

## ***Interactive comment on “JULES-crop: a parametrisation of crops in the Joint UK Land Environment Simulator” by T. Osborne et al.***

**T. Osborne et al.**

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AC: This is a reponse to reviewer's comments. We really value the input from the reviewer and thank them for this.

Reviewer Overview: The manuscript by Osborne et al. describes the JULES-crop model, an extension of the JULES land surface model to improve the representation of crops in there. The main focus of the manuscript is on global-scale application of the model (although the possibility for parameterisation at the local scale is discussed), and the model is evaluated against global yield data and site observations.

The manuscript is well-written and clear, and the strong focus on description of the model formulation and model structure is suited for Geoscientific Model Development.

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However, the manuscript needs a crucial improvement in two major aspects before it can be considered for publication:

RC: (1) In general, the model is described well, but the origin of some important equations and their parametrisation is lacking (e.g., Eqs. 1, 2, 8, 10, 11). As these equations are crop-specific for most part, I presume that these are not based on the original JULES model, and the sources that these equations originate from (or were inspired by) should be provided. (If they originate from JULES, please state this explicitly.) Similarly, the origin of parametrisations could be documented better. Even when "tuned" (p. 6785, l. 6), there must be some understanding of the range of these parameters based on the literature.

AC: The origins of the equations have now been added to the text.

RC: (2) The evaluation of the model and discussion of its performance are very superficially, and do not add much information (or confidence) in their current form. Global simulations are performed, highlighting the discrepancy between potential yields as simulated by the model and actual yields as observed (yield gap), but the authors do not discuss whether the difference is realistic. There are estimates of the yield gap (e.g., Licker et al., 2010), which the model could be compared to at the global scale - there should be at least an attempt to a better comparison with the observations.

AC: While the 'yield gap' estimates provide useful information it is not possible for us to directly compare model results. In the paper by Licker et al (2010), the climatic yield potential (which is used to generate the yield gap) is based on the 90th centile of current yields (under current management practices) within a climatic zone (as defined by GDD and soil moisture). What we model is crop yield in response to climate only – not including management practices but with a globally constant parametrization of nutrient availability (in reality a description of top level leaf nitrogen which scales GPP). Therefore, JULES-crop can simulate negative biases (due to a lack of irrigation for example) and positive biases (due to pests, disease, lower nutrient availability). That

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being said we can use the Licker et al data to qualitatively compare our results i.e. is JULES-crop over-predicting in regions with a high yield gap. We have added some discussion about this to the paper and changed the global yield figure to include observations. We have also expanded the analysis of inter-annual variability (looking more regionally) which we believe is a better evaluation of JULES-crop given the difficulties of reproducing spatial patterns due to varying management practices.

New text: Comparing the regional patterns of yield to observations gives useful insight into the existing limits of the model. It is clear that some important processes are missing particularly irrigation (although this model development will shortly be submitted for release). Developing a nitrogen cycle for JULES (model development also in progress) should also improve the model simulations as introducing nitrogen limitation has been shown to reduce overall productivity in earth system models (Thornton et al, 2009). JULES-crop will still exclude many management factors which affect regional yields. Licker et al (2010) estimated global yield gaps and showed they were greatest in tropical regions. Although not directly comparable with our simulations this study shows us that JULES-crop simulations are likely to over-estimate yields in tropical regions compared with observations. However, we have deliberately not introduced a yield gap adjustment as it would not be physically based and as such would be difficult to apply to future simulations. It is however, important to capture regional differences due to management as they will effect patterns in productivity and hence feedbacks to the climate. In an earth system model context it is better to represent these management processes explicitly were possible as they effect not only crop growth but also may well influence the local climate directly (e.g. irrigation (Sacks et al, 2009)).

RC:Similarly, the site simulations (performed for a few crops and locations only) focus exclusively on the impact of the seasonally changing LAI on the energy balance, and ignore the model's performance in terms of crop growth characteristics (are yield, crop height, net carbon fluxes, seasonality, etc. simulated correctly?).

AC:We do include evaluation of crop height and LAI but have also added GPP and  
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yield to the figures.

New text: Figures added

RC:The discussion of the model's abilities and shortcomings should be extended. E.g., the manuscript mentions the fact that spring wheat is not representative for large wheat-growing regions, but fails to discuss the implication of this for e.g. surface properties or surface fluxes. Similarly, the yield gap is acknowledged, but there is no discussion on the impact of this on the model's performance as a land surface scheme in a global model. What does this imply for the feedbacks to the climate system? I would recommend the authors to improve the manuscript in these two aspects to make this an attractive article for publication.

AC: We have expanded the discussion section to consider the yield gap as suggested-see above. We have also highlighted the implications of not including winter wheat.

New text: Inclusion of winter wheat is also high priority for JULES-crop. This is important for use of JULES-crop as a yield simulation model but also an earth system model as the additional presence of vegetation cover from autumn to spring would impact on surface characteristics (albedo, heat capacity etc).

