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Implications for water use of a shift from annual to perennial crops – A stochastic modelling approach based on a trait meta-analysis

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The projected population growth and changes in climate and dietary habits will further increase the pressure on water resources globally. Within precision farming, a host of technical solutions has been developed to reduce water consumption for agricultural uses. The next frontier for a more sustainable agriculture is the combination of reduced water requirements with enhanced ecosystem services. Currently, staple grains are obtained from annuals crops. A shift from annual to perennial crops has been suggested as a way to enhance ecosystem services. In fact, perennial plants, with their continuous soil cover and the higher allocation of resources to the below ground, contribute to the reduction of soil erosion and nutrient losses, while enhancing carbon sequestration in the root zone. Nevertheless, the net effect of a shift to perennial crops on water use for agriculture is still unknown, despite its relevance for the sustainability of such a shift. We explore here the implications for water management at the field- to farm-scale of a shift from annual to perennial crops, under rainfed and irrigated agriculture. A probabilistic description of the soil water balance and crop development is employed to quantify water requirements and yields and their inter-annual variability, as a function of rainfall patterns, soil and crop features. Optimal irrigation strategies are thus defined in terms of maximization of yield and minimization of required irrigation volumes and their inter-annual variability. The probabilistic model is parameterized based on an extensive meta-analysis of traits of co-generic annual and perennial species to explore the consequences for water requirements of shifting from annual to perennial crops under current and future climates. We show that the larger and more developed roots of perennial crops may allow a better exploitation of soil water resources and a reduction of yield variability with respect to annual species. At the same time, perennial crops are larger and may require adequate water supply for longer periods, thus leading to higher water requirements. Furthermore, they lead to lower yields per unit area, thus requiring irrigation of larger areas.