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Classification and prediction of river network ephemerality using the Budyko framework and its relevance for waterborne disease epidemiology

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The transmission of waterborne diseases hinges on the interactions between hydrology and ecology of hosts, vectors and parasites, with the long-term absence of water constituting a strict lower bound. However, the link between spatio-temporal patterns of hydrological ephemerality and waterborne disease transmission is poorly understood and difficult to account for. The use of limited biophysical and hydroclimate information from otherwise data scarce regions is therefore needed to characterize, classify, and predict river network ephemerality in a spatially explicit framework. Here, we leverage the Budyko framework to develop a novel large-scale ephemerality classification and prediction methodology based on monthly discharge data, water and energy availability, and remote-sensing measures of vegetation, that is relevant to epidemiology, and maintains a mechanistic link to catchment hydrologic processes. Specifically, with reference to the context of Burkina Faso in sub-Saharan Africa, we extract a relevant set of catchment covariates that include the aridity index, annual runoff estimation using the Budyko framework, and hysteretical relations between precipitation and vegetation. Five ephemerality classes, from permanent to strongly ephemeral, are defined from the duration of 0-flow periods. Using such classes, a gradient-boosted tree-based prediction yielded three distinct geographic regions of ephemerality. Importantly, we observe a strong epidemiological association between our predictions of hydrologic ephemerality and the known spatial patterns of schistosomiasis, an endemic parasitic waterborne disease in which infection occurs with human-water contact, and requires aquatic snails as an intermediate host. The general nature of our approach based on the Budyko framework and its relevance for predicting the hydrologic controls on schistosomiasis occurrence provides a pathway for the explicit inclusion of hydrologic drivers within epidemiological models of waterborne disease transmission.