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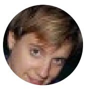

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Uncertainty in simulating biomass yield and carbon–water fluxes from grasslands under climate change

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Introduction

Uncertainty in the response of agro-ecosystem models to environmental conditions can be attributed to differences in the structure of the models. This has urged for benchmarking actions at an international level, where estimation of process-oriented epistemic uncertainties is done by running several models supposed to simulate the same reality (ensemble modelling) so as to generate an expanded envelope of uncertainty (Asseng *et al.*, 2013; Bassu *et al.*, 2014; Li *et al.*, 2014). We address the same issues with grassland ecosystems in Europe and Israel, with focus on permanent, semi-natural or sown grasslands under management for at least 5 years, composed of multiple plant species. Simulations of the grassland yield as well as carbon and water fluxes are inherently uncertain because they are driven by complex interactions. The present study evaluates a set of grassland models to estimate the uncertainty on yield and other outputs and explore how grassland models differ in simulations of response variables to individual climate change factors (temperature, precipitation and atmospheric CO_2 concentration ($[CO_2]$)).

Material and methods

In all, nine long-term grassland sites used for the modelling exercise cover a broad gradient of geographic and climatic conditions as well as a variety of management practices. In all, four of them (Laqueuille, France; Monte Bondone, Italy; Grillenburg, Germany; Oensingen, Switzerland), equipped with an eddy covariance system to determine the net ecosystem exchange (NEE) of CO_2 on a daily basis, are data-rich grasslands, including gross primary production (GPP) and total ecosystem respiration (RECO) ($NEE = RECO - GPP$). At the flux-tower sites the biophysical knowledge of the grassland ecosystem is complemented with soil water content and temperature, and actual evapotranspiration measurements. Other grassland sites (Kempten, Germany; Lelystad, the Netherlands; Matta, Israel; Rothamsted, United Kingdom; Sassari, Italy) focus on forage production under a range of conditions. A total of nine models were used: AnnuGrow, ARMOSA, Biome-BGC MuSo, CARAIB, EPIC, LPJmL, PaSim, SPACSYS and STICS. Some models (AnnuGrow, EPIC and STICS) do not generate carbon fluxes. Model evaluation included uncalibrated (blind) and calibrated simulations, and responses to climate change and atmospheric factors (sensitivity runs).

Results

While the analyses are still ongoing, a few illustrative results are given.

Figure 1 shows that the boxplot of simulated yield biomass is not very different before (nine models) and after (seven models) calibration, with quite general underestimations but on average calibrated results fit better to observations. Taking the Mediterranean site of Matta (Mat) as an example, the improvement of calibration on blind tests is reflected in the values of performance indicators (with seven models, relative root mean square error from 83% to 36%).

To study simulated responses to temperature, precipitation and $[CO_2]$ (one factor at a time) at each site and management, six scenarios were created from the baseline weather.

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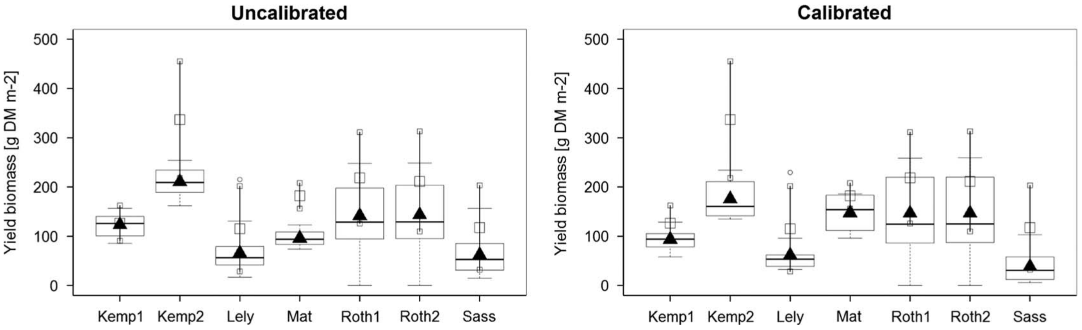

Figure 1 Observed and simulated average yearly yield biomass per cutting (g DM m^{-2}) for five locations using nine models for blind runs (left) and seven models for calibrated runs (right). Locations are: Kempten, Germany (Kemp1, cut four times per year; Kemp2, cut two times per year); Lelystad, the Netherlands (Lely); Matta, Israel (Mat); Rothamsted, United Kingdom (Roth1, NH_4–N fertilization; Roth2, NO_3–N fertilization); Sassari, Italy (Sass). Open squares are mean observed yields plus or minus one standard deviation. Filled triangles are the mean of simulated yields for each location. Boxes are delimiting the 25th and 75th percentiles with the median inside. Whiskers are 10th and 90th percentiles. Hollow circles indicate outliers.

