Stochastic description of waterlogging and hydroperiods in wetlands

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Stochastic description of waterlogging and hydroperiods in wetlands

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Wetlands are found at the interface between aquatic and terrestrial ecosystems, where different hydrologic factors and ecosystem processes interact to generate unique characteristics and a delicate balance between biotic and abiotic factors. The main hydrologic driver of wetland ecosystems is the water level, whose position above or below the ground level, determines the submergence or non-submergence of soil. When the water level lies above the soil surface, soil is saturated and hypoxic conditions affect all biochemical processes, inducing anaerobic microorganism functioning, variation of redox potential, and anoxic stress in plants, that might lead to the death of non-adapted organisms. When the water level is below the soil surface, the soil water balance is similar to that of groundwater-dependent ecosystems, which allows for both oxygen and water supply to the plant roots. Therefore, the succession of the submerged-unsubmerged conditions plays a fundamental role on the ecosystem.

Shallow or above-ground water level fluctuations, at the daily time scale, are driven by stochastic precipitation; using a simple process-based model for soil water balance, the dynamics of groundwater level is here described as a function of evapotranspiration, lateral flow to/from an external water body and random precipitation, modeled as a marked Poisson process. This simple model provides the analytical long-term probability distribution of water table depth and the crossing properties of water table dynamics, which are used to study the timing of waterlogging. The interval of time during which a wetland remains flooded, often called “hydroperiod”, is represented by the first passage time of water table in down-crossing the soil surface; here we calculate the mean hydroperiod as the Mean First Passage Time of the process, that is a function of the model parameters, and we verify this result with numerical simulations. Focusing on the statistical properties of hydroperiods, we also propose to describe their long term probability distribution with a parametric distribution, whose parameters are linked to the model parameters through simple analytical relations. Numerical simulations again confirm the validity of the approach, and its capability of describing the properties of hydroperiods as a function of the climatic, pedological, and ecological characteristics of wetlands.