Land clearing and the biofuel carbon debt

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Abstract

Increasing energy use, global climate change, and carbon dioxide (CO_2) emissions from fossil fuels make switching to low-carbon fuels a high priority. Biofuels are a potential low-carbon energy source, but whether biofuels offer carbon savings depends on how they are produced. Converting rainforests, peatlands, savannas, or grasslands to produce food crop–based biofuels in Brazil, Southeast Asia, and the United States creates a "biofuel carbon debt" by releasing 17 to 420 times more CO_2 than the annual greenhouse gas (GHG) reductions these biofuels would provide by displacing fossil fuels. In contrast, biofuels from waste biomass or biomass grown on degraded and abandoned agricultural lands planted to perennials incur little or no carbon debt and can offer immediate and sustained GHG advantages.

Introduction

Biofuel production may cause land clearing of undisturbed ecosystems either directly by planting that land to biofuel crops or indirectly by diverting existing agricultural land to biofuel production. Converting native habitats to cropland releases CO_2 from burning or microbial decomposition of organic carbon stored in plant biomass and soils. We call the amount of CO_2 released during the first 50 years after land clearing the "carbon debt" of land conversion. Over time, biofuels from converted land can repay this carbon debt if their production and combustion have net GHG emissions less than the life-cycle GHG emissions of the fossil fuels they displace. Until the carbon debt is repaid, biofuels produced from converted lands have greater GHG impacts than those of the displaced fossil fuels. Here we show carbon debts and repayments for various scenarios of biofuel production from native ecosystems and degraded cropland.

Reference

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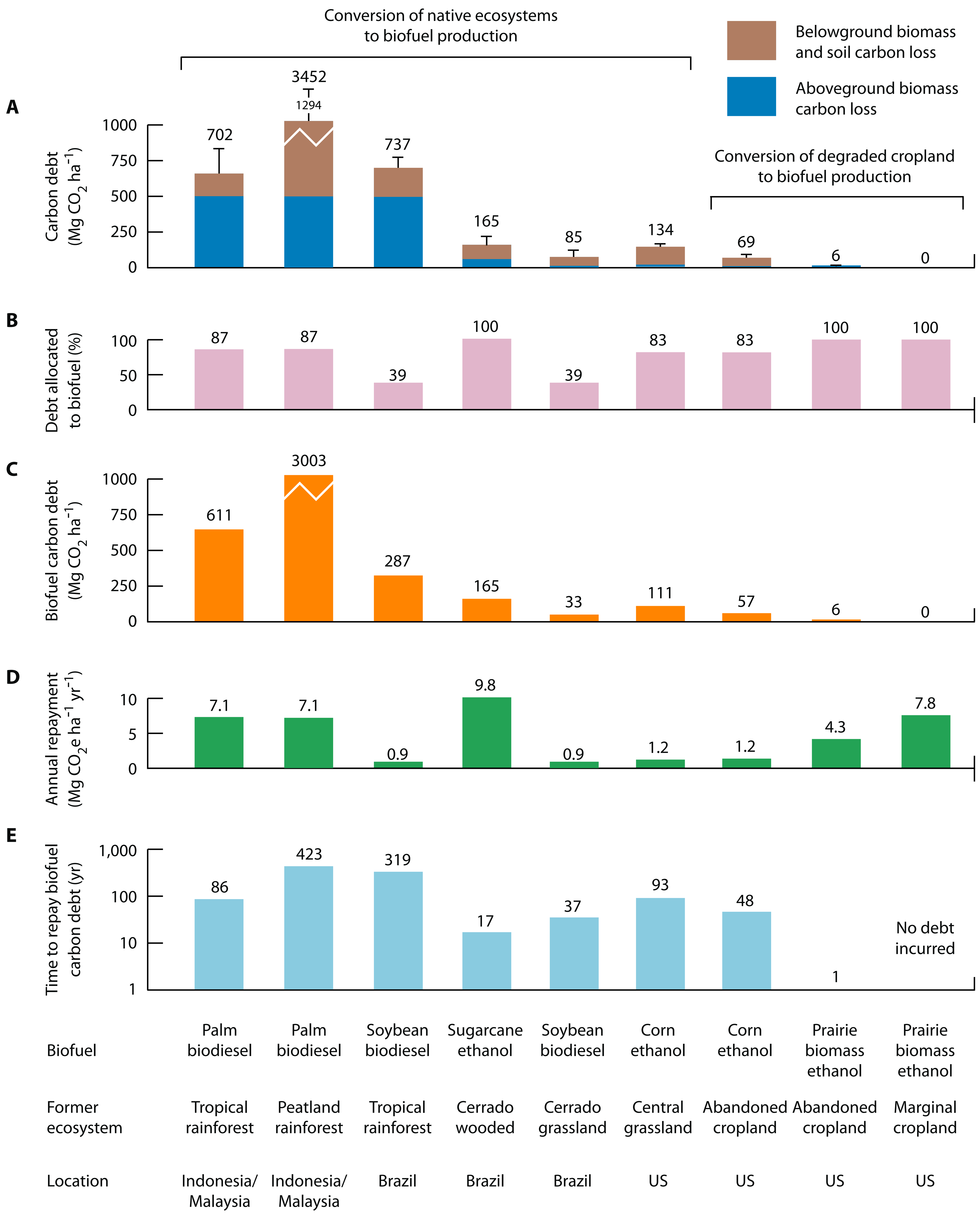

Figure legend

Carbon debt, allocation of biofuel carbon debt, biofuel carbon debt, annual repayment rate, and years to repay the biofuel carbon debt for nine biofuel production scenarios. (A) Carbon debt, including CO_2 emissions from soils and aboveground and belowground biomass resulting from habitat conversion. (B) Proportion of total carbon debt that is allocated to biofuel production after accounting for co-products. (C) Biofuel carbon debt. (D) Annual life-cycle GHG reduction from biofuels, including displaced fossil fuels and soil carbon storage. (E) Number of years after conversion to biofuel production that are required for cumulative biofuel GHG reductions, relative to the fossil fuels they displace, to repay the biofuel carbon debt.

Results

Our analyses suggest that biofuels produced on converted land (either native ecoystems or land in agricultural reserve systems) could, for long periods of time, be much greater net emitters of greenhouse gases than the fossil fuels that they typically displace. At least for current or developing technologies of biofuel production, any strategy to reduce GHG emissions that causes land conversion from native ecosystems to cropland is likely to be counter-productive.

Conclusions

If biofuels are to help mitigate climate change, our results suggest that they need to be produced with little reduction of the stores of organic carbon in the soils and vegetation of natural or managed ecosystems. Degraded and abandoned agricultural lands could be used to grow native perennials for biofuel production, which could spare the destruction of native ecosystems and help reduce GHG emissions. Diverse mixtures of native grassland perennials grown on degraded soils, particularly mixtures containing both warm-season grasses and legumes, have biomass yield advantages over monocultures and provide GHG advantages from high carbon storage rates. Monocultures of perennial grasses and woody species can also have GHG benefits over food-based crops, as can slash and thinnings from sustainable forestry, animal and municipal wastes, and crop residues.