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Supply chain optimization study for ethanol production in Brazil.

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Introduction

Due to decades-long experience and know-how, the (mature) industrial processing technology, but also due to the availability of suitable land, Brazil has a large potential to further expand its ethanol production (Walter et al., 2011). The expansion of the ethanol industry in Brazil faces important challenges; a prominent one is to reduce total ethanol production costs in order to compete with fossil fuels and other biofuels.

Objective

The objective of this study is to determine the economically optimal location and scale of 1st and 2nd generation ethanol production plants, taking into account the expansion of biomass supply regions between 2012 and 2030. The resulting supply chain designs are also used to determine the distribution of available biomass among the industrial plants and the economic cost breakdown of ethanol production up to 2030. The state of Goiás is selected as case study area, considering both sugarcane as well as eucalyptus as feedstock.

Methods

The optimization problem is to determine the economic optimal location and scale of ethanol production facilities while utilizing the available biomass cultivated in the biomass supply regions. We deploy a strategic optimization model that considers the ethanol supply chain as a network of biomass supply regions which directly deliver to industrial processing locations. The distribution of biomass supply regions over the time period 2012-2030 is based on the land use change model PLUC (Verstegen et al. 2012). The costs of cultivation and industrial processing also declines over time due to yield improvement, increased efficiency and increase of industrial scale, similar to (Jonker et al 2015). By including the transport distances between supply regions, the optimization model BioScope (see Lin et al 2013) is utilized to determine the amount of biomass transported between the biomass supply regions and potential locations of processing plants. This model is deployed for 3 different approaches; considering no existing plants; considering the existing plants, in one time step to 2030; and considering existing plants but in five-year time steps towards 2030.

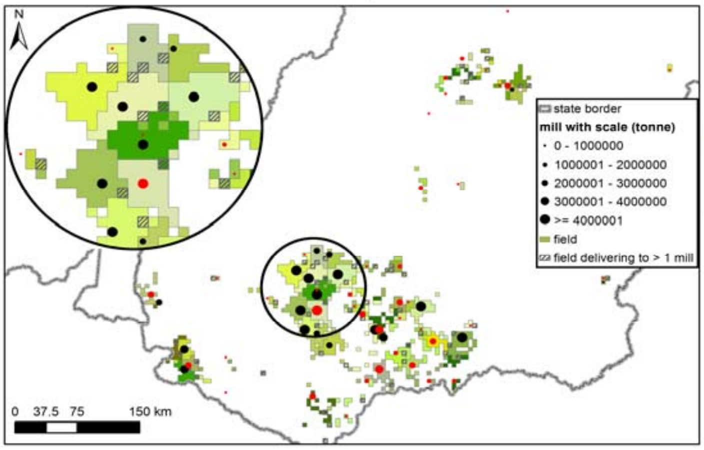

Figure 1. Distribution of sugarcane fields in Goiás in 2030 and industrial processing plants; red are existing plants and black are new plants as suggested by the model using multi step approach

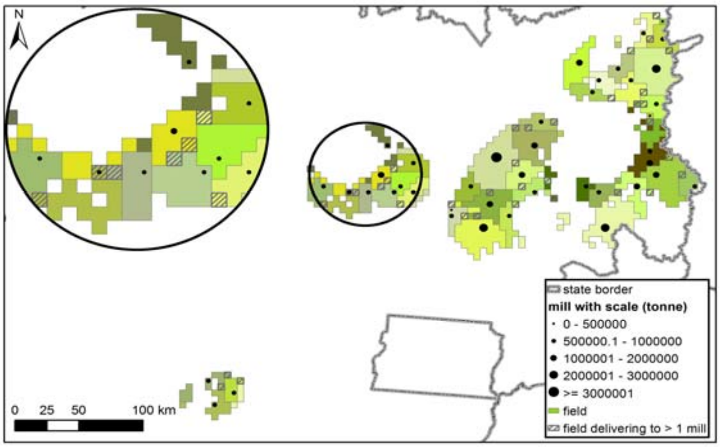

Figure 2. Distribution of eucalyptus fields in Goiás in 2030 and industrial processing plants; no existing plants, only new second generation plants as suggested by the model using multi step approach

