Modelling winter wheat in the UK using JULES Crop

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(2) ECMWF

UK Centre for Ecology & Hydrology

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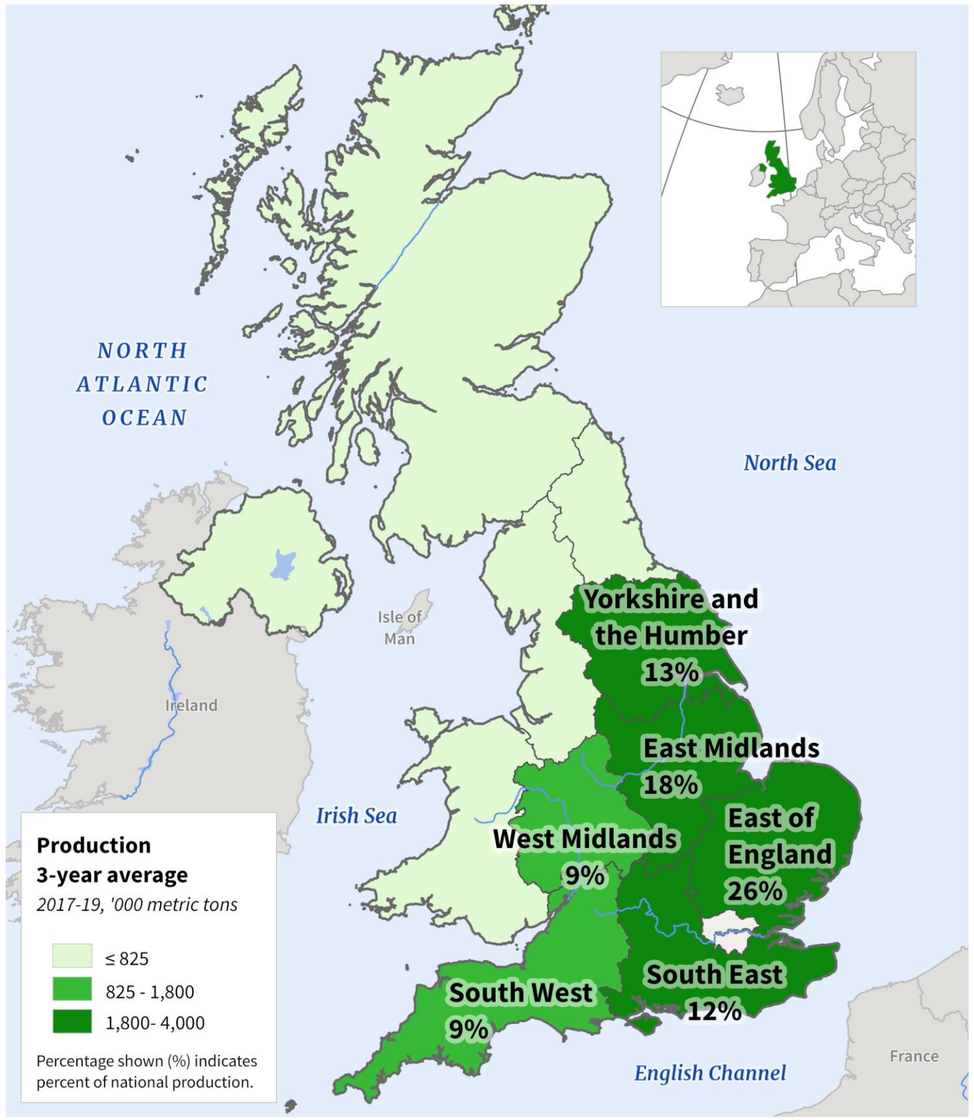
Background

- Wheat is an important cereal crop in the UK
- Cultivation mainly in the South and East of England
- Production area of ~2000 ha (8% of the total UK area)
- Production and yields affected by ‘weather’ at key growing stages (sowing, growth, harvest)

- As part of the UKRI Climate Resilience CropNET project, investigated how UK crop will yields be affected by climate change (in terms of changed meteorological parameters and CO_2 concentrations)?



Precision-yield measurements from CropNET

- Physical sensors on combine harvesters measure crop weight and moisture content, together with accurate GPS location.
- High density of point data that can be used to map fine-scale spatial variation (<10m) in arable and grass crop yields within fields
- UKCEH has access to precision yield data points, collected as part of the Achieving Sustainable Agricultural Systems (ASSIST) project
- Raw measurement data filtered and cleaned
- Where available, average field wheat yields for the years 2015-2019 derived to give a total of 1163 location-years
- Average field size = 13.9 (2.4-25.4, 1) ha.

