Modelling European Agriculture with Climate Change for Food Security

MACSUR

Sensitivity of a grassland model ensemble to climate change factors: the MACSUR approach

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ROTHAMSTED RESEARCH

INRA SCIENCE & IMPACT

MACSUR Science Conference 2017, May 22-25, Berlin(Germany)

Objective:

Improving the mechanistic understanding of plant responses to the effects of (increasing) atmospheric [CO_2] and other abiotic factors, including higher temperature and altered patterns of precipitation

Challenge:

Ensuring robust modelling approaches under changing climate conditions

- the implicit assumption that well-designed and calibrated models under current conditions will remain valid under future climate realizations can be an unrealistic one

MACSUR approach:

MACSUR-1

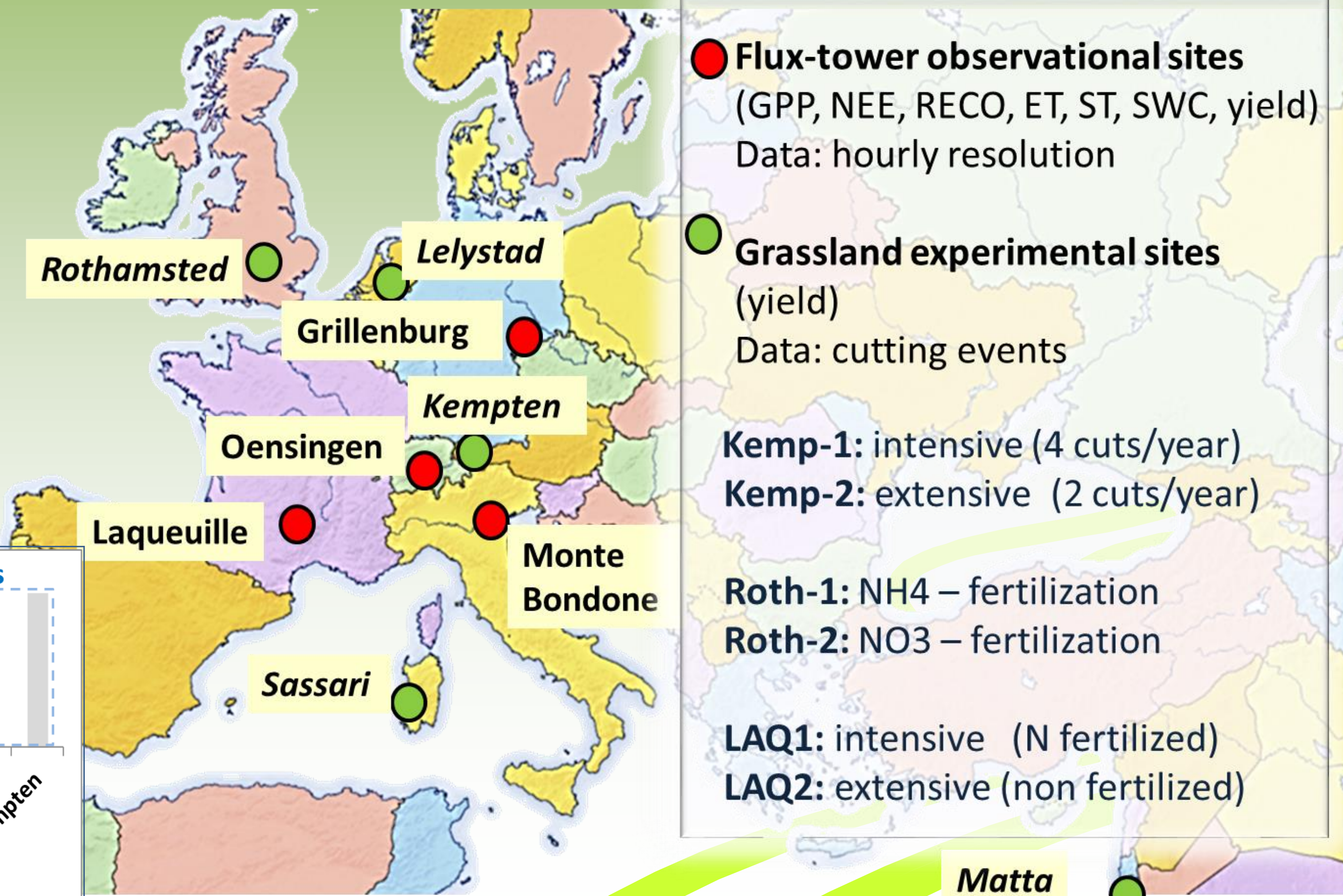
Evaluate nine grassland models: simulation of water content and temperature in the topsoil, and of biomass production

