Water, land and climate nexus of electricity from biomass

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Motivation

Renewable Energy Systems (RES) are a key strategy to decarbonize the power sector and contribute to the climate change mitigation targets.

Large-scale deployment of bioenergy may cause possible trade-offs, adverse side-effects and implications to sustainable development.

Understanding the sustainability profile along the entire life-cycle of electricity production is fundamental if we want to realize the transition to cleaner technologies in the energy sector.

Objectives

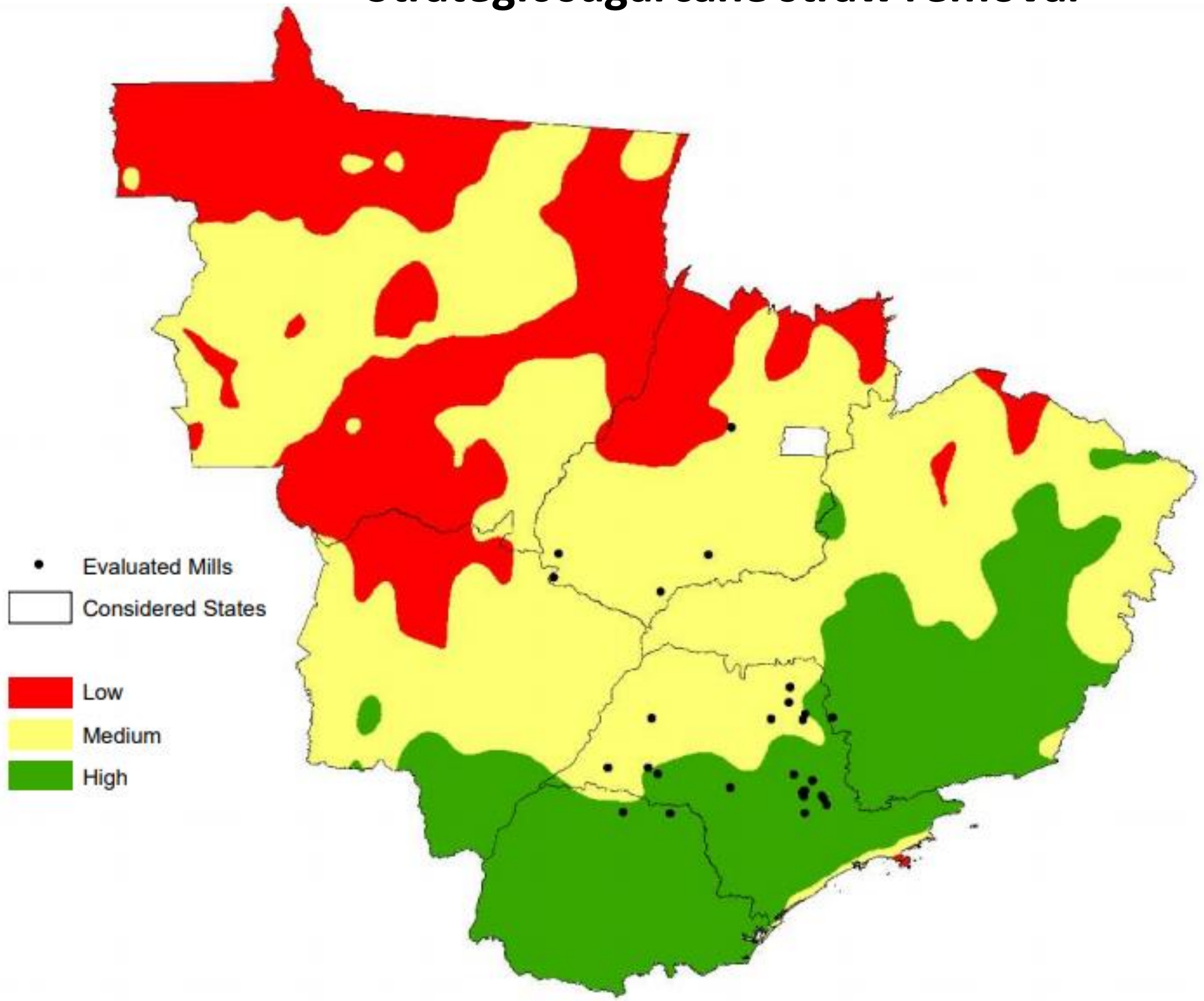
To analyze the water, land and climate impacts of electricity production systems in the context of the Sustainable Development Goals (SDGs).

We focus our analysis in the electricity production from sugarcane biomass in Brazil, since there is a great opportunity for better using this lignocellulosic material for bioenergy applications.

