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Land Use and Water Efficiency in Current and Potential Future U.S. Corn and Brazilian Sugarcane Ethanol Systems

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Background

Domestic biofuel production from renewable energy sources could potentially yield environmental and social benefits such as reducing greenhouse gas (GHG) emissions and promoting rural development. But as biofuel production continues to increase worldwide, concerns about land competition between food and fuel, excessive demand for water by competing users, and other unintended environmental consequences have grown.

Biofuels' water, energy, and land footprints are context-dependent. Footprints are very reliant on the types of crops used, crop yield, inputs required by crops, efficiency of biofuel conversion process, sources of process energy, and co-products generated.

Goal

1. Assess the current and potential future land use efficiency and water use of U.S. corn ethanol and Brazilian sugarcane ethanol—the two largest ethanol production systems in the world.

2. Examine tradeoffs between land and water use among potential future ethanol systems.

Scope

➢**Ethanol Systems**
- ➢U.S. corn
- ➢Brazilian sugarcane
- ➢From 2000 to 2020.

➢**Impact Assessment Scope**
- ➢Water: Consumption and evapotranspiration (ET) during crop growth
- ➢Land: Direct use at the field
- ➢GHG emissions: Life cycle without land use change (LUC)
- ➢Energy efficiency: Life cycle.

Methods

Primary method: Literature review and meta-analysis (i.e., recalculation from reported results).

Corn and sugarcane systems searched for:
- ➢Current and historical commercial industry averages
- ➢Advanced, current commercial systems
- ➢Parallel future systems between corn and sugarcane
- ➢Future systems with CCS.

Literature screening:
- ➢Recently published
- ➢High level of disclosure for the calculation of alternative metrics.

Metrics examined:
- ➢GHG emissions savings : Life cycle GHG emission savings of biofuel compared to gasoline of 92 g $CO_2eq/MJ_{biofuel}$
- ➢Land energy productivity: Difference between life cycle bioenergy produced and life cycle fossil energy consumed per unit of land used
- ➢Consumptive water use: m^3/GJ including green (i.e., rainwater) and blue (i.e., surface) water
- ➢ET (sum of transpiration and evaporation): Mg/GJ.

Abstract

Biofuels represent an opportunity for improved sustainability of transportation fuels, promotion of rural development, and reduction of GHG emissions. But the potential for unintended consequences, such as competition for land and water, necessitates biofuel expansion that considers the complexities of resource requirements within specific contexts (e.g., technology, feedstock, supply chain, local resource availability).

Through technological learning, sugarcane and corn ethanol industries have achieved steady improvements in resource use efficiency and environmental performance. Even greater improvements could be realized in future systems through a combination of continuous technological learning and better utilization of crop residues.

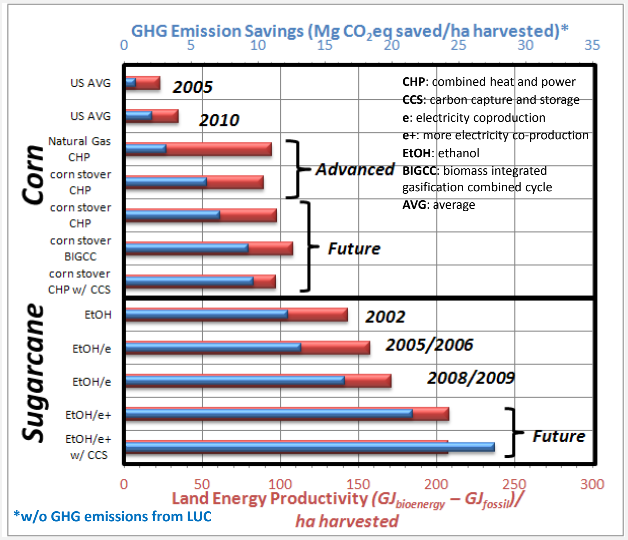
Conclusions

➢The GHG savings and land energy productivity of both ethanol systems have improved significantly due to continued adoption of more efficient technologies over time.

➢Advanced future systems are expected to continue to improve their environmental performance. However, how far these improvements reach depends on factors such as the assumed technologies, agricultural practices, technological learning, and how the crops and associated residues will be used to produce different combinations of products.

➢The water impacts of biofuel systems are largely determined within the local contexts (e.g., water availability, the land-water nexus, and other ecosystem constraints). As such, biofuel water and land use footprints can only be understood within these contexts.

Results

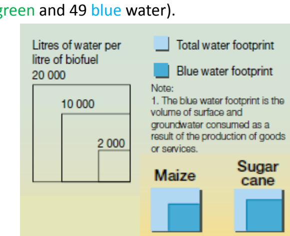


Average consumptive water footprints (all in m^3/GJ):
- ➢U.S. corn ethanol : 110 (43 green and 67 blue water)
- ➢Brazilian sugarcane ethanol: 108 (58 green and 49 blue water).

Potential site-specific (e.g., soil and climate) variation:

U.S. corn ethanol
- ➢Consumption (including green and blue): 50 – 380 m^3/GJ
- ➢ET: 73 – 346 m^3/GJ.

Brazilian sugarcane ethanol
- ➢Consumption (including green and blue): 50 - 250 m^3/GJ
- ➢ET: 37 – 155 m^3/GJ.



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NREL and other DOE laboratories are researching water supply and demand at the watershed scale for current and future biomass production to understand the tradeoffs of agricultural intensification and biofuel expansion.

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