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Development of the "Agricultural Simulator" AgraSim for comprehensive experimental simulation and analysis of environmental impacts on processes in the soil-plant-atmosphere system

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For studying the effects of future climate conditions on plant physiological, biogeochemical, hydrological and atmospheric processes in agroecosystems, we developed a large-scale research infrastructure, called AgraSim. AgraSim is an experimental simulator consisting of six mesocosms, each of them consisting of an integrated climate chamber, plant chamber and lysimeter system. The system makes it possible to simulate the environmental conditions in the mesocosms in a fully controlled manner under different weather and climate conditions ranging from tropical to boreal climate. Moreover, it provides a unique way of imposing future climate conditions which presently cannot be implemented under real-world conditions. It allows monitoring and controlling states and fluxes of a broad range of processes in the soil-plant-atmosphere system. This information can then be used to give input to process models, to improve process descriptions and to serve as a platform for the development of a digital twin of the soil-plant-atmosphere system. In detail, each mesocosm consists of a high-precision lysimeter (weighable, control of temperature and lower boundary) with a monolithic soil core (1 m2 surface area and 1.5 m depth) and a transparent, fully controllable plant chamber (7 m3 volume) with an LED light source very similar to the natural solar spectrum with a maximum intensity of 2,500 µmol of photosynthetically active photons per square meter and second. With an in-house developed, fully automated process control system, defined climatic and weather conditions as well as air compositions can be set and varied on the basis of a predefined weather data profile. The inner surfaces of the plant chambers have the purest and most inert properties possible, with the aim of minimizing interactions between the ambient air of the plants and the chamber wall. Strong LED-based plant lighting provides light conditions similar to daylight, which prevents too large heat input into the chamber. A new concept was developed and implemented to dissipate this heat by avoiding condensation at all times, as condensation dissolves gas molecules from the air in the condensate, changing the isotope composition and thus impeding the atmospheric measurements. The process technology

includes the precise control of the supply air volume flow, pressure, humidity, carbon dioxide content, air temperature, light intensity within the plant chamber, soil temperature and irrigation.