RC:Major comments: Fig. 1: The figure seems to suggest that there is no accounting for belowground carbon pools in the model. Is this correct?

AC:Yes, JULES-crop is not coupled to soil carbon model yet.

RC:6781/6782: I am somewhat confused by the authors' estimate of the number of parameters needed to describe the allocation (not least by the statement " $2+(4-1)=6$ ", p.

AC:This should be  $2*(4-1)$ . This paragraph has been simplified.

New Text: Partition coefficients for a given crop are typically pre-defined in process-based crop models according to either the length of time since emergence, or to crop

development stage (DVI, i.e. a function of thermal time since emergence). They are represented by fixed values for a given period of time (or thermal time) since emergence, and these values are listed in a look-up table and referenced for each iteration of the model.

Here we define the partition coefficients as a function of thermal time using 6 parameters to describe continuously varying partition coefficients over the duration of the crop cycle. We use a multinomial logistic to define this function:

RC:6781, l. 19). I understand that there is no allocation to harvested compounds during the vegetative period (p. 6782, l. 12), but this would result in  $(3-1)+(4-1)=5$  parameters, whereas the authors consistently talk about 6. Moreover, the parameter  $\tau$  in Eq. 5 is not mentioned or described in further detail, whereas it will need an estimate (constant or temporally varying), adding to the parameters needed for the allocation description. Clarification would be appreciated.

AC:We talk about 6 as the equations apply over the whole growing season (DVI= 0-2). The parameter in Eq 5 is described on line 8. Its value varies by crop, but is constant in time and space.

RC:6783, l. 16: Are the parameters  $k$  and  $\lambda$  fitted for each crop separately, or do you derive a relationship valid for all crops? And how applicable is the relationship to the crops that are not grown at the FLUXNET site? Do you anticipate this relationship to be applicable at a global scale?

AC:Yes they are specified for each crop. Variations in height are a function of variations in the amount of carbon partitioned to stems, rather than in the relationship between stem carbon and height. By specifying crop-specific parameters we capture the fact that given the same stem carbon, maize is taller than soybean. There may be small differences in this relationship for different varieties of maize (for example) but these differences are not the primary reason for variations in height and stem thickness.

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RC:6788, l. 14: I do not agree with the statement that early season performance is crucial for future growth: Yes, there is a strong feedback from early assimilation and leaf growth to light interception, but this feedback decreases rapidly upon closure of the crop canopy.

AC: Agreed - text removed.

RC:Minor comments and technical corrections:

RC:6778, l. 9: replace "know" by "known"

AC:Done

RC:6779, l. 1: please refer to Table 1 for explanation of the subscripts b, o and m

AC:Done

RC:6780, l. 15: add "with" (or equivalent) before "the following equation" AC:Done

RC:6781, l. 18: I take that " $2+(4-1)$ " should read " $2*(4-1)$ " AC:Done

RC:6784, l. 7: remove "being" AC:Done

RC:6784, l. 15: The mentioning of five plant functional types is somewhat confusing, as you talk about 9 surface types before. Upon rereading, I realized that 4 out of 9 are not plant-covered, which may explain the difference. Please clarify this.

AC:Text modified to clarify that there are 9 surface types including 5 plant functional types. New text: The standard version of JULES represents the land surface as a combination of up to 9 surface types including five plant functional types: broad-leaf trees, needle-leaf trees,  $C_3$  grass,  $C_4$  grass, shrubs, bare-soil, inland lakes, snow and ice.

RC:6784, l. 18 (and elsewhere): please use subscripts for C3 and C4. AC:Done

RC:6784, l. 20: The mentioning of tropical oilseed confused me - do you consider this to be a cereal crop? What is the difference between crops and crop types in this

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sentence?

AC:The values of the parameters required in Eqs. (1)–(13) determine which crop type is being simulated. (e.g. maize, wheat, or rice). It is also possible that alternative sets of parameter values could be specified to simulate different cultivars of the same crop or generic crop functional types. Text has been amended to clarify this.

New text: The values of the parameters required in Eqs. (??)–(??) determine which crops are being simulated and can be varied according to different user requirements e.g crop species (e.g. maize or wheat), generic crop type (e.g.  $C_3$  cereals) or cultivar (e.g. Soy bean PS123121 or Soy bean 21h321).

RC:6785, l. 3: I presume that the comma is placed wrongly here and should go after "model" instead? AC:Done

RC:6785: "widely used in the literature": Why not add references for these?

AC:Reference added New Text: The cardinal temperatures ( $T_b$ ,  $T_o$ , and  $T_m$ ) were specified values in line with the range of values reported in the literature (see ? and ?).

RC:6785, l. 19: replace "he" with "The" AC:Done

RC:6785, l. 21: Please specify the rough dimensions of an N96 grid for readers that are not familiar with climate modelling. AC:Done

RC:6785, L. 27: add "was" before "obtained" AC:Done

RC:6786, l. 3: What do these ratios between length of vegetative and reproductive period originate from?

