A biome-based analysis of current and future global crop yields.

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2. Methods

Global LPJ-GUESS dynamic vegetation and crop model simulations (without interactive N; Lindeskog et al., 2013) driven by forcings from WATCH climate (historic) or 5 global climate models (future). Wheat, maize and rice are simulated for the entire globe and analysed according to the current natural biome for that location.
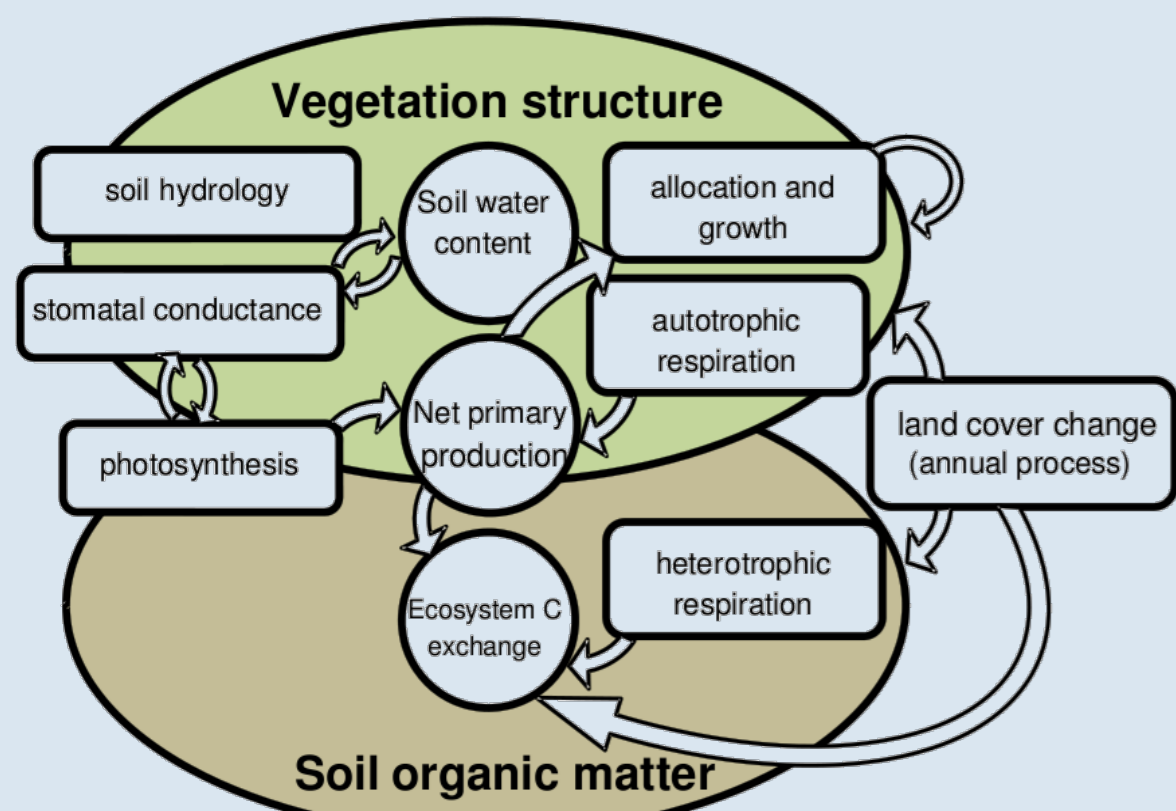
Crop model considers:
> Dynamic sowing
> Cultivar adaptation
> Harvest
> Water stress
> Irrigation
> CO_2 fertilisation
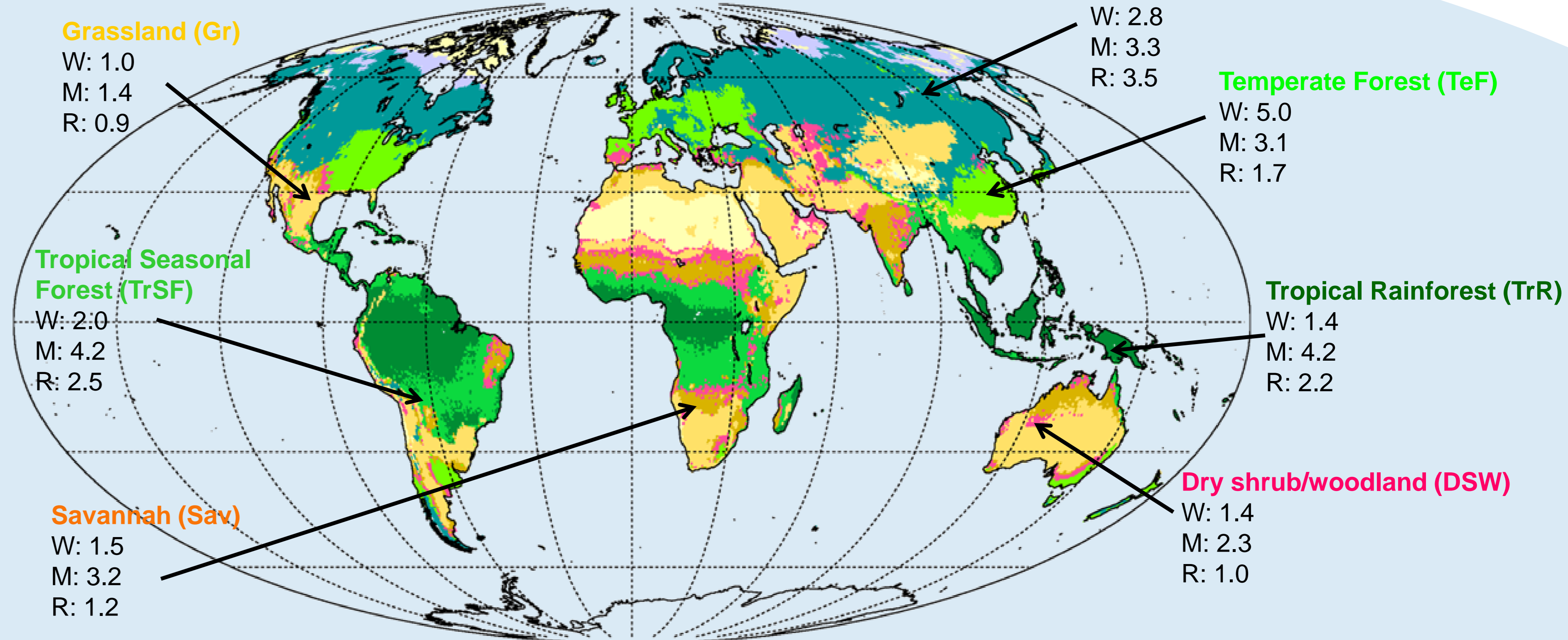> Crop-specific parameters (e.g. Temperature windows)