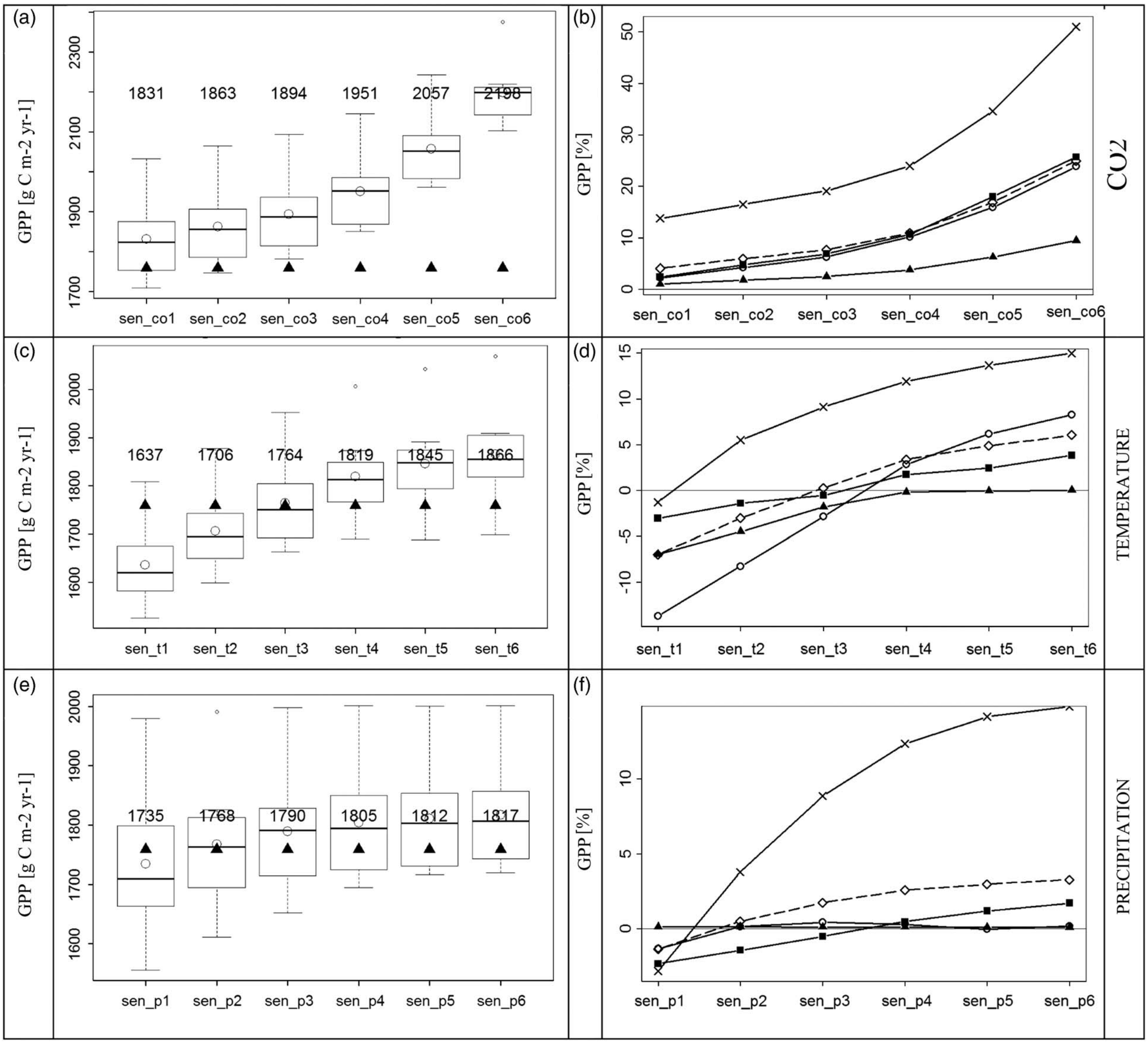

Figure 2 Simulated effects of [CO_2], temperature and precipitation changes on the yearly GPP (g C m^{-2} $year^{-1}$), obtained at Oensingen (Switzerland) with five calibrated models. Scenarios were generated by changing the weather baseline (2002–08): for [CO2] by +5%, +10%, +15%, +25%, +50%, +100% on a baseline of 380 ppm (sen_co1 to sen_co6); for hourly or daily maximum and minimum temperatures by −25%, −10%, −5%, +5%, +10%, +25% of the standard deviation (sen_t1 to sen_t6); for rainy hours or days, hourly or daily precipitations by −25%, −10%, −5%, +5%, +10%, +25% of the standard deviation (sen_p1 to sen_p6). On the left, hollow circles and the values are the mean of sensitivity simulations, and filled triangles are the mean of calibrated runs (same value for each scenario). On the right, different markers indicate different models.

