BIOENERGY

Location, location, location

The sustainability of biomass production for energy depends on site-specific biophysical and socio-economic conditions. New research using high-resolution ecosystem process modelling shows the trade-offs between economic and environmental performance of biomass production for an ethanol biorefinery.

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In order to meet the Paris Agreement and keep the global temperature rise well below 2 °C compared to pre-industrial levels, biomass is expected to play an important role in the future energy supply[1]. For bioenergy to make a significant contribution, dedicated bioenergy crops are required[2]. However, the large-scale deployment of dedicated bioenergy crops raises several sustainability concerns[3], many of which are related to direct or indirect land-use change resulting from their production[4]. The environmental and socio-economic impact of land-use change induced by bioenergy crop production strongly depends on the spatially heterogeneous biophysical and socio-economic conditions in conjunction with the crop management that is applied[5]. Therefore, the sustainability of bioenergy crop production is greatly affected by its location. Now, writing in *Nature Energy*, John Field and colleagues in the US deploy a modelling framework to quantify, and to understand the trade-offs associated with, the environmental and economic performance of biomass produced to supply a cellulosic ethanol biorefinery[6].

The environmental and economic performance of biomass production is related to numerous factors, such as previous land use, climate conditions, and soil characteristics, which are mostly site specific. Field and colleagues assess the greenhouse gas (GHG) emissions and the cost of ethanol production from switchgrass in southwestern Kansas, USA, using a spatially explicit approach, taking into account site-specific factors such as historic land use, soil texture, and distance from the cultivation site to the conversion plant. Furthermore, they also assess various levels of crop management intensity, since performance depends on how crops are managed in relation to these site-specific factors. For example, the amount of fertilizer that is used impacts biomass yields and N_2O emissions differently depending on local conditions. Using a high-resolution ecosystem process model in combination with upstream supply GHG emissions and economic evaluation, the researchers examine various landscape strategies (for example, using only cropland, rangeland, ecologically marginal land or biophysically marginal land). For each land category, a Pareto frontier (a range of optimal solutions where it is impossible to improve one objective without impairing the other) was constructed indicating the trade-offs between cost and GHG emissions, an approach that is also used elsewhere[7].

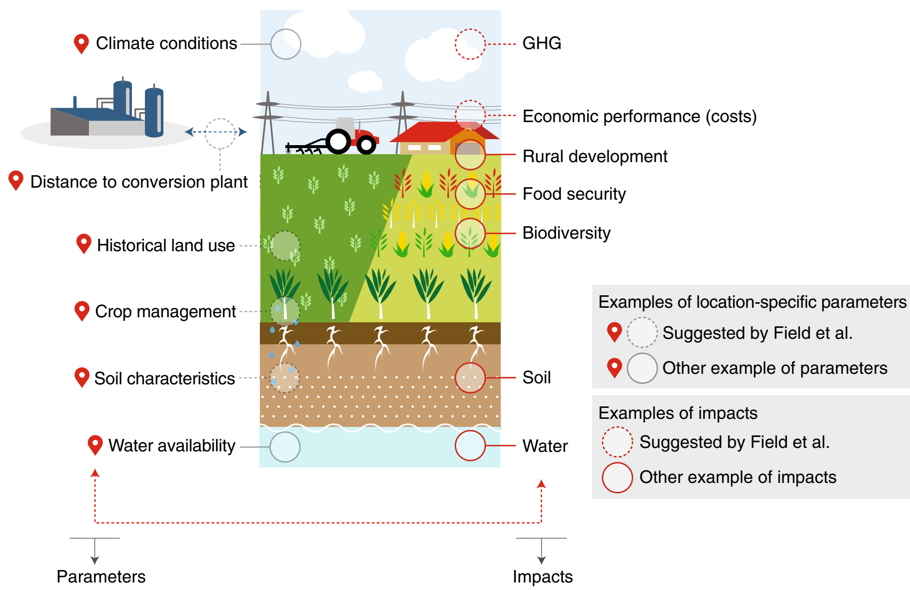

Fig. 1 | Location-specific parameters and sustainability impacts of energy crop production. The left side of the schematic shows examples of location-specific parameters that influence the impacts of biomass production for bioenergy. The right side shows examples of potential environmental and socio-economic impacts of biomass production that are affected by local conditions. Figure designed by Studio Infograph and adapted with permission from Meinou de Vries.

The results show large variations in the economic and environmental performance of switchgrass ethanol between different historical land-use categories as well as within land-use categories. This indicates that besides historical land use, other site-specific factors such as soil texture have a large impact on the environmental and economic performance. The study also shows that the current distribution of switchgrass cultivation results in suboptimal performance from both an economic as well as an environmental point of view. Strategies to improve the environmental and economic performance, such as minimizing the radius of the biomass sourcing area, or using only marginal land, do not result in optimal performance. However, the researchers conclude that careful selection of cultivation sites and associated fertilizer rates could lead to significant GHG emission reductions (>20 Mg CO_2e MJ^{-1}) at low additional cost, highlighting once more that location and site-adjusted management are key for the sustainability of biomass production. Although the results of this study are specific for this particular biofuel supply chain and region, the approach of the ex-ante assessment of the environmental and economic performance of bio-based supply chains could be applied to any supply chain in any region of the world.

While GHG emission reduction potential and production costs are key for large-scale deployment of biomass for bioenergy, there are other concerns that need to be addressed in order to ensure sustainable biomass production. Impacts on soil, water and biodiversity as well as on food security and rural development are key areas of concern that are also affected by local biophysical and socio-economic conditions (Fig. 1). Expanding this type of spatially explicit assessment on costs and GHG emission to an integrated approach including several sustainability indicators could contribute to finding the best locations for sustainable biomass production expansion.

This type of work is of the utmost importance for the field of bioenergy as it enables the quantification of the sustainability of bioenergy production and of the trade-offs between environmental and economic performance. Currently, the debate on biofuels and bioenergy is a heated one, and is often based on emotions rather than numbers and facts. The resulting polarized viewpoints on the sustainability of biofuels lead to inertia of decision-makers, while immediate action is required to reduce GHG emissions. By feeding the debate with objective quantitative information on impacts and performance of bio-based supply chains, the debate should move towards a more constructive discussion on how to do things right.

Next to the energy sector, land use, land-use change and forestry (LULUCF) plays an important role in anthropogenic GHG emissions. Sustainable land use is therefore key to meeting emission reduction targets and mitigating climate change. Optimizing land use only for bioenergy crops will automatically lead to suboptimal land use solutions. An integrated approach on sustainable land use, and selecting suitable locations for all land purposes, is therefore required to achieve substantial and sustained reductions in anthropogenic GHG emissions. ❐

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References

1. Peters, G. P. et al. *Nat. Clim. Change* **7**, 118–122 (2017).
2. Chum, H. et al. *Bioenergy: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation* (eds. Edenhofer, O. et al.) 209–332 (IPCC, Cambridge Univ. Press, 2011).
3. Creutzig, F. et al. *Global Change Biol. Bioenergy* **7**, 916–944 (2015).
4. Wicke, B., van Vuuren, D. P., Verweij, P. A., Van Meijl, H. & Faaij, A. P. C. *Biofuels* **3**, 87–100 (2012).
5. van der Hilst, F. et al. *Renew. Sustain. Energy Rev.* **16**, 2053–2069 (2012).
6. Field, J. L. et al. *Nat. Energy*. https://doi.org/10.1038/s41560-018-0088-1 (2018).
7. Verstegen, J. A. et al. *Environ. Modelling Software* **97**, 287–302 (2017).