3. Evaluation
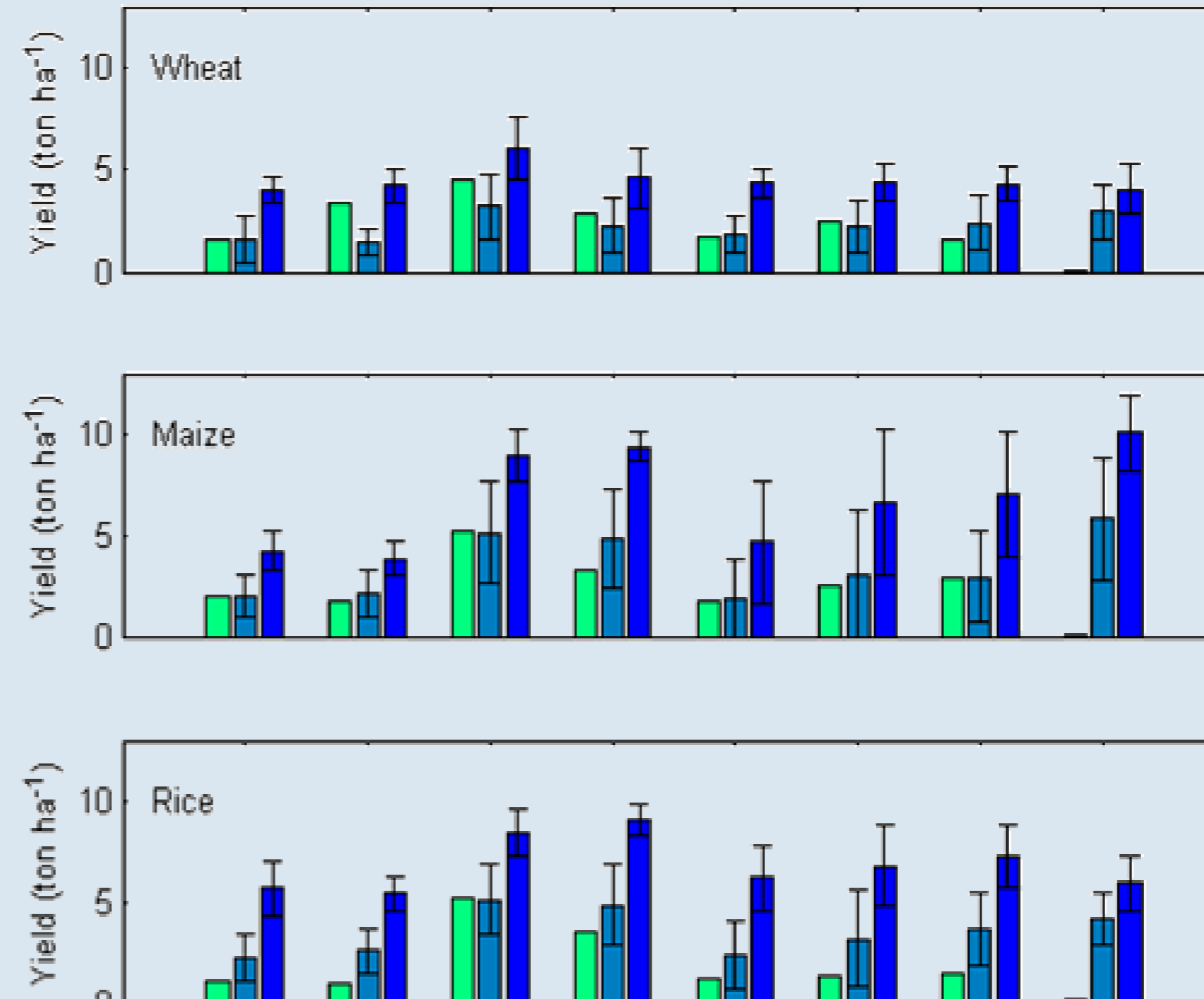
LPJ-GUESS yields based on current cropped area alone (green) agree well with observed actual yields (light blue) for wheat and maize. Lower yields for rice are likely a result of only a single growing season being simulated. Dark blue bars show observed potential yields. Generally temperate and boreal biomes have highest actual and potential yields. Error bars are ±1 standard deviation.