Methods

- We related appropriate Life Cycle Assessment (LCA) indicators to SDGs for electricity produced from sugarcane biomass in the Center-South region in Brazil
- **Irrigated and rainfed sugarcane yields**
  - Agroecological Zone Model (AZM) - FAO (Doorenbos and Kassam, 1979).
  - Climate data: National Center for Environmental Prediction (NCEP), Climate Forecast System Reanalysis (CFSR) (Saha et al., 2010, 2014)
- **Strategic sugarcane straw removal**
  - Based on site-specific recommendations for sugarcane straw removal (Hernandes et al., 2019)

Strategic sugarcane straw removal



Methods

- **Biomass value chain modeling**
  - Virtual Sugarcane Biorefinery (VSB), developed by the Brazilian Biorenewables National Laboratory (LNBR/CNPEM) (Bonomi et al., 2016).

- Each production point was assumed as one sugarcane mill, processing 4 million tonnes of sugarcane per year.
  - Products: ethanol, sugar and electricity.
  - Surplus electricity varies with different amounts of straw (according to the suitability of recovery).
  - Electricity is produced from sugarcane bagasse and straw.
  - Irrigated yield: Water requirements met with full irrigation in all the sugarcane area.

Methods

- Spatially-explicit Life Cycle Assessment

Sugarcane yield points plotted on Center-South map in GIS platform → Sugarcane yields and straw suitability for recovery per point as inputs in the VSB → VSB results reincorporated in GIS platform and interpolated to generate spatialized LCA results

- A Life Cycle Assessment was performed, considering one kWh of electricity as function unit, and energy allocation among sugarcane processing outputs (ethanol, sugar, electricity).
  - LCIA Method: Recipe Midpoint (H).
  - Impact categories: Water depletion (m^3/kwh), Agricultural land occupation (m^2/kWh); Climate change (gCO_2eq/kWh).
- The life cycle inventories were built based on VSB modeling.

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LCA indicators related to SDGs

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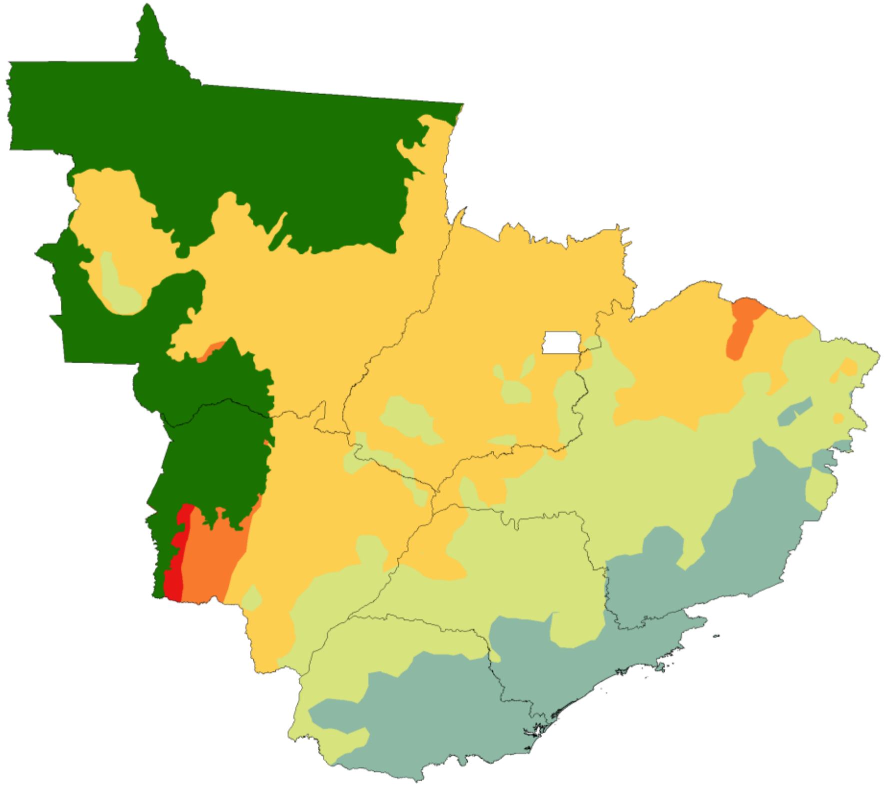
Impacts	LCA indicators	SDGs
Water	Water depletion (m^3/kWh)	6 CLEAN WATER AND SANITATION
Land	Agricultural land Occupation (m^2a/kWh)	15 LIFE ON LAND
Climate	Climate change (CO_2eq)	13 CLIMATE ACTION

