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Large-scale coupled system dynamics modelling and resilience to climate change in Guatemala's drought-prone areas

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System dynamics (SD) modelling is a useful tool for representing the socioeconomic components of coupled environmental-human systems and has been frequently used to include stakeholders in the development of environmental management decision-support systems to increase the potential for stakeholder adoption and use of the completed model. Given that SD is not very apt at representing hydrological and other physically-based environmental processes, recent research (such as the Tinamït software) has seen the development of methods of dynamically coupling stakeholder-built SD and physically-based models at runtime to allow decision-makers to analyse complex feedback loops between socioeconomic and environmental domains and to make informed policy decisions.

However, there remains a lack of methods to validate and calibrate socioeconomic SD models in data-poor settings, which complicates the analysis of important feedback processes when using coupled SD-physical models to assess the resilience of agricultural systems in the face of climate change. While hydrological and crop data for physically-based model components is often available in longer time series, socioecoomic data in more low-resource regions is often obtained from highly spatially explicit censuses conducted in a very few recent years.

In this research, we present a method to take advantage of the high spatial extent of very short time-series socioeconomic data with a case study from drought-prone areas of Guatemala, where Tinamït was used to couple a stakeholder-built SD model of food security with the cropping model DSSAT and CMIP5 climate change predictions. In this region, most but not all farming is dependent on rainfed agriculture, and complex interrelated issues of climate change-induced droughts, economics and food security, farming knowledge transfer, technology adoption choices and market structures that emerged from stakeholder interviews are included in the SD part of the model. The cropping model, in turn, takes farming management choices from the SD model and returns expected yields from the combination of management and present and future climate. We used national socioeconomic survey data to calibrate individual relationships that stakeholders had identified between the SD model variables, using the spatial extent of data to identify which relationships hold between nearby regions and which do not. The overall coupled model's behaviour was then tested with the few outcome variables for which we do have longer-term time series observations available.

Results show that key socioeconomic feedbacks within the model, such as the links between income, agriculture and food security, vary importantly in strength and even polarity between regions. These results highlight the need to develop region-specific model variants and associated policies in order to effectively plan for climate change resilience, adaptation and mitigation for smallholder farmers in Guatemala.