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Ecohydrology of agroecosystems: probabilistic description of yield reduction risk under limited water availability

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Supplemental irrigation represents one of the main strategies to mitigate the effects of climate variability and stabilize yields. Irrigated agriculture currently provides 40% of food production and its relevance is expected to further increase in the near future, in face of the projected alterations of rainfall patterns and increase in food, fiber, and biofuel demand. Because of the significant investments and water requirements involved in irrigation, strategic choices are needed to preserve productivity and profitability, while maintaining a sustainable water management - a nontrivial task given the unpredictability of the rainfall forcing. To facilitate decision making under uncertainty, a widely applicable probabilistic framework is proposed. The occurrence of rainfall events and irrigation applications are linked probabilistically to crop development during the growing season and yields at harvest. Based on these linkages, the probability density function of yields and corresponding probability density function of required irrigation volumes, as well as the probability density function of yields under the most common case of limited water availability are obtained analytically, as a function of irrigation strategy, climate, soil and crop parameters. The full probabilistic description of the frequency of occurrence of yields and water requirements is a crucial tool for decision making under uncertainty, e.g., via expected utility analysis. Furthermore, the knowledge of the probability density function of yield allows us to quantify the yield reduction hydrologic risk. Two risk indices are defined and quantified: the long-term risk index, suitable for long-term irrigation strategy assessment and investment planning, and the real-time risk index, providing a rigorous probabilistic quantification of the emergence of drought conditions during a single growing season in an agricultural setting. Our approach employs relatively few parameters and is thus easily and broadly applicable to different crops and sites, under current and future climate scenarios. Hence, the proposed probabilistic framework provides a quantitative tool to assess the impact of irrigation strategy and water allocation on the risk of not meeting a certain target yield, thus guiding the optimal allocation of water resources for human and environmental needs.