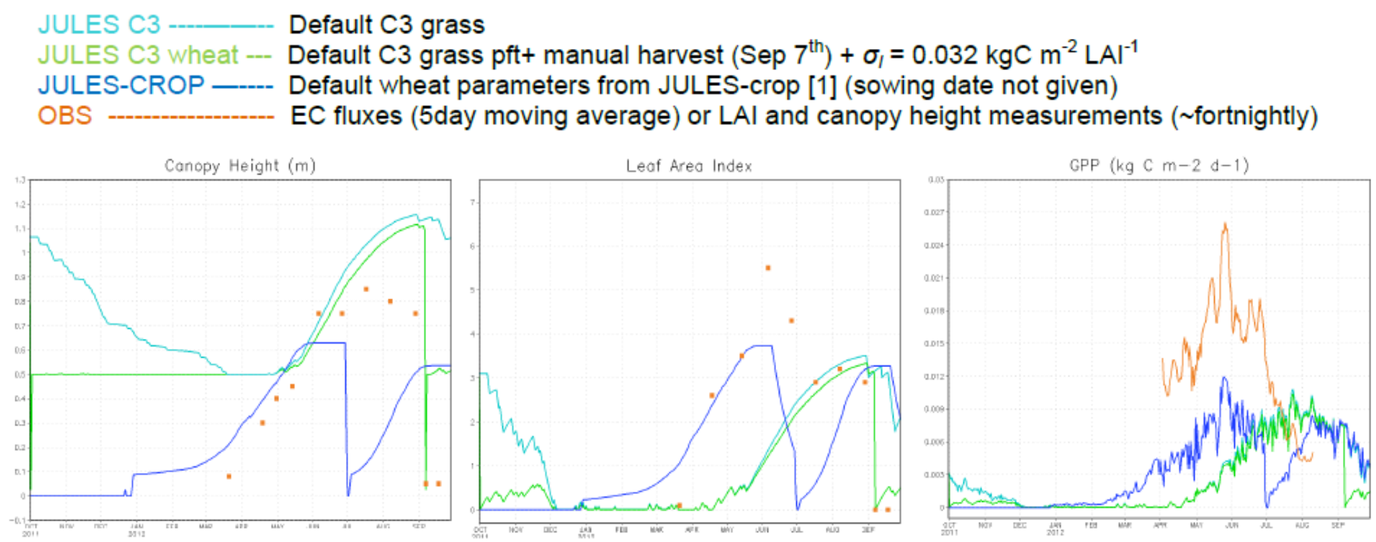
Builds on previous study using JULES Crop - 1

Martínez-de la Torre et al. (2015) use JULES-Crop to model winter wheat in the UK

1. Used UKCEH eddy co-variance (EC) fluxes of energy, water and carbon, and manual observations of leaf area index (LAI) and canopy height made at the Brattelby site (in Lincolnshire)

2. Find that JULES-crop improves the timing of the growing season but reaches harvest (through the crop development index) too early. Also:

- Gross primary productivity (GPP) is significantly underestimated;
- LAI does not follow the observations;
- Plant activity is overestimated due to the high LAI; and
- There is not enough energy to reach observed sensible heat



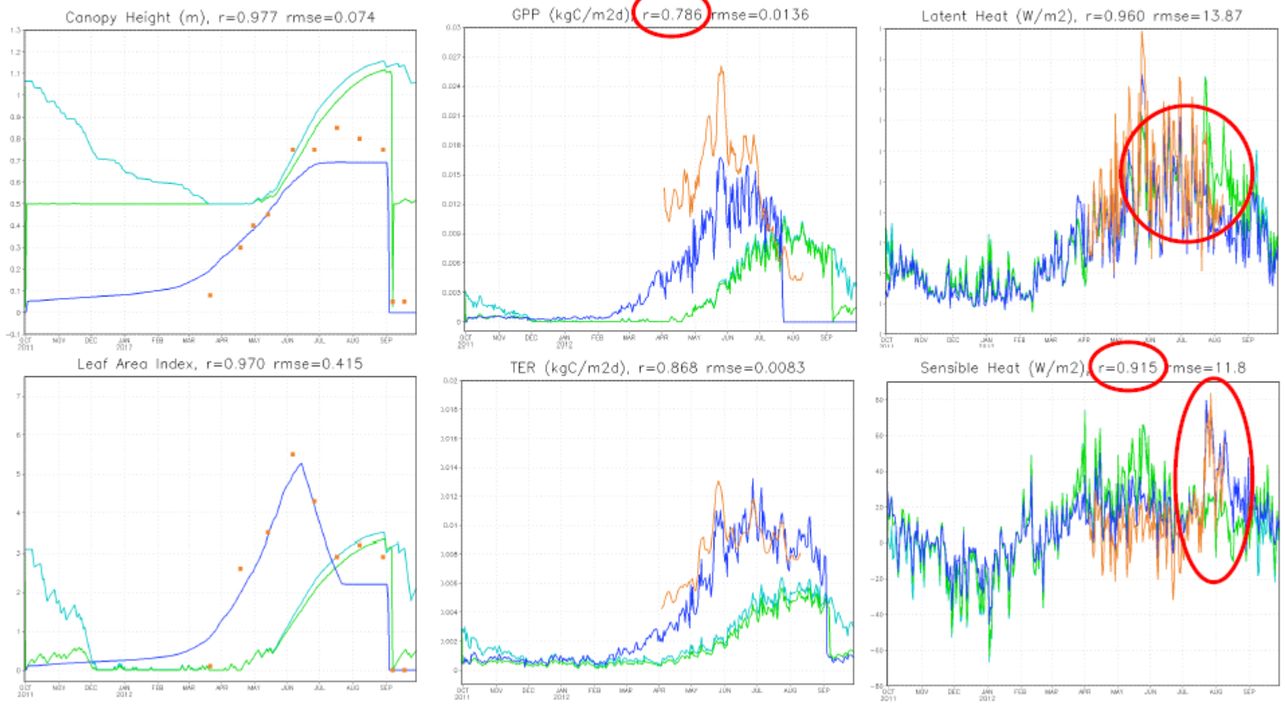
Builds on previous study using JULES Crop - 2

Based on the comparison with phenology and flux observations, Martínez-de la Torre et al. (2015) made a number of changes to the JULES-crop module and the winter wheat crop parameters:

- Initialize leaf senescence after flowering (DVI=1.0);
- Mobilize less carbon to harvest during leaf senescence;
- Introduce a dormant leaf factor to stop mobilizing and to close stomata at a critical value of DVI

Determined the optimal mobilization rate and value of DVIcrit.