1. Motivation

Biomes are defined as areas where vegetation shares key compositional characteristics, and are defined ultimately by their environmental boundary conditions (climate, nutrient availability, etc.). Croplands necessarily replace the natural vegetation, but must function within the same boundary conditions. As natural vegetation also provides ecosystem services which can be strongly biome dependent, considering crop yields by biome aids in a trade-off analysis.


Grassland (Gr)
W: 1.0
M: 1.4
R: 0.9

Boreal Forest (BF)
W: 2.8
M: 3.3
R: 3.5

Temperate Forest (TeF)
W: 5.0
M: 3.1
R: 1.7

Tropical Seasonal Forest (TrSF)
W: 2.0
M: 4.2
R: 2.5

Tropical Rainforest (TrR)
W: 1.4
M: 4.2
R: 2.2

Savannah (Sav)
W: 1.5
M: 3.2
R: 1.2

Dry shrub/woodland (DSW)
W: 1.4
M: 2.3
R: 1.0

Present day biome-mean rainfed yields (ton ha^{-1}) of the three main staple crops wheat (W), maize (M) and rice (R). Natural biome map is generated by LPJ-GUESS.

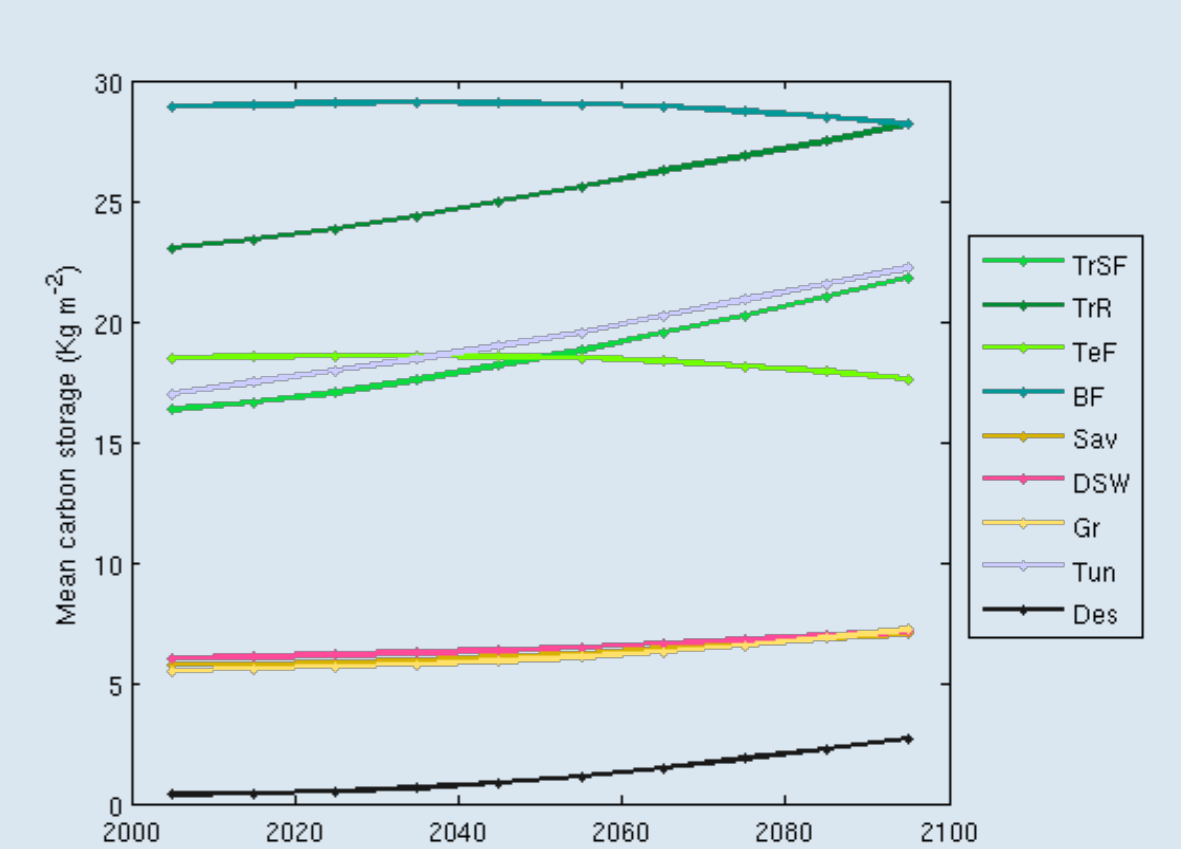## 4. Future projections
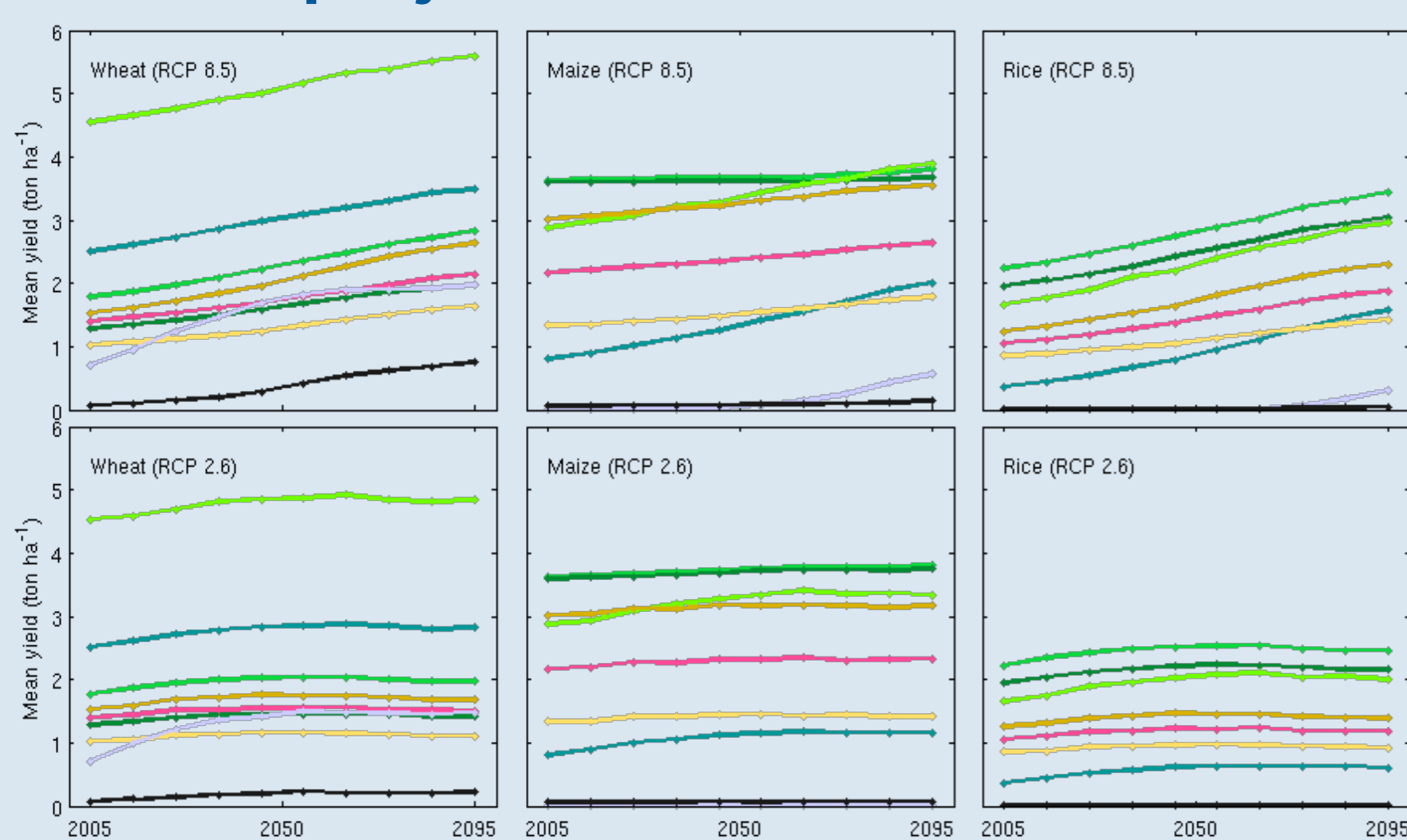
Yield development for rainfed crops under extreme (top) and moderate (bottom) future climate projections.