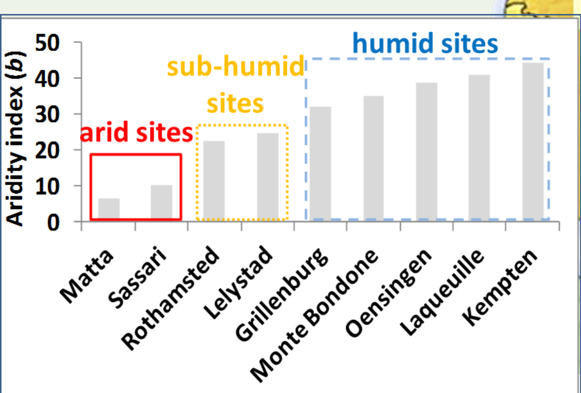
↓

Analyze the sensitivity of simulated dry matter, water and temperature fluxes to altered weather conditions created by changing temperature, precipitation and atmospheric [CO_2]

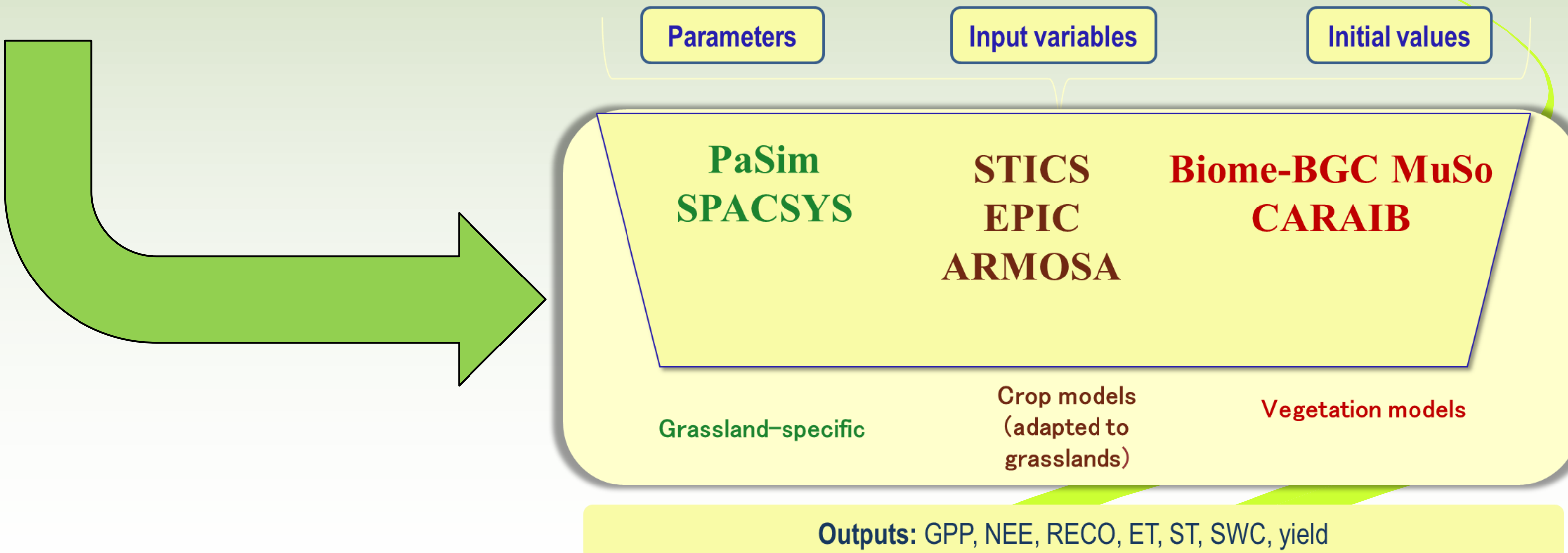
Study design and sites:

Seven grassland models were run at nine long-term grassland sites representing a broad gradient of geographic and climatic conditions

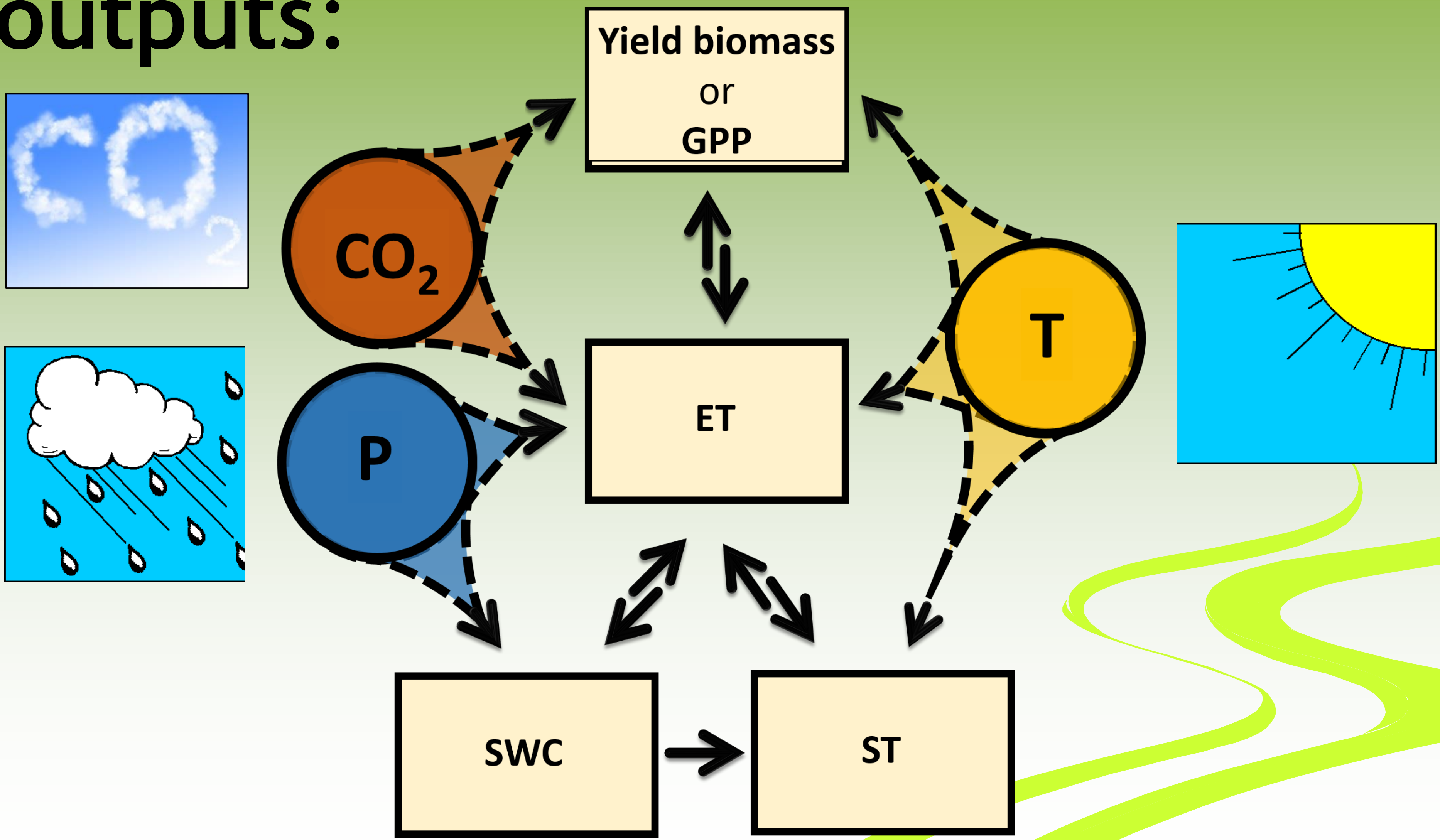




Input		Climate scenarios						
		Scen 1	Scen 2	Scen 3	Scen 4	Scen 5	Scen 6	Baseline
Temperature	Standard deviation	−25%	−10%	−5%	5%	10%	25%	current
Precipitation	Standard deviation	−25%	−10%	−5%	5%	10%	25%	current
CO_2	ppm	5%	10%	15%	25%	50%	100%	380



