PS-4.1-05

## Assessment of the impact of climate change in temperate zone on grain legume yield and N2 fixation

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**Abstract:** Climate change is likely to strengthen abiotic stresses on crops in temperate zones. Grain legumes and the associated provision of ecosystem services are the cornerstone of more sustainable cropping systems, yet the impact of climate change on their performance has not been extensively quantified. Based on previous experiments carried out in south-western France with low biotic stress, we calibrated the STICS soil-crop model for spring pea (SP), winter pea (WP) and winter faba bean (WF) grown on two types of soil with available soil water ranging from 64 to 167 mm and evaluated its quality of prediction on an independent dataset. STICS was used to explore the effect of climate change scenarios on the legumes performance. Assuming no adaption of crop management, mean and inter-annual variability of grain yield and $N_2$ fixation were assessed for historical (1995-2015), mid-term (2020-2040) and long-term (2060-2080) periods, considering projections from two coupled atmosphere-ocean Global Circulating Models (GCM), and two Representative $CO_2$ Concentration Pathways (RCP), *i.e.* RCP 4.5 and RCP 8.5. The GCMs consistently predicted no significant change in rainfall amounts but indicated a 1.7°C and 2.5°C increase in average temperature over the growth period in the long term under RCP 4.5 and RCP 8.5 respectively. Therefore, simulations indicated no extra water stress with future climate. The increase in temperature entailed a shortening in crop duration and a slight but significant increase in the temperature stress factor values for grain filling, for photosynthesis and for $N_2$ fixation during the reproductive period (+1% to +13 % depending on temperature stress, crop and RCP). Under RCP 4.5, yield decreased by 23 to 34% (depending on crop) in the long term. Average fixed $N_2$ decreased by 16% to 34%. Probability of yield failure (i.e. yield below the 20$^{th}$ percentile of historical yield) increased from 20 to 50, 54 and 58% for WF, WP and SP respectively. Probability of N2 fixation failure increased from 20 to 34, 50 and 53% for WP, WF and SP respectively. In contrast, under RCP 8.5, the CO2 fertilisation effect would offset the decrease in yield due to the shortening in crop duration and simulations predicted a 8 to 13 % average yield increase in the long term. Average $N_2$ fixation would increase by 15 to 23%. Probability of yield failure would increase from 20 to 21, 25 and 27% for WF, WP and SP respectively. Probability of $N_2$ fixation failure would increase for SP (from 20 to 31%) but decrease for WF (from 20 to 13%) and WP (from 20 to 11%). The increased probability of yield and $N_2$ fixation failure simulated with the RCP 4.5 scenario indicates the need for technical and transformational adaptations for grain legumes to deliver the expected ecosystem services with future climate. Under RCP 8.5, better yield and $N_2$ fixation with elevated $CO_2$ highlight the opportunity represented by climate change for inclusion of more grain legumes in cropping systems.

**Keywords:** STICS, pea, faba bean, risk

PS-4.1-06

## Comparison of Water Balance and Root Water Uptake Models in Simulating CO2 and H2O Fluxes and Growth of Wheat

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**Abstract:** Accurate modelling of how soil water stress affects canopy exchange, crop growth and yield is crucial for reliable predictions in heterogeneous fields and landscapes from crop models. Current crop models use a coupled photosynthesis-stomatal conductance model ($A – g_s$) for simulating canopy $CO_2$ and $H_2O$ exchange. These models account for water stress which is simply calculated either from soil water content (SWC) or soil water potential without considering the plant hydraulic conductance and are thus unable to represent specific stomatal behaviors. We modified the original LINTULCC2 crop model using the coupled ($A – g_s$) model and linked it with Couvreur's root water uptake model (RWU) and the HILLFLOW 1D water balance model in order to explicitly represent stomata regulation and the whole plant hydraulic signal. We carried out a comprehensive comparison of the following modelling approaches for simulating gas fluxes and crop growth: HILLFLOW 1D with modified LintulCC2-Couvreur's RWU at daily (CoD) and hourly (CoH) model resolutions; HILLFLOW 1D with modified LintulCC2-Feddes at daily (FeD) and hourly (FeH) resolutions, and the original LintulCC2 with daily resolution considering a tipping-bucket water balance approach (TiD). The simulations were compared with corresponding data collected from a wheat grown in a heterogeneous farmers field under three water supply regimes (sheltered, rain-fed and irrigated) and two soil types (stony and silty) in Western Germany in 2016. CoD and CoH consider the whole plant hydraulic conductance while FeD, FeH, and TiD do not. Comparing approaches at daily time step and under all studied water regimes CoD and FeD out-performs TiD in predicting gross primary product (Pg) with $R^2$ (0.58, 0.6 and 0.46) and RMSE (8.11, 7.87, and 9.74 micromole $m^{-2}$ $s^{-1}$), respectively. Under optimum water conditions, all simulations had a similar performance for Pg prediction ($R^2$ = 0.65 for all models), while the $R^2$ of CoD, FeD, and TiD under severe drought (stony soil with the shelter) were 0.5, 0.48 and 0.28, respectively. This indicated that the performance of the modelling approaches declined in the following order: CoD >= FeD > TiD. A similar performance order was observed for the simulated above ground biomass, actual transpiration, and seasonal SWC profiles. The simulations with hourly time step (CoH and FeH) performed slightly better than approaches with daily time step (CoD and FeD, respectively). In the coupled A-gs model, consideration of the hydraulic conductance from root to shoot not only improved the prediction of canopy gas exchange and other outputs under heterogeneous fields but also required less parameter calibration as compared to the Feddes' empirical RWU approach. The newly coupled model (modified LINTULCC2 with Couvreur's method) with hourly resolution requires further testing for other wheat cultivars and crop types.

**Keywords:** crop model, gas exchange, heterogeneous field, hydraulic conductance, water balance, water stress, winter wheat

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