Tipping points and regime shifts in dynamic systems : a new modeling approach to study Sahelian ecohydrology

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Résumé

The Sahel witnessed a climatic drought from the 1970s to the 2000s. During this period, vegetation cover decreased and surface runoff increased in many places. While annual rainfall has partly recovered since the begining of this century, runoff has not reacted accordingly. The state of the ecohydrological system changed, and it responds in a new way to similar forcings. This study aims to better understand these regime shifts : their modalities (abrupt or gradual changes), the involved processes, and their impact on the water cycle components. System dynamics modeling is considered. The system (watershed) evolution under forcings (the climate) is modeled by a system of ordinary differential equations. This approach is common in theoretical ecology, but still little explored in hydrology. It allows representing regime shifts and studying their causes and consequences.

A model representing the dynamics of vegetation cover and runoff has been developed. The first order processes and their feedbacks (positive or negative) under the Sahelian climate are considered.

A first case study allowed to test the model on a tiger bush site in the Malian Gourma exhibiting very little anthropic forcing, and where observations exist since the 1950s. This site evolved from a vegetated and low runoff state before drought to a very low vegetated and high runoff state nowadays. Forced by the rainfall time series, the model allows, after calibration, to reproduce the observed regime shift and to characterize the tipping points (date, causes). The approach is then applied on other case studies to improve its reliability at the regional scale.
This study demonstrates the ability of system dynamics models to contribute to understand the instabilities in the Sahelien eco-hydrological functioning.

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