DVI_{crit}	1.20	1.22	1.24	1.26	1.28	1.30	1.32	1.34	1.36
	1.38	1.40	1.42	1.44	1.46	1.48	1.50		
Mob_rate	0.01	0.015	0.015	0.025	0.025	0.035	0.035	0.045	0.05



Recent code development and model runs

JULES Code Changes

1. Implemented the 'crop senescence' code changes into JULES vn6.3: fcm:jules.x/branches/dev/garryhayman/JULES_vn6.3_crop_dvicrit

2. Used the 'optimised' JULES-Crop parameters:

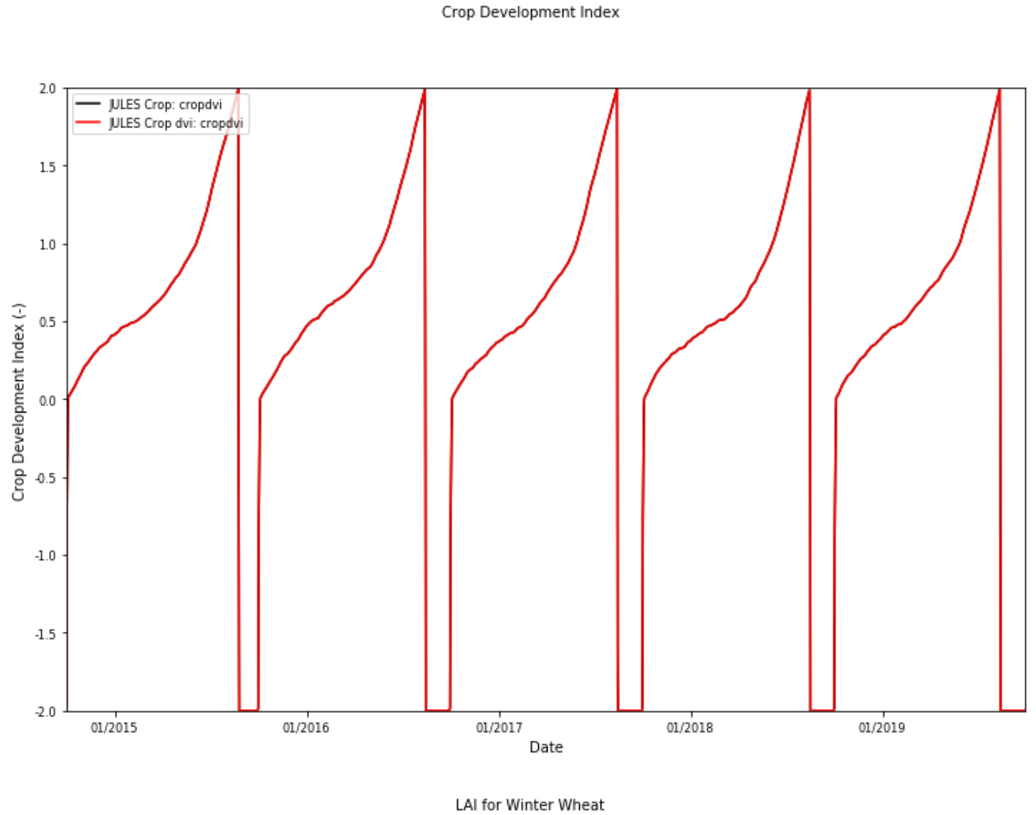
Model runs

1. JULES runs using suite u-cm847 on JASMIN:
   - **JULES** with JULES Crop switched off
   - **JULES Crop** (vn6.3 trunk), with optimised parameters
   - **JULES Crop DVI** (vn6.3 branch above), with optimised parameters and critical value of DVI for senescence=1.55
2. CHESS 1 km x 1km GB grid, with CHESS met driving data (2006-2019, see https://doi.org/10.5285/2ab15bf0-ad08-415c-ba64-831168be7293 for 1961-2017)
3. Only use the grid cells where there is at least one observed wheat yield measurement (461 cells)

Results

Time series comparison of JULES Crop and JULES Crop DVI (October 2014-September 2019)