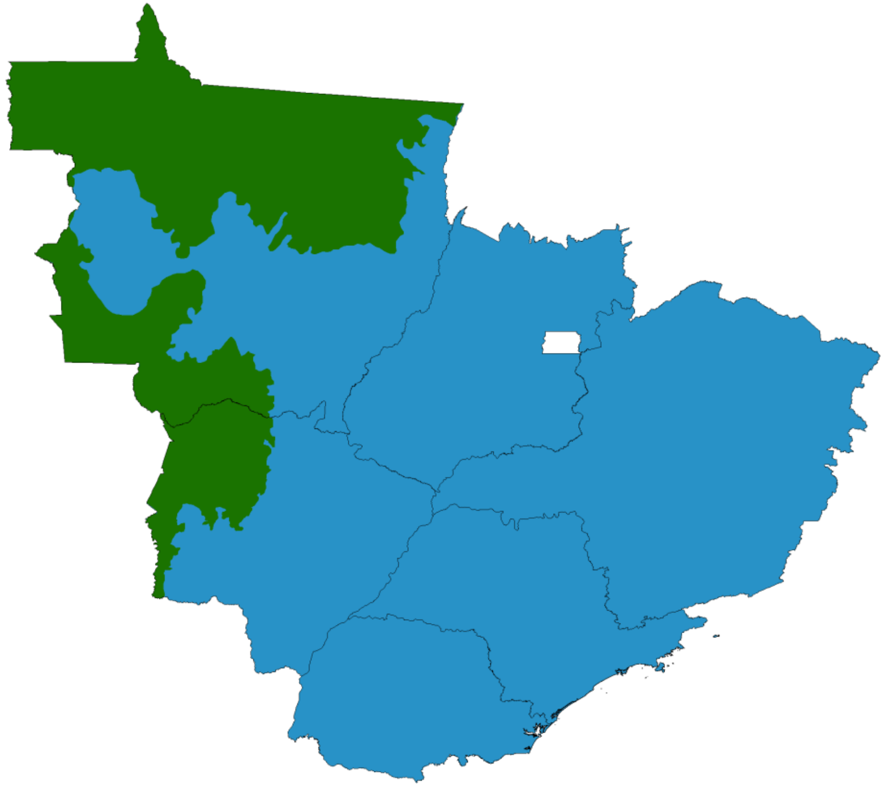
Water impacts

Water depletion (m³/kWh)

- States
- 0 - 3
- 3 - 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100 - 130
- Amazon and Pantanal biomes



