Alejandra Narváez Vallejo

Can the introduction of the topographic indices in LPJ-GUESS improve the spatial representation of environmental variables?

Ecosystem modelling is an always evolving science trying to catch the complexity of the nature and its principles to model environmental responses in a realistic way. Over and over, models try to introduce more variables and interactions to achieve better representations of phenomena of interest like the responses of the ecosystem to a fast changing world (climate change, land use change). LPJ-GUESS is a flexible dynamic ecosystem model widely used to model the structure and dynamics of terrestrial ecosystems. It is based on plant physiology, biochemical cycles and feedbacks on independent grid cells; nevertheless there is no consideration of lateral transfer of water between cells and this interaction with the surroundings becomes more important when analysing smaller scales such as the watershed level.

Topography is an important driver on determining the overland flow of water on a catchment, thus influencing the spatial variation of soil moisture and all the hydrological and biological conditions and processes linked to it (i.e. Evapotranspiration, decomposition, plant productivity, CO_2 production, etc.). Topographic characteristic can be summarized on topographic indices aim to represent the key hydrological processes driven by topography in a simplified but realistic way. Some of the most often studied topographic indices related to the distribution of water in the environmental compartments are slope, aspect and drainage area, and compound attributes such as the topographic wetness index a combination of both slope and specific drainage area.

Based on the former information, the current thesis considered important to assess the modelled spatial representation of environmental variables from LPJ-GUESS and to evaluate a possible method to include the effect of topography over the hydrology in LPJ-GUESS model. For this, Alergaarde catchment, a catchment with little relief located on central Jutland Denmark, was chosen, and by the use of correlation analysis and visual interpretation of observed and simulated spatial patterns of environmental variables (soil moisture, Leaf area index - LAI) the following issues were studied: 1) Importance of topography on the spatial distribution of environmental variables based on topographic indices (Ln (Drainage area), tan (angle slope) and topographic wetness index, TWI); 2) LPJ-GUESS ability to catch the environmental variables spatial distribution and 3) Implementation of a coupled LPJ-GUESS - topographic indices model (LPJ-Topographic index, LPJ-TI) to account for the topography influence on hydrology and assessment of its performance on modelling the spatial patterns of environmental variables. The coupled model, LPJ-TI, bases on making a cell wise characterization of the catchment based on giving weights to the range of values of the topographic index and using them to affect the water inputs to the soil layer as a way to account for hydrological processes driven by topography.

Results and conclusions

The results of the first two topics showed how LPJ-GUESS could not catch the spatial variations of satellite based LAI, and that even the gentle topography of the catchment was an important issue on explaining the heterogeneity of vegetation related variables. Nevertheless, it was also noticed that there are many factors (ex. weather conditions, land management activities) affecting the strength of this relationship, as reflected by the low correlation coefficients (never over 0.25), the variable correlation coefficients along the

year and the identification of areas more related to the topographic indexes than others. Additionally on the first topic, TWI was proven to be a good index for demonstrating the association of topography with LAI and was therefore selected to be used on the model LPJ-TI.

Regarding the last issue, LPJ-TI showed localized and time dependent improvement of the spatial representation of the satellite based LAI. These results confirm the need to include the topographic influence on the hydrological module of LPJ-GUESS and present a possible low computational method to start working on.

Keywords: Geography, Geographic information systems, GIS Physical Geography and Ecosystem analysis, GIS , LPJ-GUESS, topographic wetness index, slope, drainage area, smooth topography, leaf area index, spatial patterns, MODIS LAI.

Advisor: **Abdulghani Hasan**
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Department of Physical Geography and Ecosystems Sciences, Lund University.
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