5. Sensitivities
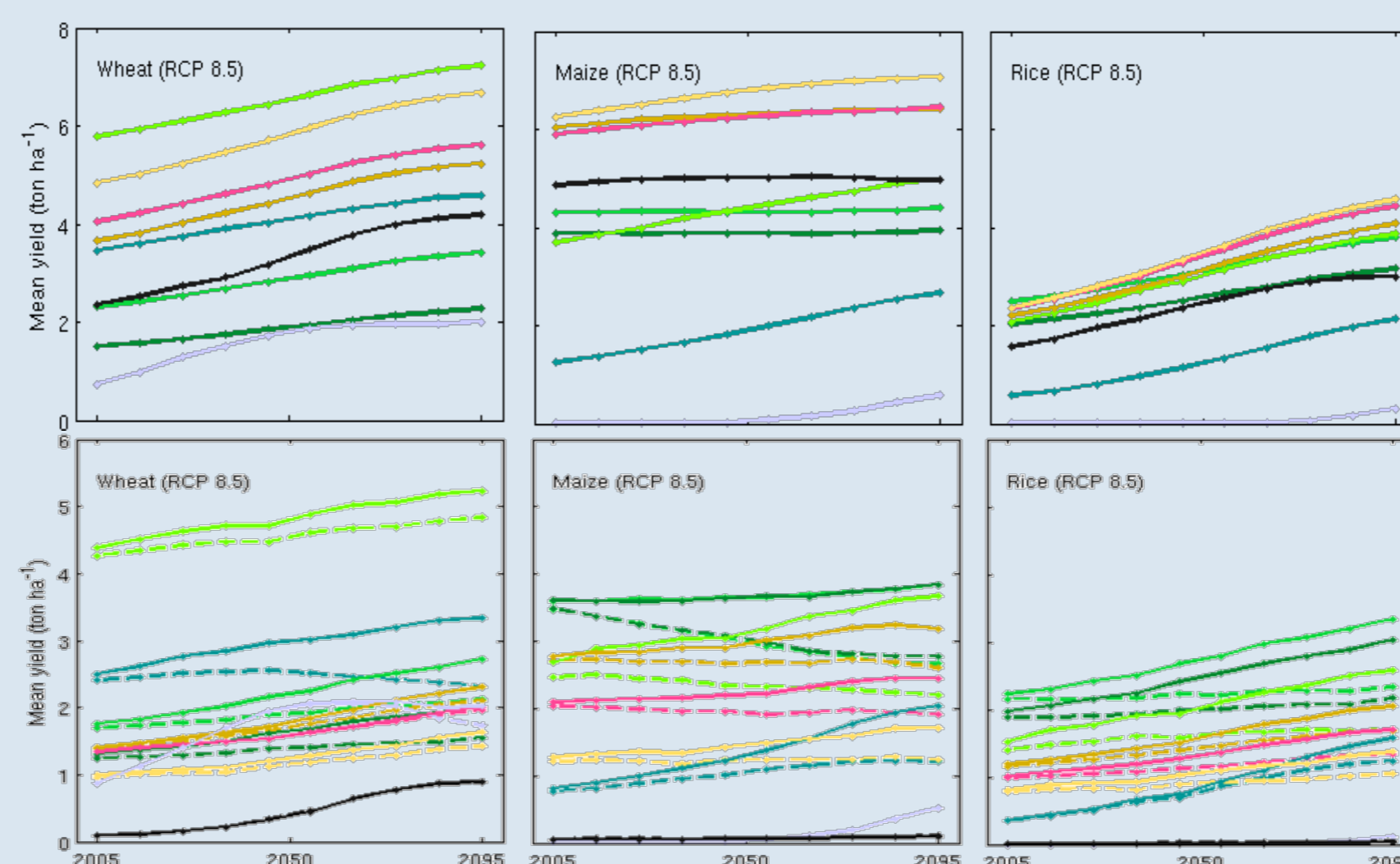
Yield development for irrigated crops (top). Also for rainfed crops (bottom) without cultivar adaptation (dashed lines)

6. Carbon stocks

Change in mean carbon storage (Kg m^{-2}) by biome for an extreme future climate projection. Boreal and temperate stocks are vulnerable.

7. Discussion

The highest biome-wide mean yields across all crops are simulated for temperate forest, whereas the highest mean carbon stocks are in tropical rainforest and boreal forest. Tropical rainforest carbon is especially vulnerable to land conversion as it is mostly in standing vegetation.

Yields initially appear to be robust to future change across all biomes, but if cultivar adaption to increased growing season temperatures cannot keep pace then boreal, temperate and tropical forest biomes (all the most productive ecosystems) show vulnerability to decreased yield.

References.
Lindeskog et al. (2013) *Earth Syst. Dynam. Discuss.*, **4**, 235-278.
Monfreda et al. (2008) *Global Biogeo. Cycles*, **22**, GB1022.
Mueller et al. (2012) *Nature*, **490**, 254-257.
Smith et al. (2001) *Global Ecology & Biogeography*, **10**, 621-637.