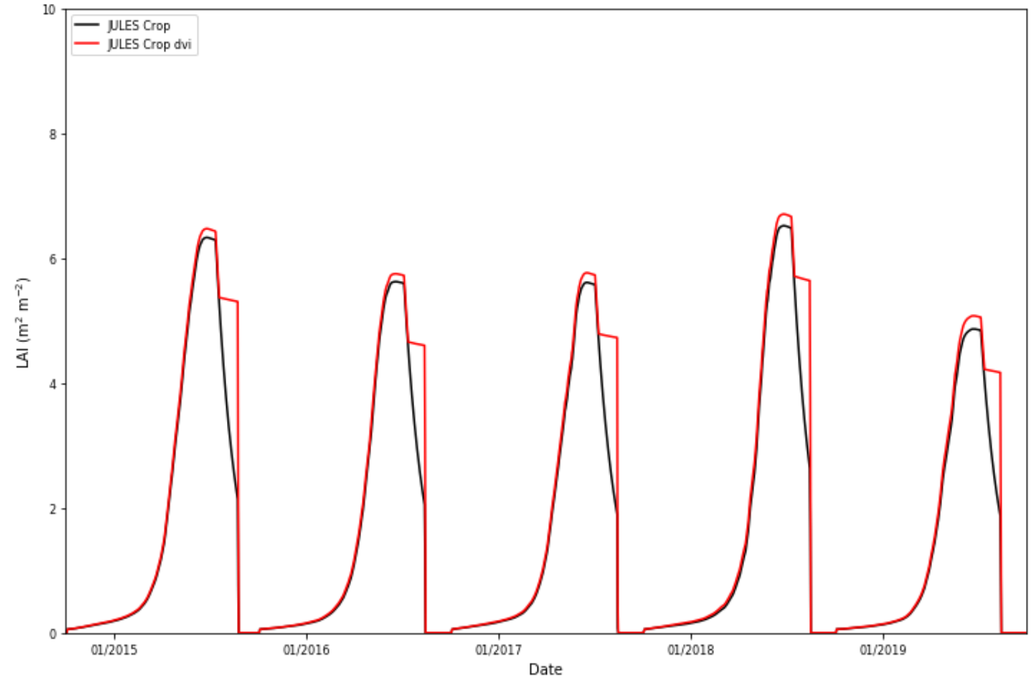
Crop development index



LAI for Winter Wheat

Leaf area index

- see effect of dormant leaf factor to stop mobilizing and to close stomata at a critical value of DVI

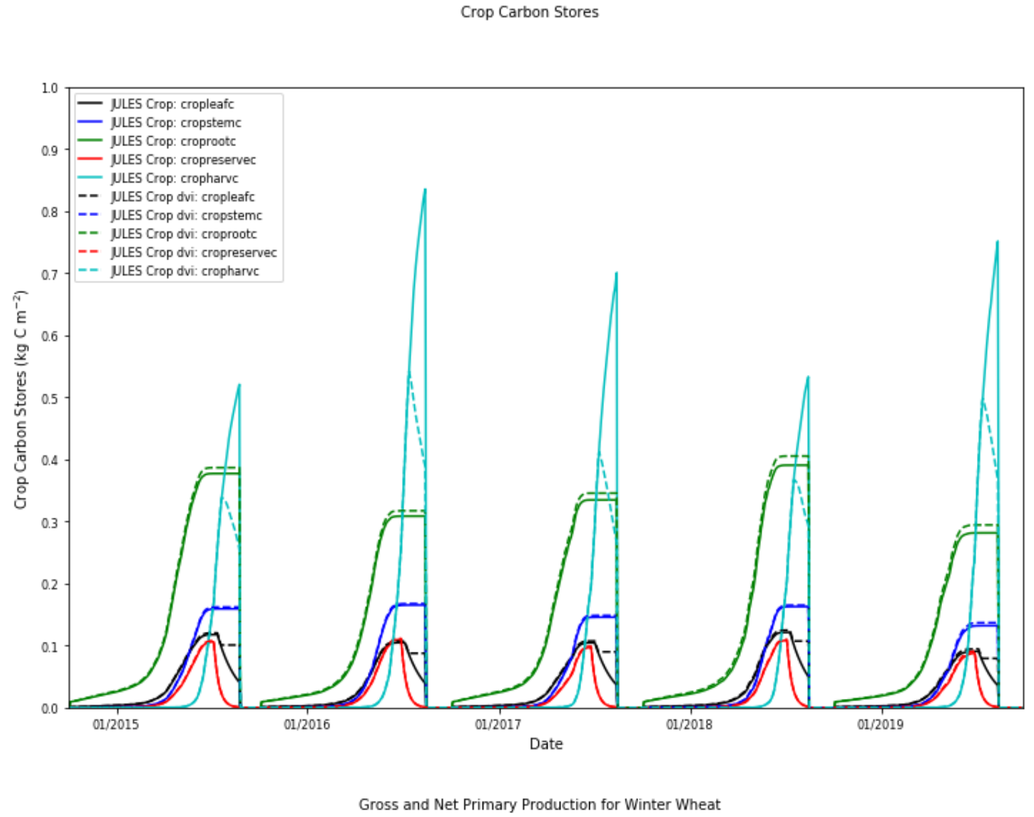


Results

Time series comparison of JULES Crop and JULES Crop DVI (October 2014-September 2019)

