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Level crossing properties of eco-hydrological systems driven by dichotomic Markov noise

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Level crossing properties and mean first passage times (MFPT) in systems driven by external noise have been frequently utilized to characterize stochastic dynamics in different fields, including chemistry, physics, and statistics. MFPT can also have useful applications to the study of the soil moisture dynamics in eco-hydrology. For example, their analysis is important to investigate the linkage between climate, soil, and vegetation through soil moisture dynamics. In fact, plants begin to close their stomata and to suffer water stress when soil moisture is below a threshold value. The mean first passage time of this threshold has been shown to be an important indicator of plant conditions in water-limited ecosystems. Earlier studies have determined a relatively simple analytical expression for MFPT of processes driven by uncorrelated noise, i.e. white shot noise and gaussian white noise, while more complicate expressions are needed when dealing with processes forced by correlated noise, such as the dichotomous Markov noise. Earlier studies have also shown that ecosystem dynamics in semi-arid environments can be well-described through a dichotomous Markov process, i.e., as an alternation between two different states, corresponding to stressed and unstressed conditions for vegetation. In each state the dynamics are described by a different equation, and the long term behavior of the system can be investigated using the framework of the dichotomous Markov processes. The persistence of these dynamics below or above a threshold level can be expressed in terms of MFPT. Here we propose a rather intuitive and direct method to determine analytical expressions for MFPT for processes forced by dichotomic Markov noise, and use this framework to describe the

effect of water stress on arid and semi-arid ecosystems.