Irrigated sugarcane yields

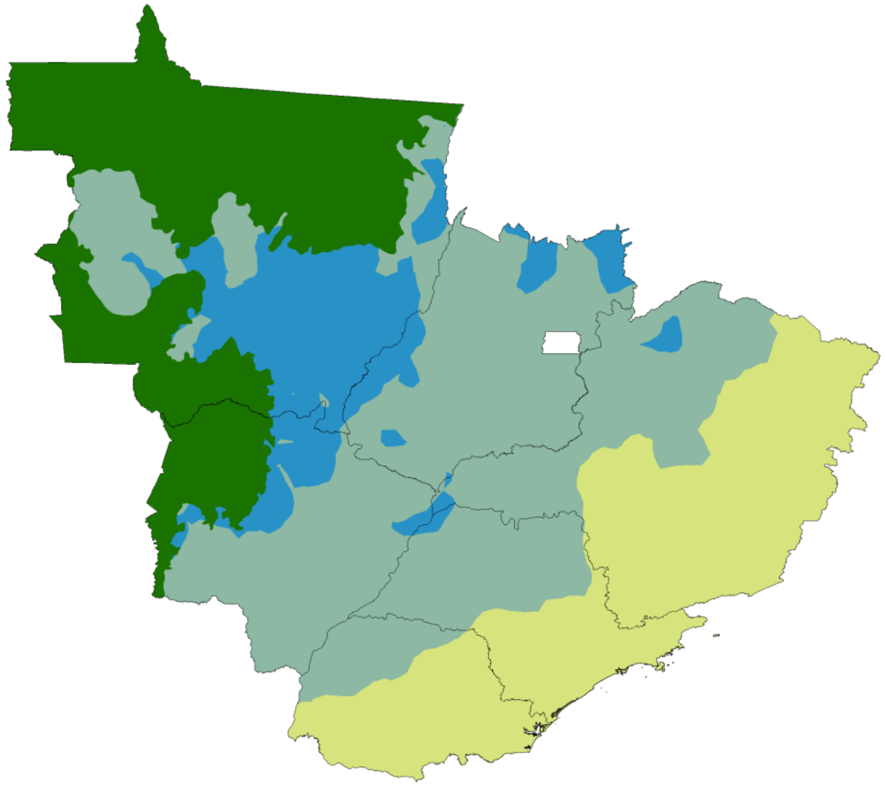


Rainfed sugarcane yields

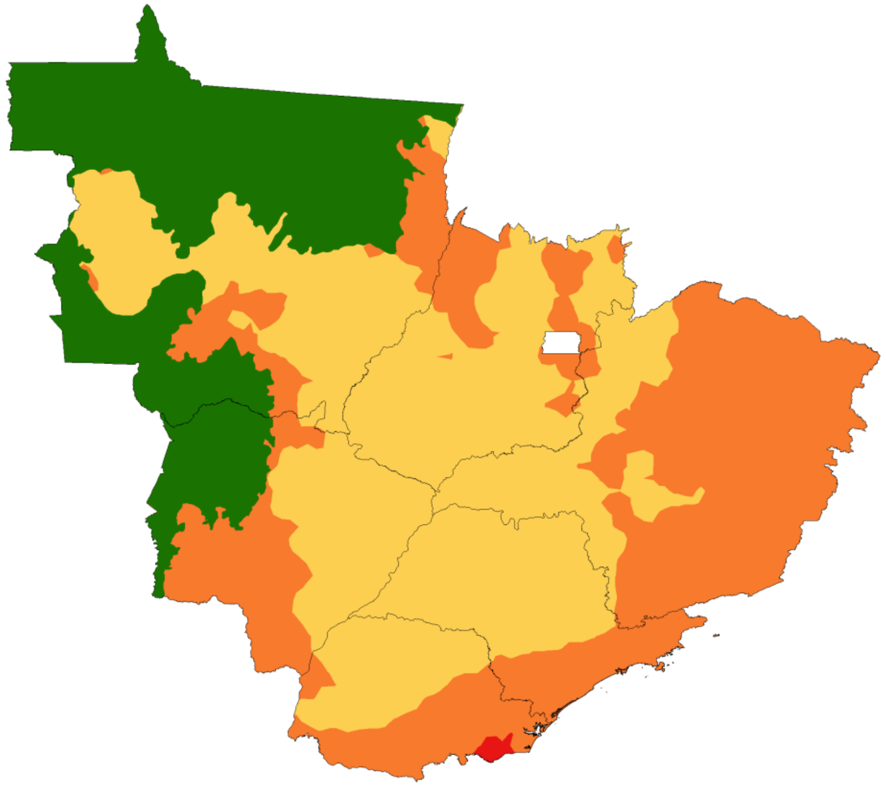
Land impacts

Agricultural land occupation (m^2a/kWh)

- States
- 60 - 75
- 75 - 85
- 85 - 180
- 180 - 205
- 205 - 290
- 290 - 390
- Amazon and Pantanal biomes



