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Integrated assessment of future land use in Brazil under increasing demand for bioenergy

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Environmental impacts of a future increase in demand for bioenergy depend on the magnitude, location and pattern of the direct and indirect land use change of energy cropland expansion. Here we aim at 1) projecting the spatiotemporal pattern of sugar cane expansion and the effect on other land uses in Brazil towards 2030, and 2) assessing the uncertainty herein.

For the spatio-temporal projection, four model components are used: 1) an initial land use map that shows the initial amount and location of sugar cane and all other relevant land use classes in the system, 2) an economic model to project the quantity of change of all land uses, 3) a spatially explicit land use model that determines the location of change of all land uses, and 4) various analysis to determine the impacts of these changes on water, socio-economics, and biodiversity.

All four model components are sources of uncertainty, which is quantified by defining error models for all components and their inputs and propagating these errors through the chain of components. No recent accurate land use map is available for Brazil, so municipal census data and the global land cover map GlobCover are combined to create the initial land use map. The census data are disaggregated stochastically using GlobCover as a probability surface, to obtain a stochastic land use raster map for 2006.

Since bioenergy is a global market, the quantity of change in sugar cane in Brazil depends on dynamics in both Brazil itself and other parts of the world. Therefore, a computable general equilibrium (CGE) model, MAGNET, is run to produce a time series of the relative change of all land uses given an increased future demand for bioenergy. A sensitivity analysis finds the upper and lower boundaries hereof, to define this component's error model.

An initial selection of drivers of location for each land use class is extracted from literature. Using a Bayesian data assimilation technique and census data from 2007 to 2012 as observational data, the model is identified, meaning that the final selection and optimal relative importance of the drivers of location are determined. The data assimilation technique takes into account uncertainty in the observational data and yields a stochastic representation of the identified model. Using all stochastic inputs, this land use change model is run to find at which locations the future land use changes occur and to quantify the associated uncertainty.

The results indicate that in the initial land use map especially the shape of sugar cane and other land use patches are uncertain, not so much the location. From the economic model we can derive that dynamics in the livestock sector play a major role in the land use development of Brazil, the effect of this uncertainty on the model output is large. If the intensity of the livestock sector is not increased future projections show a large loss of natural vegetation. Impacts on water are not that large, except when irrigation is applied on the expanded cropland.