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Stochastic physical ecohydrologic-based model for estimating irrigation requirement

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Climate uncertainty affects both natural and managed hydrological systems. Therefore, methods which could take this kind of uncertainty into account are of primal importance for management of ecosystems, especially agricultural ecosystems. One of the famous problems in these ecosystems is crop water requirement estimation under climatic uncertainty. Both deterministic physically-based methods and stochastic time series modeling have been utilized in the literature. Like other fields of hydroclimatic sciences, there is a vast area in irrigation process modeling for developing approaches integrating physics of the process and statistics aspects. This study is about deriving closed-form expressions for probability density function (p.d.f.) of irrigation water requirement using a stochastic physically-based model, which considers important aspects of plant, soil, atmosphere and irrigation technique and policy in a coherent framework. An ecohydrologic stochastic model, building upon the stochastic differential equation of soil moisture dynamics at root zone, is employed as a basis for deriving the expressions considering temporal stochasticity of rainfall.

Due to distinguished nature of stochastic processes of micro and traditional irrigation applications, two different methodologies have been used. Micro-irrigation application has been modeled through dichotomic process. Chapman-Kolomogrov equation of time integral of the dichotomic process for transient condition has been solved to derive analytical expressions for probability density function of seasonal irrigation requirement. For traditional irrigation, irrigation application during growing season has been modeled using a marked point process. Using the renewal theory, probability mass function of seasonal irrigation requirement, which is a discrete-value quantity, has been analytically derived.

The methodology deals with estimation of statistical properties of the total water requirement in a growing season that could be used in shorter time horizon applications under special circumstances. Also, a wide range of irrigation management policies from stress-avoidance to rainfed, including deficit irrigation, could be addressed. The presented model has been applied in three real cases with semi-arid climate in Iran including Dasht-e-Abbas, Ein-Khosh and Fakkeh Irrigation Districts in which respectively surface, sprinkler and micro irrigation techniques are utilized. Sensitivity analysis with respect to all influential parameters has been performed. Results show that while increase in rainfall parameters (leading to increase of total seasonal rainfall) reduces irrigation water requirement, they have contrasting effects on uncertainty of irrigation requirement.