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Tipping points in hydrology: observed regional regime shift and System Dynamics modeling

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River runoff and climate data existing from 1950 to present time in West Africa are analyzed over a climatic gradient from the Sahel (semi-arid) to the Gulf of Guinea (humid). The region experienced a severe drought in the 70s-90s, with strong impact on the vegetation, soils and populations. We show that the hydrological regime in the Sahel has shifted: the runoff increased significantly between pre- and post-drought periods and is still increasing. In the Guinean region, instead, no shift is observed.

This suggests that a tipping point could have been passed, triggered by climate and/or land use change. In order to explore this hypothesis, we developed a System Dynamics model representing feedbacks between soil, vegetation and flow connectivity of hillslopes, channels and aquifers. Model runs were initialized in 1950 with maps of land use/land cover, and fed with observed rainfall (climate external forcing).

The modeling results accurately represent the observed evolution of the hydrological regime on the watersheds monitored since the 50s (ranging from 1 to 50000 km²). The model revealed that alternative stable states can exist for the climatic conditions of the study period. From the model runs, we showed that the drought triggered the crossing of a tipping point (rainfall threshold), which explains the regime shift. We identified domains within the watersheds where tipping

occurred at small scale, leading to larger scale shifts. This result supports that tipping points exist in semi-arid systems where ecohydrology plays a major role. This approach seems well suited to identify areas of high risk of irreversible hydrological regime shifts under different climate and land-use scenarios.

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