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# Time-dependent climate impact of bioenergy due to greenhouse gases and albedo

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Land use affects the global climate by greenhouse gas and aerosol emissions, as well as by changes in biophysical properties of the surface. Anthropogenic land use over time has caused substantial climate forcing due to changes in albedo, i.e. the share of solar radiation reflected back off the ground. There is growing concern that albedo change may offset climate benefits provided by emission reduction measures that affect land cover, such as afforestation or crop cultivation for carbon sequestration in biomass and soil. Albedo change may also be an important contributor to the life cycle climate impact of bioenergy. However, its relative importance depends on a range of case-specific factors such as local climate, insolation, soil type, vegetation, management and yield as well as on the timeframe of assessment.

The aim of this study was to improve the understanding of how bioenergy affects the climate due to albedo change and to compare it with the effects of carbon sequestration and greenhouse gas emissions along the supply chain. For this purpose, life cycle assessment methodology was combined with time-dependent models of radiative transfer, net primary production, carbon stocks in biomass and soil, field emissions and management operations. Potential climate impacts were expressed as global mean surface temperature change, which is a function of time, and as $CO_2$-equivalents for reference.

The model was used to analyse the cultivation of short rotation coppice willow on previously fallowed land in Southern Sweden, supplying wood chips to a combined heat and power plant. Our results show a net cooling effect of the bioenergy system, even if the replacement of fossil fuels is not considered. The main cooling was a result of higher soil carbon stocks under willow than under green fallow, which was sufficient to offset the emissions from field operations and supply chain processes. Albedo was higher for willow than for fallow throughout most of the year, causing additional cooling. Snow deposition led to higher albedo for fallow in winter months, but the impact on climate was negligible as snowfall occurred only between November and March when incoming radiation and atmospheric transmittance were low. The temperature response to albedo change was of the same order of magnitude as the net greenhouse gas impact. The relative importance of albedo decreased over time as soil carbon accumulated under sustained production. Using GWP100, albedo was responsible for 25-75% of the total climate impact from the bioenergy system, depending on yield levels.

Our findings demonstrate the potential importance of albedo change in a bioenergy system. Considering the timing of impacts can significantly improve the information in relation to climate targets as albedo change and greenhouse gases act on different time scales.