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Virtual water content of temperate cereals and maize: Present and potential future patterns

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Knowledge of the virtual water content (VWC) of crops and especially its possible future developments is helpful for improvements in water use efficiency and water management, which are necessary due to rising demand for food, the necessity to ease present and future water scarcity, and the reduction of poverty. Using the dynamic global vegetation and water balance model LPJmL, we quantified the VWC of two of the most important crop types worldwide, temperate cereals and maize, at high spatial resolution (0.5°). We analyzed present conditions (1999–2003) as well as scenarios of future climate and increasing atmospheric CO_2 concentrations (2041–2070; HadCM3, ECHAM5 and CCSM3 climate models, A2 emissions scenario). VWC presently differs significantly among regions: lowest values were found $e.g.$for Central Europe ($<$0.5 $m^3 kg^{-1}$), and highest values are common in large parts of Africa ($>$2 m^3 kg^{-1}), indicating that water-use efficiency of crops is much lower in the latter region. This also implies that there is a high potential for improvements in crop water-use efficiency in tropical and subtropical regions, especially in Africa and Southeast Asia. The regional patterns of VWC result from complex and interactive processes; the dominant factor is the crop yield level (high VWC values occur most frequently in regions with low yields). Climate change and rising atmospheric CO_2 concentration will have non-uniform effects on crop yields and evapotranspiration. Worldwide VWC patterns will change significantly, with a pronounced regional pattern that reflects primarily the changes in yields as driven mainly by regionally decreasing precipitation, increasing temperature and increasing atmospheric CO_2 concentration. Although globally the water use efficiency is projected to increase, many regions—including parts of the U.S., East and Mediterranean Europe, South Africa, Argentina, Australia and South East Asia—are projected to become less water efficient (higher VWC) for at least one of the crop types. CO_2 fertilisation was simulated to generally reduce VWC, though realisation of this effect in the field will depend, for example, on the intensity of nutrient management in the future. The potentially adverse future changes in VWC found in this study pose a challenge to water management efforts and eventually global trade policies.