Irrigated sugarcane yields

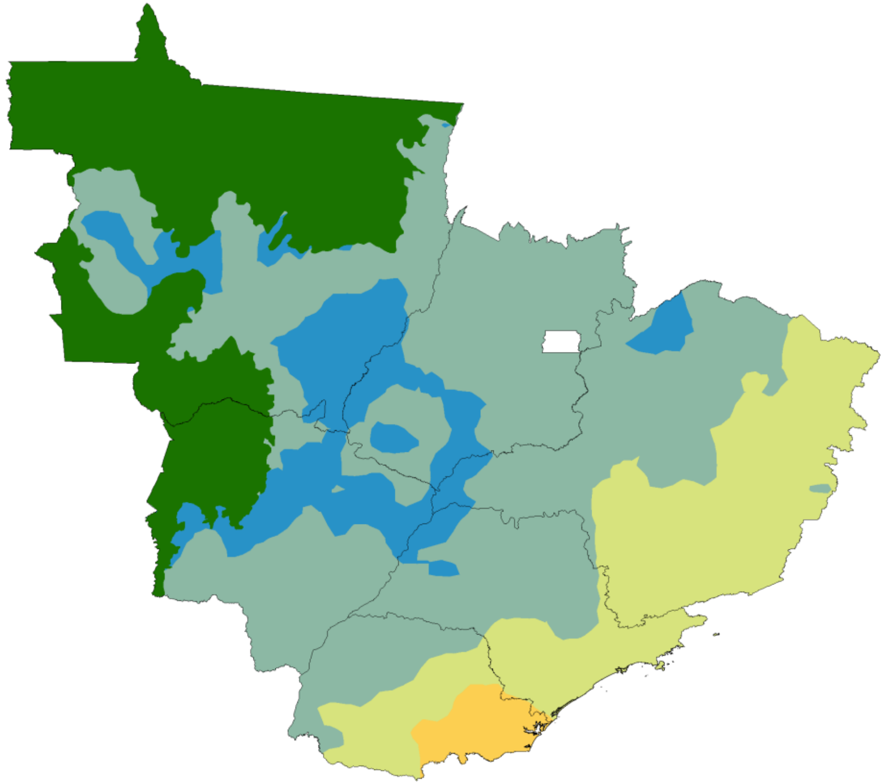


Rainfed sugarcane yields

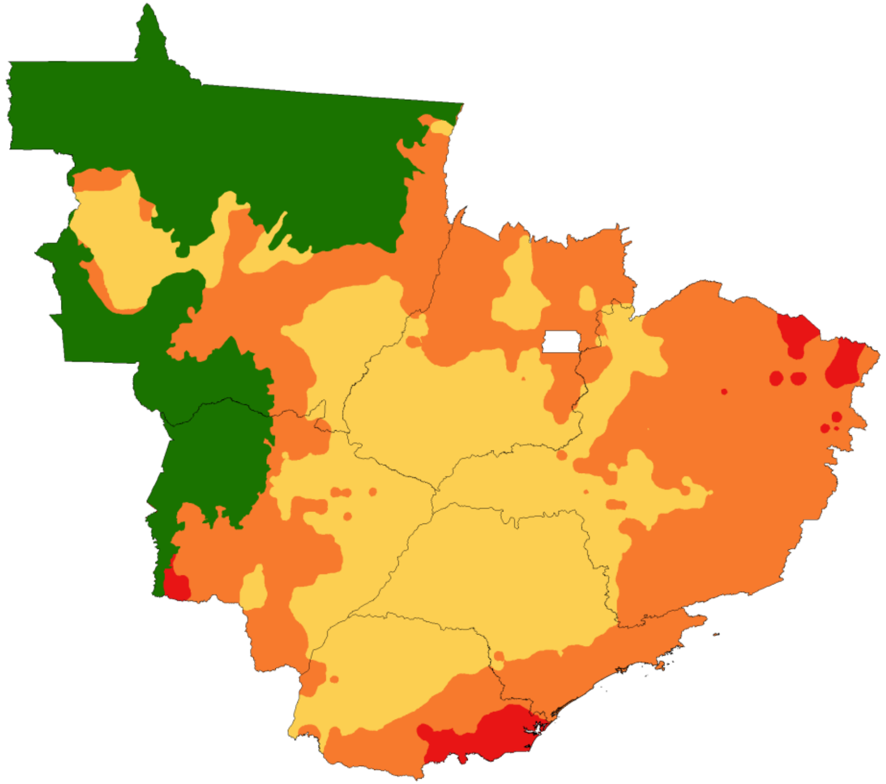
Climate impacts

Climate change (gCO_2eq/kWh)

- States
- 28 - 30
- 30 - 33
- 33 - 40
- 40 - 60
- 60 - 70
- 70 - 100
- Amazon and Pantanal biomes



Irrigated sugarcane yields



Rainfed sugarcane yields

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Water, land and climate nexus

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		Rainfed sugarcane yields	Irrigated sugarcane yields
6 CLEAN WATER AND SANITATION	Water impacts	Low	Medium
15 LIFE ON LAND	Land impacts	Medium	Low
13 CLIMATE ACTION	Climate impacts	High	Low

Electricity from rainfed sugarcane = lower water depletion

Electricity from irrigated sugarcane = lower demand of agricultural land

Electricity from irrigated sugarcane = lower CO_2eq emissions

Discussion

Electricity production from irrigated sugarcane provides lower climate and land use impacts, however, it has higher water impacts when compared to the rainfed sugarcane electricity.

A broader sustainability analysis identifying water, land and climate nexus of bioenergy production is key to achieve the SDGs.

The environmental impacts are site-specific and a spatially-explicit LCA can suggest technological solutions to minimize possible trade-offs among the analyzed impacts.

Final Remarks

Our analysis demonstrates the nexus implications of electricity production from sugarcane biomass in the context of the SDGs, as well as the spatially explicit environmental implications of electricity production from sugarcane biomass.

References

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