Effect of climate drivers on outputs:

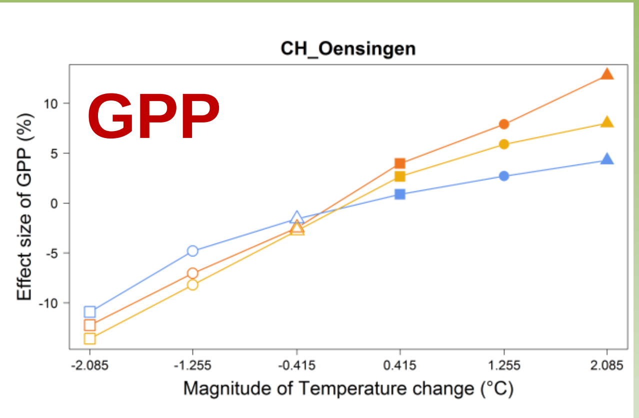


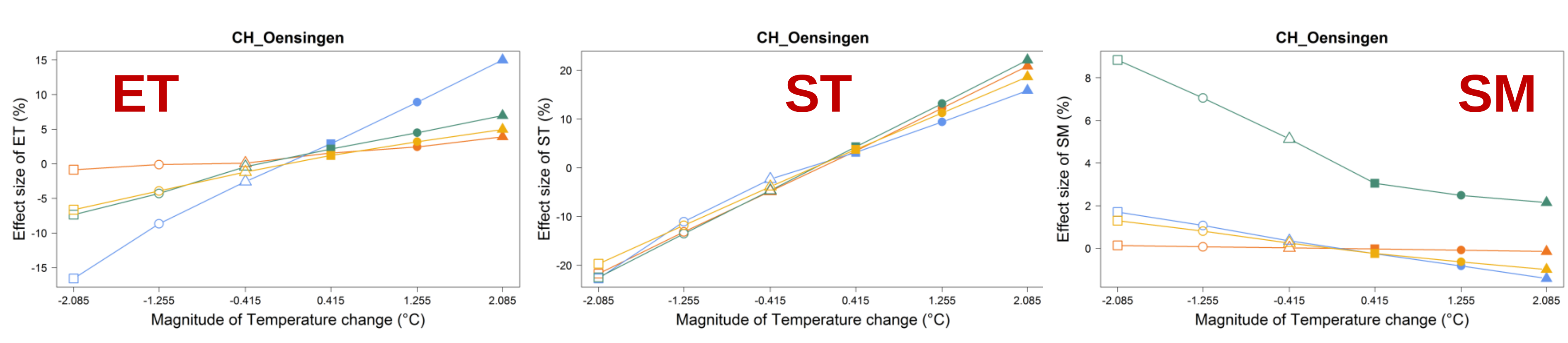
Effect of temperature scenarios:

- Multi-year averages of GPP, evapotranspiration and soil temperature increase with the higher temperature values at humid sites

- Soil moisture has a negative or non-sensitive answer to temperature increase

- Non-biotic model results (e.g. ST) show less uncertainty in their respond to climate manipulation