Taken the example of Oensingen (Switzerland) with five models, simulated yearly changes of GPP (2002-2008 average) increases with [CO_2] at roughly exponential rate, by ~25% on average with doubled [CO_2] (Figure 2a and b). The latter is in agreement with the experimental evidence (e.g., Ainsworth and Rogers, 2007). However, large differences in the response of different models to [CO_2] are visible, which suggest the need to apply an ensemble of models to capture the potential GPP changes. A common trend of the models is that yearly GPP increases with air temperature (Figure 2c). On average, GPP increases by 6-7% when temperature increases by 25% but, even in this case, one model is more sensitive than others to temperature conditions and may have overestimated the effect of warming (Figure 2d). Precipitation scenarios show a lesser effect on GPP changes than temperature and [CO_2] with the exception of one model, and the average response is more complex (Figure 2e and f). At a relatively humid site like Oensingen, some reduction in precipitation can even have a positive effect on GPP owing to, for instance, less nitrogen leaching or non-saturated conditions (e.g., simulated GPP increased on average by 1% when the amount of precipitation decreased by 10%).

Conclusions

Some calibration may be required to improve accuracy and reduce uncertainty in biomass and carbon-water cycle estimations in Europe and Israel. The results indicate that alternative models show a different sensitivity to climate change factors (which can be explained later by looking into the processes in the models) and that the application of an ensemble of models might attain better performance than a single model. In particular, the high sensitivity of simulated GPP values to [CO_2] and temperature indicates the need for model users to pay more attention on the responsiveness to these factors other than precipitation. This is important, also considering the fundamental effect of rising temperature and [CO_2] on the C cycling of terrestrial ecosystems (Dieleman *et al.*, 2012).

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Further information

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References

Ainsworth EA and Rogers A 2007. Plant, Cell and Environment 30, 258–270.

Asseng S, Ewert F, Rosenzweig C, Jones JW, Hatfield JL, Ruane A, Boote KJ, Thorburn P, Rötter RP, Cammarano D, Brisson N, Basso B, Martre P, Aggarwal PK, Angulo C, Bertuzzi P, Biernath C, Doltra J, Gayler S, Goldberg R, Grant R, Heng L, Hooker JE, Hunt LA, Ingwersen J, Izaurralde RC, Kersebaum KC, Müller C, Naresh Kumar S, Nendel C, O'Leary G, Olesen JE, Osborne TM, Palosuo T, Priesack E, Ripoche D, Semenov MA, Shcherbak I, Steduto P, Stöckle CO, Stratonovitch P, Streck T, Supit I, Travasso M, Tao F, Waha K, Wallach D, White JW and Wolf J 2013. Uncertainties in simulating wheat yields under climate change. Nature Climate Change 3, 827–832.

Bassu S, Brisson N, Durand JL, Boote K, Lizaso J, Jones JW, Rosenzweig C, Ruane AC, Adam M, Baron C, Basso B, Biernath C, Boogaard H, Conijn S, Corbeels M, Deryng D, De Sanctis G, Gayler S, Grassini P, Hatfield J, Hoek S, Izaurralde C, Jongschaap R, Kemanian AR, Kersebaum KC, Kim SH, Kumar NS, Makowski D, Müller C, Nendel C, Priesack E, Pravia MV, Sau F, Shcherbak I, Tao F, Teixeira E, Timlin D and Waha K 2014. How do various maize crop models vary in their responses to climate change factors? Global Change Biology 20, 2301–2320.

Dieleman WIJ, Vicca S, Dijkstra FA, Hagedorn F, Hovenden MJ, Larsen KS, Morgan JA, Voder A, Beier C, Dukes JS, King J, Leuzinger S, Linder S, Luo Y, Oren R, de Angelis P, Tingey D, Hoosbeek MR and Janssens IA 2012. Simple additive effects are rare: a quantitative review of plant biomass and soil process responses to combined manipulations of CO_2 and temperature. Global Change Biology 18, 2681–2693.

Li T, Hasegawa T, Yin X, Zhu Y, Boote K, Adam M, Bregaglio S, Buis S, Confalonieri R, Fumoto T, Gaydon D, Marcaida M III, Nakagawa H, Oriol P, Ruane AC, Ruget F, Singh B, Singh U, Tang L, Tao F, Wilkens P, Yoshida H, Zhang Z and Bouman B 2014. Uncertainties in predicting rice yield by current crop models under a wide range of climatic conditions. Global Change Biology. doi: 10.1111/gcb.12758.