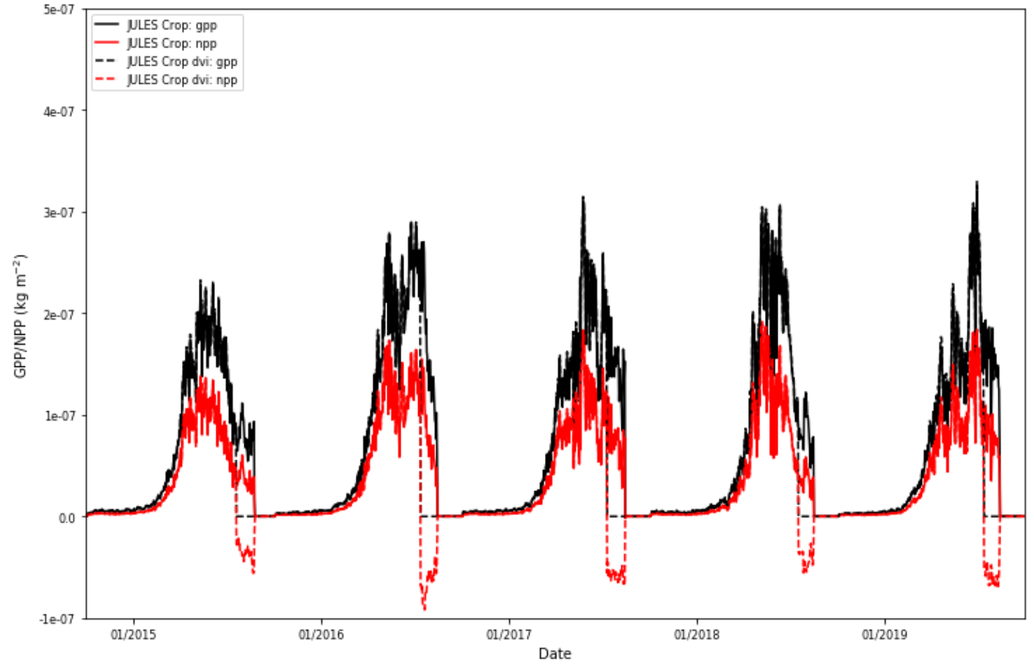
Crop Carbon Stores

- Less mobilization of carbon to harvest during leaf senescence



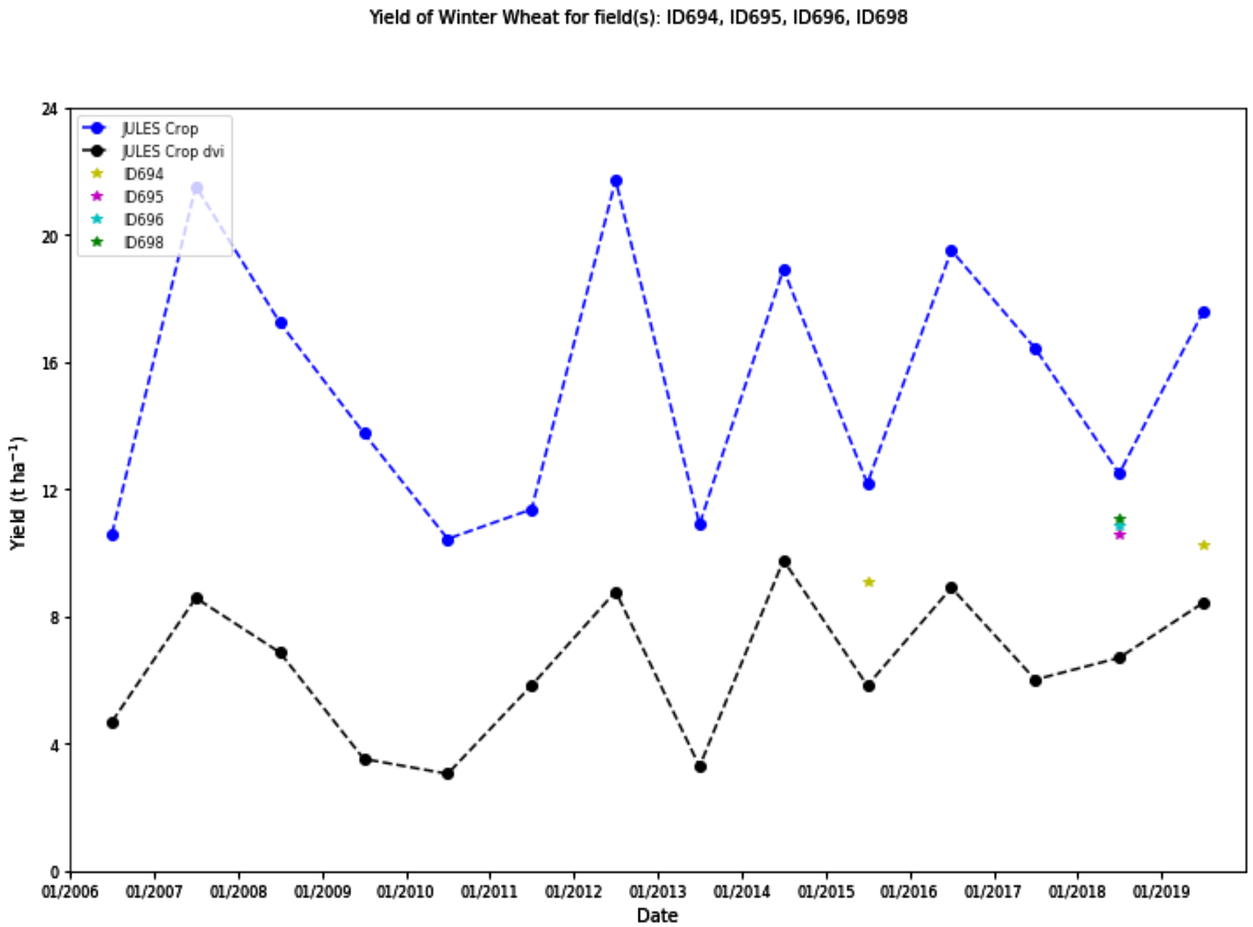
Gross and Net Primary Productivity

- Again, GPP reduced for crop pft, with associated changes in NPP



Time series for grid cell centred (541500, 356500)

JULES Crop with leaf senescence and stomatal closing has lower yields than the ‘standard’ version

