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Frost risk for overwintering crops in a changing climate

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Climate change scenarios predict a general increase in daily temperatures and a decline in snow cover duration. On the one hand, higher temperature in fall and spring may facilitate the development of overwintering crops and allow the expansion of winter cropping in locations where the growing season is currently too short. On the other hand, higher temperatures prior to winter crop dormancy slow down frost hardening, enhancing crop vulnerability to temperature fluctuation. Such vulnerability may be exacerbated by reduced snow cover, with potential further negative impacts on yields in extremely low temperatures. We propose a parsimonious probabilistic model to quantify the winter frost damage risk for overwintering crops, based on a coupled model of air temperature, snow cover, and crop minimum tolerable temperature. The latter is determined by crop features, previous history of temperature, and snow cover. The temperature-snow cover model is tested against meteorological data collected over 50 years in Sweden and applied to winter wheat varieties differing in their ability to acquire frost resistance. Hence, exploiting experimental results assessing crop frost damage under limited temperature and snow cover realizations, this probabilistic framework allows the quantification of frost risk for different crop varieties, including in full temperature and precipitation unpredictability. Climate change scenarios are explored to quantify the effects of changes in temperature mean and variance and precipitation regime over crops differing in winter frost resistance and response to temperature.