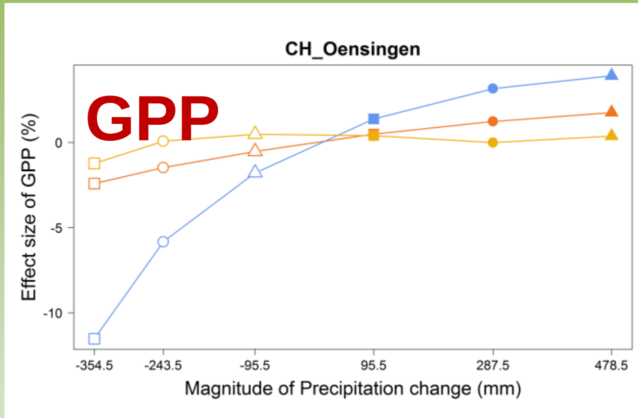


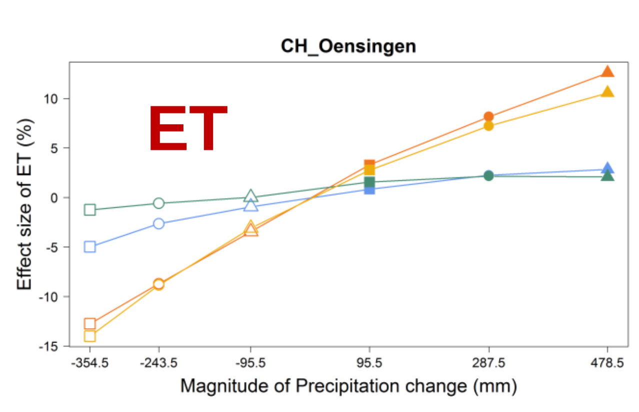
Effect of precipitation scenarios

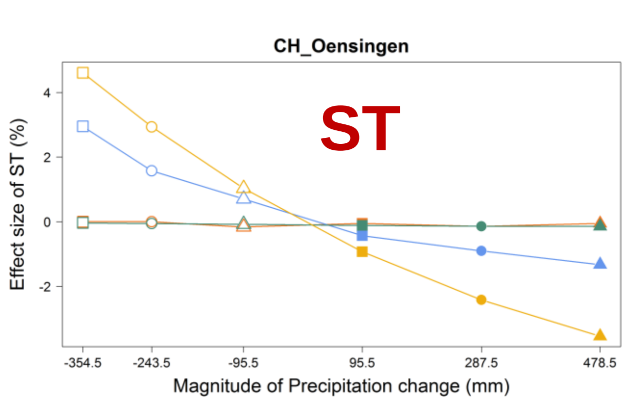
- In gereral, reduced amount of precipitation slightly decreases GPP and evapotranspiration

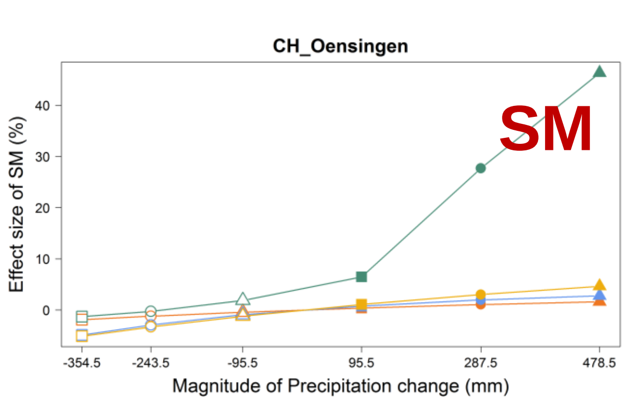
- Soil temperature decreses with higher precipitation

- Soil moisture correlates with the elevated level of precipitation according to the expectations