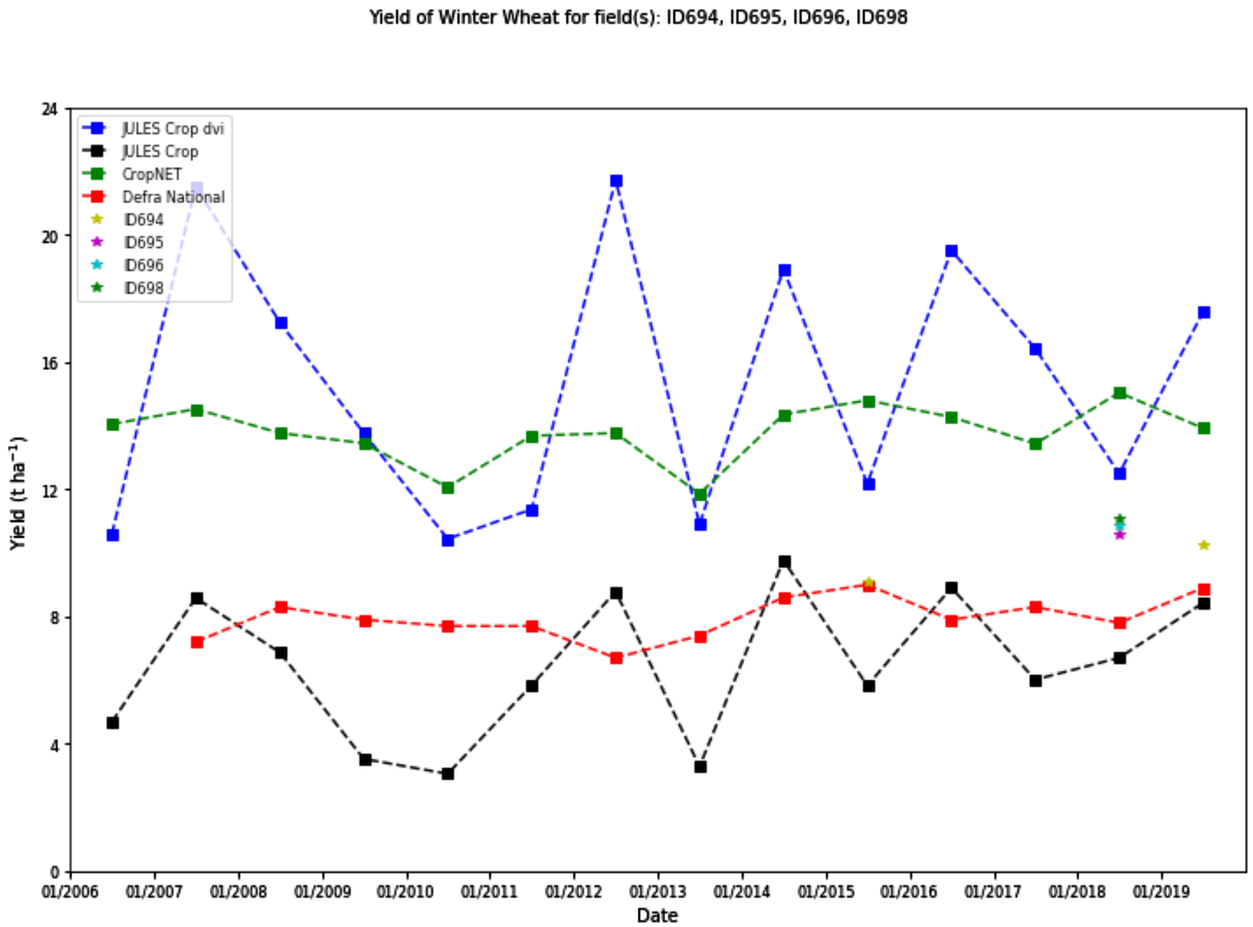


Time series for grid cell centred (541500, 356500)

CropNET Winter Wheat growth & yield model

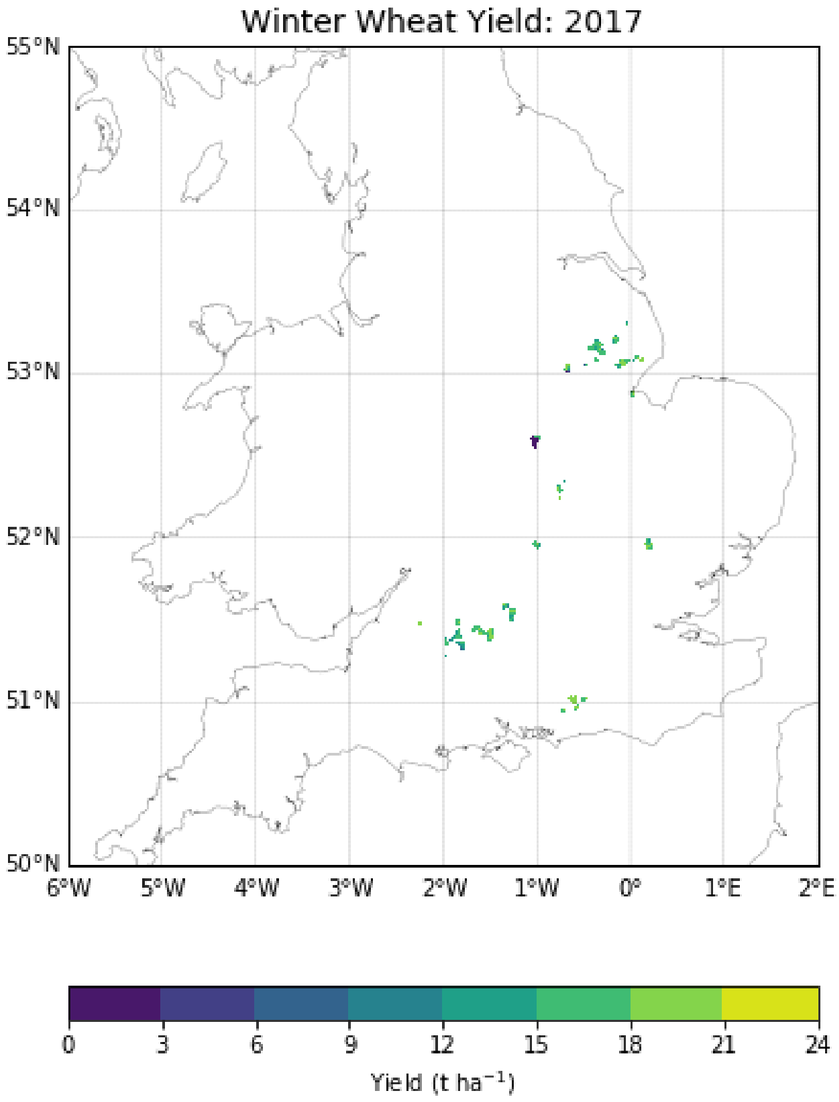
- Simpler data-driven model
- Also use growth stages based on accumulated thermal time
- Same CHESS met driving data
- Gives ‘potential’ not ‘actual’ yield as missing effects of pests & diseases, farm management practices, ….
- Also version which assimilates Sentinel-2 leaf area index

