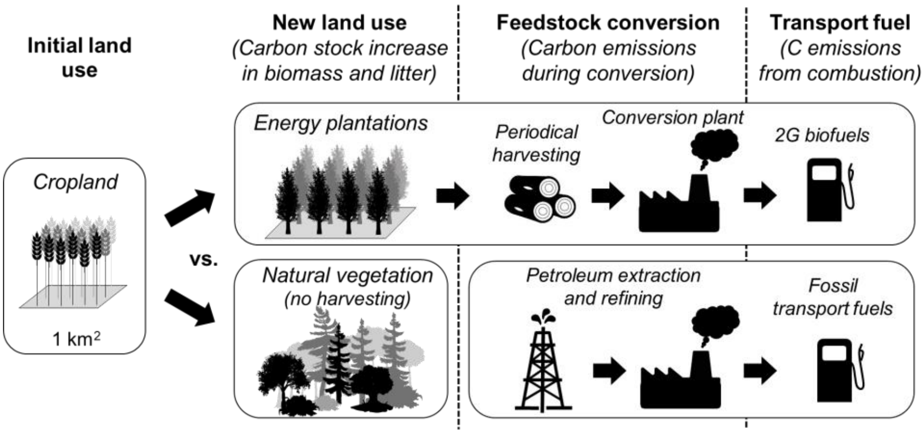

Figure 1. Schematic illustration of the research topic: Energy plantations are harvested periodically for biofuel production; alternatively, the same area is allowed to revert to its natural state and petroleum is used for transport fuel production

Methodology

C benefits of the two options are calculated for an area of 1 km^2. The dynamics of C accumulation in natural vegetation as well as plantations (i.e. biomass yields) strongly depend on site-specific natural conditions. We apply a global perspective and assume that this km^2 is distributed among ecological zones and climate zones exactly like actual global cropland areas. To this end, global raster data (5 arcmin resolution) on cropland distribution [1], ecosystem zones [2] and climate zones [3] are merged, and a global average C accumulation pattern derived. For natural succession, this is done on the basis of IPCC Tier 1 approaches and standard values [4]. As no default values are available for energy plantations, the required parameters (annual biomass growth, corresponding biomass yields, aboveground biomass losses and litter accumulation) are derived from the literature.

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Due to considerable uncertainties with regard to the yields of energy plantations, losses and future conversion efficiencies of 2G biofuel processes, a Monte Carlo simulation is carried out with these parameters being varied in ranges derived from literature (see caption to Fig. 2 for actual ranges).

Results and conclusions

Results show that natural succession is highly likely to be superior (i.e. to result in higher C benefits) for timeframes up to 50 years. Hence, it takes more than 50 years of continuous land use as short rotation plantation and substitution of fossil fuels with 2G biofuels until this alternative results in higher cumulated C benefits than renaturation. This finding, that natural succession is a worthwhile alternative to energy plantations and 2G biofuel production, is robust to uncertainties related to short rotation yields and technological progress in 2G biofuel production. We conclude that allowing agricultural land to revert to its natural state must seriously be considered as low-cost climate mitigation strategy and alternative to biofuel production.

These results have strong implications for climate policies: Plantation-based 2G biofuels are apparently inefficient in climate mitigation within reasonable timeframes. Considering that large and early reductions in GHG emissions are needed until 2050 for holding global warming to “well below 2 degrees”, the fact that natural succession can provide early C savings is a clear asset. Hence, allowing agricultural land to revert to its natural state must seriously be considered as low-cost climate mitigation strategy and alternative to bioenergy.

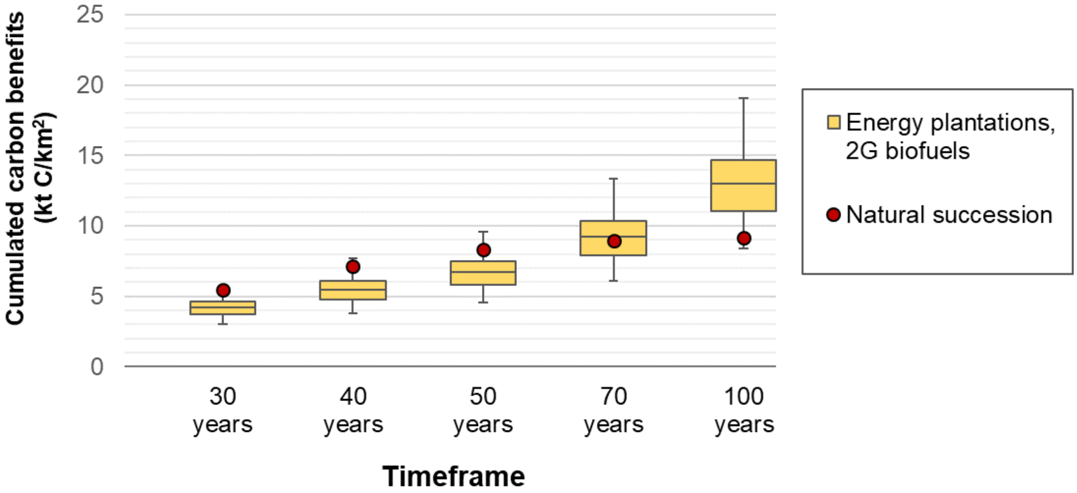

Figure 2. Cumulated carbon benefits (i.e. negative emissions) resulting from natural succession and second generation biofuels from short rotation plantations for different timeframes. Results for biofuels are shown as box plots resulting from Monte Carlo simulation with 10^4 runs and variation of the following parameters (uniform distributions assumed): plantation yields (+/-20 % of default yields derived from literature), aboveground biomass losses (10 to 30 %) and biofuel conversion efficiency (biomass-to-fuel efficiencies: 30 to 55 %).

Acknowledgement

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Literature

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