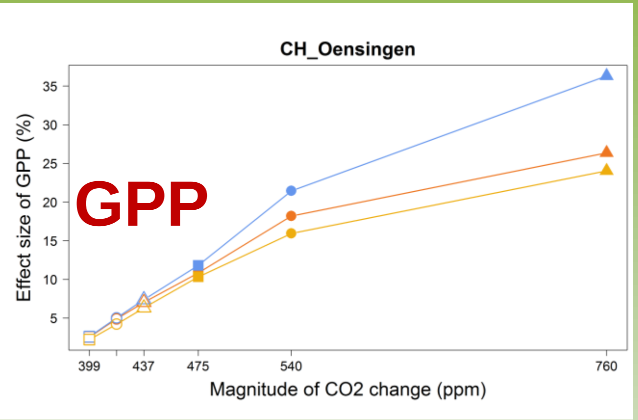


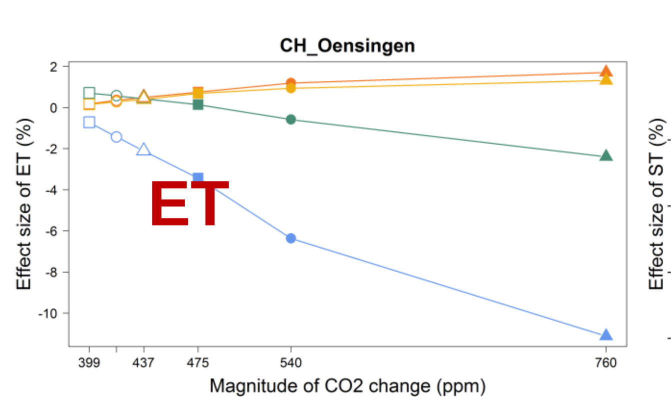
Effect of $[CO_2]$ increase

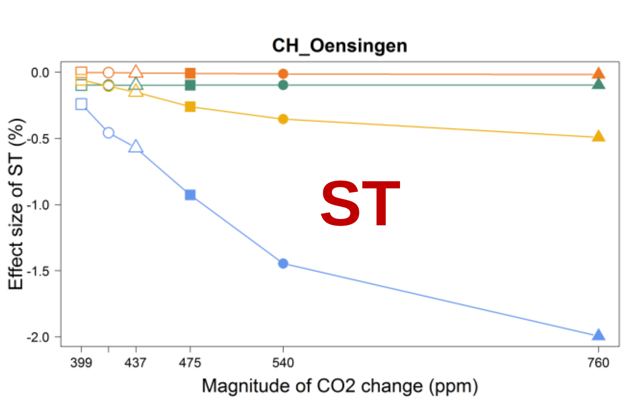
- The magnitude of $[CO_2]$ concentration positively correlates with GPP

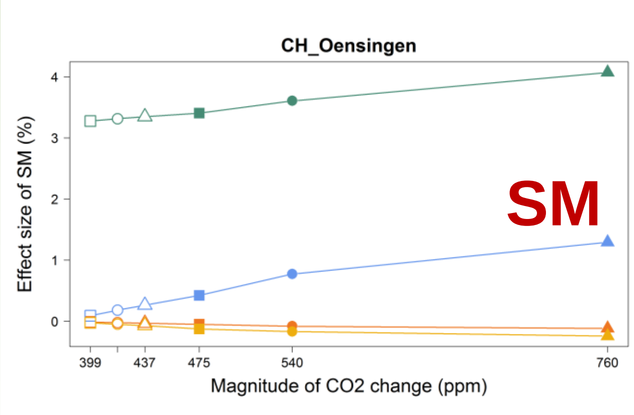
- The soil moisture content slightly increases owing to the increased amount of SOC and the hydrological cycle is likely to speed up by about 10% with CO_2 doubling