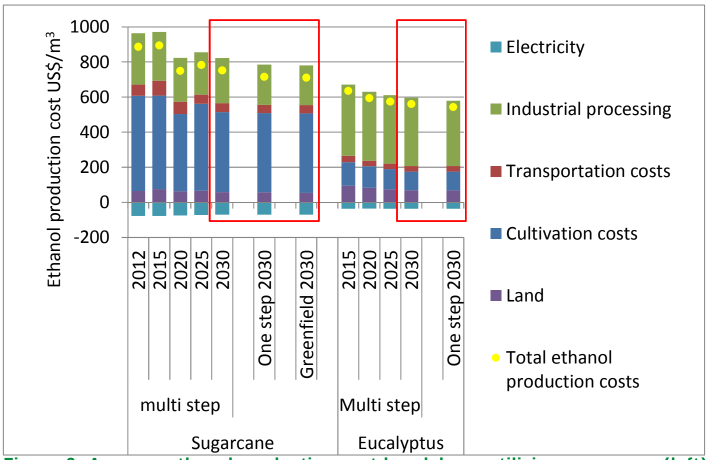

Figure 3. Average ethanol production cost breakdown utilizing sugarcane (left) and eucalyptus (right) in Goiás for multi-step, (2015, 2020, 2025 and 2030) one-step (2030) and greenfield optimisation (2030).

Key results

The optimization model selects large scale processing plants in high yield biomass supply regions, especially for sugarcane processing, see Figure 1 and 2. Compared to 2012, ethanol production costs decrease due to yield improvement or the change to second generation industrial processing, see Figure 3. Under the three different expansion approaches the total ethanol production costs of sugarcane ethanol decrease from 894 US$/m³ ethanol in 2012 to 752, 715 and 710 US$/m³ ethanol in 2030 for the multistep, one step and greenfield expansion respectively. For eucalyptus, ethanol production costs decrease from 635 US$/m³ in 2015 to 560, and 543 US$/m³ in 2030 for the multistep and one-step approach respectively. The differences between the different expansion approaches are small. Important to note that while costs for eucalyptus appear to be lower to sugarcane, the second generation industrial processing of eucalyptus utilizes a novel conversion process and its costs remain uncertain.

Conclusion

Given the predefined biomass supply region in Goiás, if the biomass availability is sufficient, the transport costs are offset by economy of scale for large scale industrial processing. We recommend to simultaneously optimize biomass supply regions, locations and size of industrial processing plants in future research. Furthermore, direct and indirect environmental impacts should be considered, as this provides more insight on the impact of biofuel expansion.

References

J.G.G. Jonker, F. van der Hilst, H.M. Junginger, O. Cavalett, M.F. Chagas APCF. Outlook for ethanol production cost in Brazil up to 2030, for different biomass crops and industrial technologies. Appl Energy 2014;-:14.

Lin T, Rodriguez LF, Shastri YN, Hansen AC, Ting K. GIS-enabled biomass-ethanol supply chain optimization: model development and Miscanthus application. BioFPR 2013;7:314–33.

Verstegen JA, Karssenberg D, van der Hilst F, Faaij A. Spatio-temporal uncertainty in Spatial Decision Support Systems: A case study of changing land availability for bioenergy crops in Mozambique. Comput Environ Urban Syst 2012;36:30–42.

Walter A, Dolzan P, Quilodrán O, de Oliveira JG, da Silva C, Piacente F, et al. Sustainability assessment of bio-ethanol production in Brazil considering land use change, GHG emissions and socio-economic aspects. Energy Policy 2011;39:5703–16.

Full research paper named "Supply chain optimization of sugarcane first generation and eucalyptus second generation ethanol production in Brazil" is submitted to Applied Energy

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