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Coupled hydrologic and land use change models for decision making on land and water resources in the Upper Blue Nile basin

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Hydrology of a basin, alongside climate change, is well documented to impact and to be impacted by land use/land cover change processes. The need to understand the impacts of hydrology on land use change and vice-versa cannot be overstated especially in basins such as the Upper Blue Nile in Ethiopia, where the vast majority of farmers depend on rain-fed agriculture. A slight fluctuation in rainy seasons or an increase or decrease in magnitude of precipitation can easily trigger drought or flooding. On the other hand, ever growing population and emerging economic development, among others, is likely to continually alter land use/land cover change, thereby affecting hydrological processes.

With the intention of identifying and analyzing interactions and future scenarios of the hydrology and land use/land cover, we carried out a case study on a meso-scale catchment, in the Upper Blue Nile basin. A land use model using SITE (SImulation of Terrestrial Environments) was built for analyzing land use trends from aerial land cover photographs of 1957 and simulate until 2009 based on socio-economic as well as biophysical factors. Major land use drivers in the catchment were identified and used as input to the land use model. Separate land use maps were produced using Landsat images of 1972, 1986, 1994 and 2009 for historical calibration of the land use model. By the same token, a hydrological model for the same catchment was built using the SWAT (Soil and Water Assessment Tool) model. After calibration of the two independent models, they were loosely coupled for analyzing the changes in either of the models and impacts on the other.

Among other details, the coupled model performed better in identifying limiting factors from both the hydrology as well as from the land use perspectives. For instance, the simulation of the uncoupled land use model alone (without inputs from SWAT on the water budget of each land use parcel) continually considered a land use type such as a wet land/marsh land, simply as a wetland until the simulation period finishes. The wetland or the marsh land, which is not crop friendly in the location, does not get allocated to any other land use such as for certain crop types or settlement, because the land use model cannot tell how much water is added to or drained from each parcel every season. However, the simulation feedback from the coupled hydrological model shows that certain wetland/marsh land parcels, in fact, hold less and less water or even dry up during the simulation period, thereby putting themselves as a good candidate to be picked by the land use model in a next time step and to be allocated to other land use types. The same way, a measure in the land use aspect, which considers socio-economic as well as biophysical driving forces of in the catchment, shows changes in runoff and sedimentation levels in SWAT model outputs. The results of a future scenario considering the continuing population growth projects that about 35% of the wetland dries up and gets converted to cultivation by 2020.

This study emphasizes the importance of identifying possible impacts of the future hydrology on other components of the socio-environmental systems and contrariwise during environmental decision making, especially in areas where a relatively small change may have large impacts (such flood and/or drought prone basins as the Nile). The study also demonstrates a sound methodology for assessing the impact of land use change on hydrology and vice-versa by dynamically exchanging data through feedback mechanisms (coupling socio-environmental and hydrological models) which lead to a better understanding of socio-environmental problems.

Keywords: Coupling, socio-environment, Nile, land use models, hydrological models