- Whilst soil temperature and evapotranspiration slightly decreased

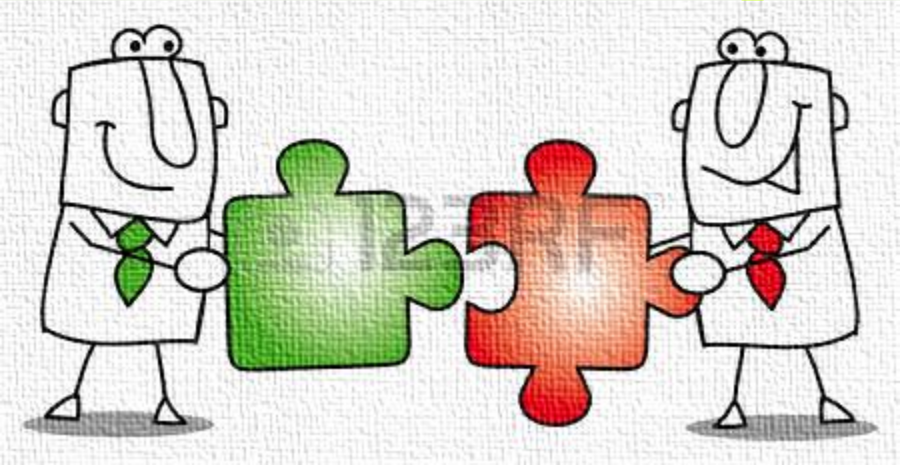




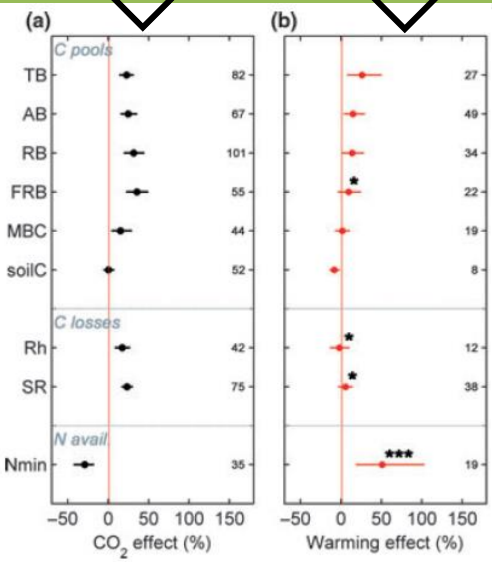




Our obtained model simulation results are comparable with experimental meta-analysis:



Effect of [CO_2] and warming in experimental manipulations:



Global Change Biology

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REVIEW

Simple additive effects are rare: a quantitative review of plant biomass and soil process responses to combined manipulations of CO_2 and temperature

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Data source: extracted from published figures and tables from 150 experimental sites across different ecosystems and climates

Fig. 1 Overall meta-analysis effect sizes for elevated [CO_2] (a), warming (b) and the combined elevated [CO_2] and warming treatment (c) reported as the percentage change relative to the control. Data listed are total biomass (TB), aboveground biomass (AB), root biomass (RB), fine root biomass (FRB), soil C content (soilC), heterotrophic respiration (Rh), soil respiration (SR), and mineral N availability (Nmin). Positive values indicate a positive treatment effect, negative values indicate a decrease. Error bars represent the 95% confidence interval. Data are the weighted means for n data points. The number of studies is given along the *Y*-axis. Significant differences in the response to [CO_2] enrichment vs. the warming response are indicated (* indicates differences with the [CO_2] responses, ¥ indicates differences with the warming responses. * or ¥ indicates a significant difference at $P < 0.05$; ** or ¥¥ indicates a significant difference at $P < 0.01$, *** or ¥¥¥ indicates a significant difference at $P < 0.001$). References to all individual experiments included in this meta-analysis are listed in Tables S5 and S6.

- Considering [CO_2] and warming treatments, effects of elevated [CO_2] often dominate on C storage and C and nutrient cycling in terrestrial ecosystems …
- … suggesting a larger sensitivity to rising [CO_2] compared to rising temperatures

Effect of warming in experimental manipulations:

- Warming stimulates plant productivity because of increasing aboveground due to enhanced soil nutrient mineralization

Global Change Biology

Global Change Biology (2011) **17**, 927–942, doi: 10.1111/j.1365-2486.2010.02302.x

REVIEW

Responses of terrestrial ecosystems to temperature and precipitation change: a meta-analysis of experimental manipulation

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Data source: extracted from published figures and tables from experimental sites across different ecosystems and climates

Effect of precipitation in experimental manipulations:

- Water availability is the major limiting factor of the functioning of grasslands

- Plant productivity and ecosystem C fluxes generally show higher sensitivities to increased precipitation than to decreased precipitation

- Increased precipitation stimulated both respiration and photosynthesis, and reflected in both increased plant biomass

- Decreased precipitation not only suppresses plant biomass and physiological processes (such as nutrient availability), it can also cause plant mortality

- The quantity of precipitation has an effect on plant growth and ecosystem C-fluxes, yet the timing and frequency of precipitation can also have large effects (Knapp et al., 2008)

Conclusions:

- The multi-model responses to precipitation (P), temperature (T) and atmospheric CO_2 concentration [CO_2] revealed different levels of sensitivity

- GPP strongly responded to elevated [CO_2] at all sites

- Multi-model responses show parallel results with experimental findings:

- [CO_2] has the most significant positive effect on biomass production, C-fluxes: all the models show larger and more explicit sensitivity to rising [CO_2]

- The effects of temperature and precipitation suggest greater variablilty, which also has an effect on the uncertainty of model estimates

Thank you

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