# Adapting the CERES model to simulate growth and production of cereal rye

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Rye (*Secale cereale L.*) is primarily grown as an annual winter crop throughout the temperate zones of the northern hemisphere. Due to its high resource use efficiency, rather low input requirements and high resistance to frost and drought, it has good potential to support more sustainable crop production in the face of future climate change and rising food demand.

Process-based dynamic crop models are cutting-edge tools in current agronomic research by simulating crop growth, development, and yield under diverse soil, climate, and management conditions. They enable to evaluate the impacts of climate variability and management practices on agricultural production beyond limited field experiments. We choose to adapt the widely applied CSM CERES-wheat as a starting point for the rye model development, as rye is similar to wheat in terms of its morphological and physiological proper-ties.

We created large agronomic trial datasets of cultivar-specific data (rye cv. Palazzo and wheat cv. Winnetou) using value for cultivation and use (VCU) trial data from the Federal Plant Variety Office and state variety trials of Saxony-Anhalt (SVT). The datasets cover all relevant wheat and rye-growing regions in Germany, allowing us to scale up model calibration. We added in-season data from an N-regime trial in Kiel, Northern Germany, from 2008 to 2010, and the Julius Kuehn Institute in Braunschweig, Central Germany, from 2009 to 2010. Weather data for each experimental site were retrieved from the German weather service's climate data center (DWD), and soil data were derived from the European Soil Database (ESDB) v2.0, both data in $1km^2$ grid scale.

The CERES-rye model showed satisfactory simulation accuracy regarding phenology, LAI, aboveground biomass, and tiller m-2 at harvest, unit grain weight, grain m-2 at harvest, and grain yield. Simulation-observation comparisons resulted in an RMSE of 3.3 days for emergence, 7.2 days for anthesis, and 7.3 days for harvest maturity date for the calibration dataset from the phenology part. From the growth and yield simulation, RMSE of 1.61 for LAI, 2468.7 kg $ha^{-1}$ for biomass, 169.6 for tiller $m^{-2}$, 7708.0 for grain $m^{-2}$, 3.6 mg for unit grain weight, and 2182.7 kg $ha^{-1}$ for grain yield.

CERES-rye is available to conduct various CSM-based analysis including the evaluation of crop management strategies, consideration in analyzing crop rotations in DSSAT, and assessing rye's suitability for cultivation in different growing environments.