Annual wheat yields from the Defra surveys “Agriculture in the UK”

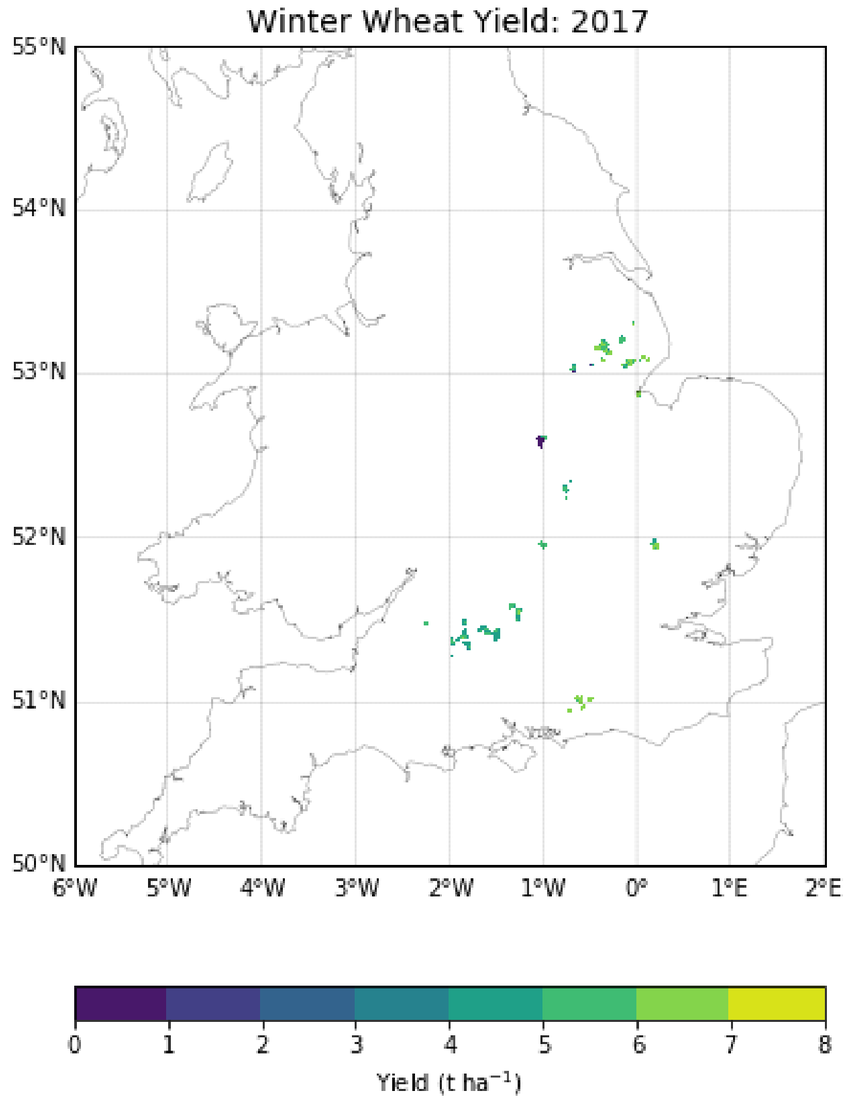


Results

‘standard’ JULES Crop



JULES Crop with leaf senescence and stomatal closing



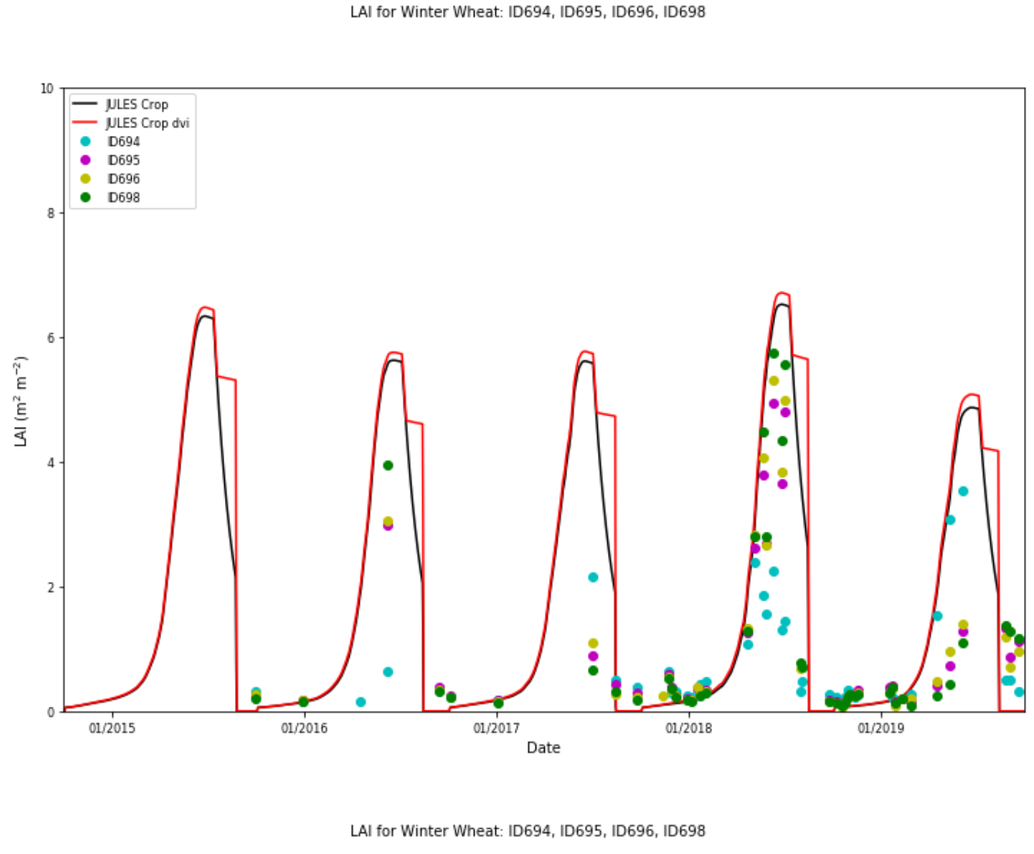
Similar pattern but note scale change

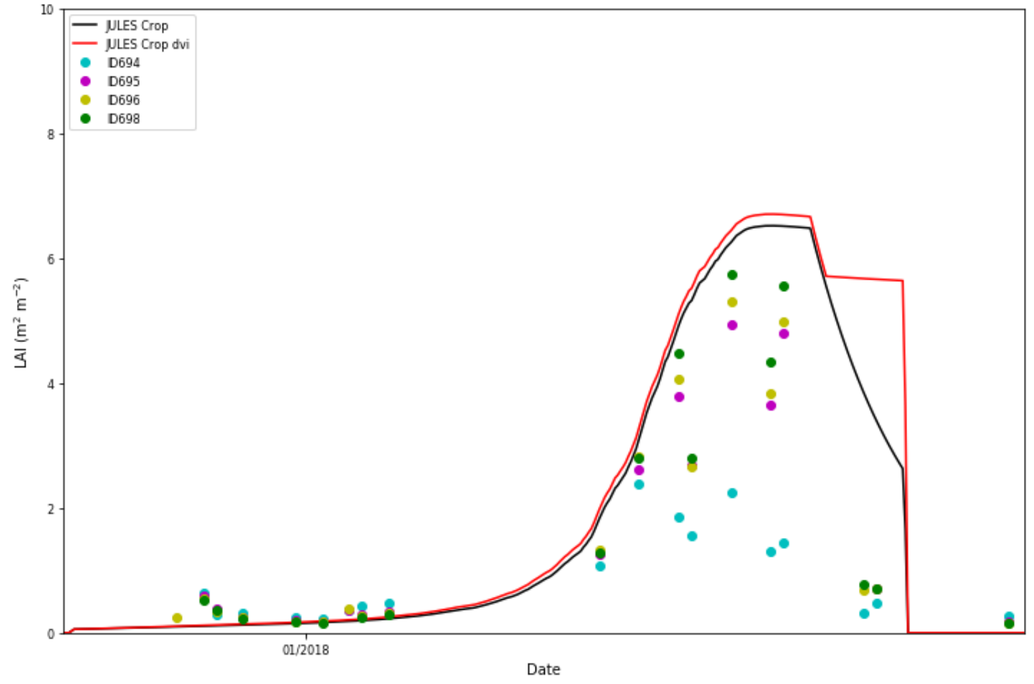
Results

Time series comparison of JULES Crop and JULES Crop DVI (October 2014-September 2019)

Leaf Area Index: modelled versus Sentinel-2

Leaf area index (2018)





Summary

JULES Code Development

1. Implemented the ‘crop senescence’ code changes into JULES vn6.3: fcm:jules.x/branches/dev/garryhayman/JULES_vn6.3_crop_dvicrit
2. Used the ‘optimised’ JULES-Crop parameters

Key points and further work

1. Initial results promising - JULES Crop with leaf senescence and stomatal closing has lower yields than the ‘standard’ version
2. As a result, this JULES Crop development is in ‘better’ agreement with field-scale yields of winter wheat
3. Further investigation needed of modelled LAI versus the Sentinel-2 LAI measurements
4. Extend to UK scale and for future climate using CHESS-SCAPE
5. Note: JULES Crop does not account for effects of pests & diseases, farm management practices, ….