AC:They are an approximation of the relative length of each phase.

RC:6786, l. 15: replace "an" with "at" AC:Done

RC:6788, l. 8: replace "over estimated" with "overestimated" AC:Done

RC:6788, l. 28: replace "where as" with "whereas" AC:Done

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RC:6790, l. 17: replace "over estimates" with "overestimates" AC:Done

RC:6790, l. 21: replace "over estimate" with "overestimate" AC:Done

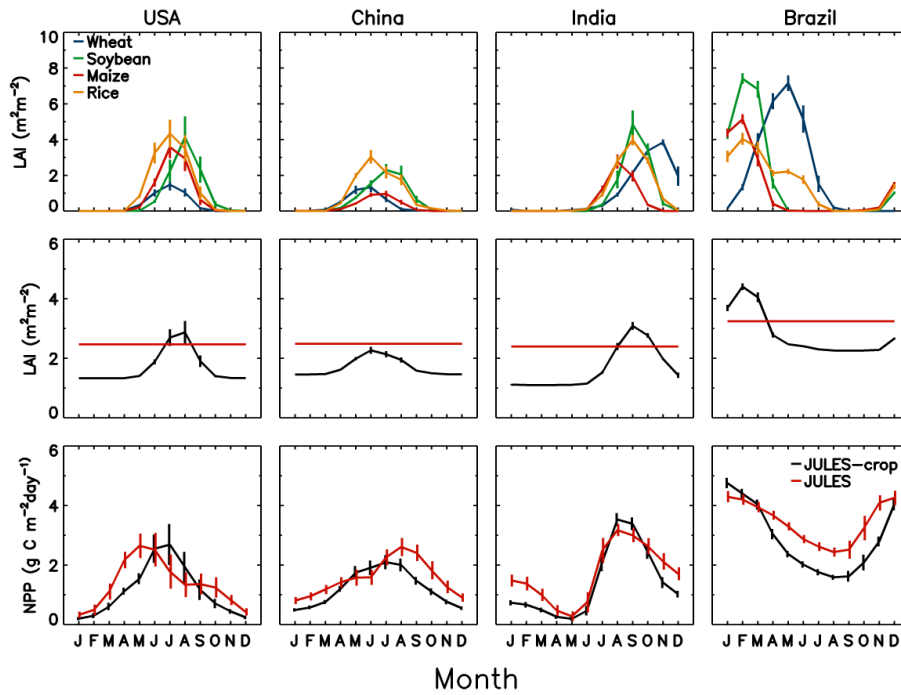
RC:6791, l. 16: The feedbacks mentioned here are typically referred to as biogeophysical, not biogeochemical. AC:Done

RC:6791, l. 17: replace "parametrization" with "parametrisation" AC:Done

RC:6792, l. 20: replace "day length" by "daylength" AC:Done

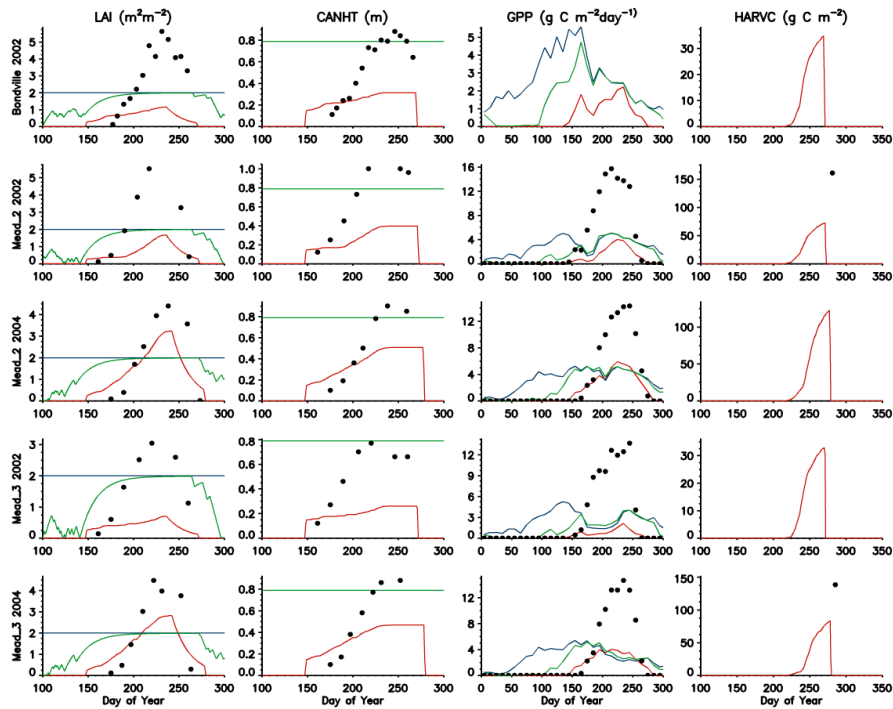
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Interactive comment on Geosci. Model Dev. Discuss., 7, 6773, 2014.



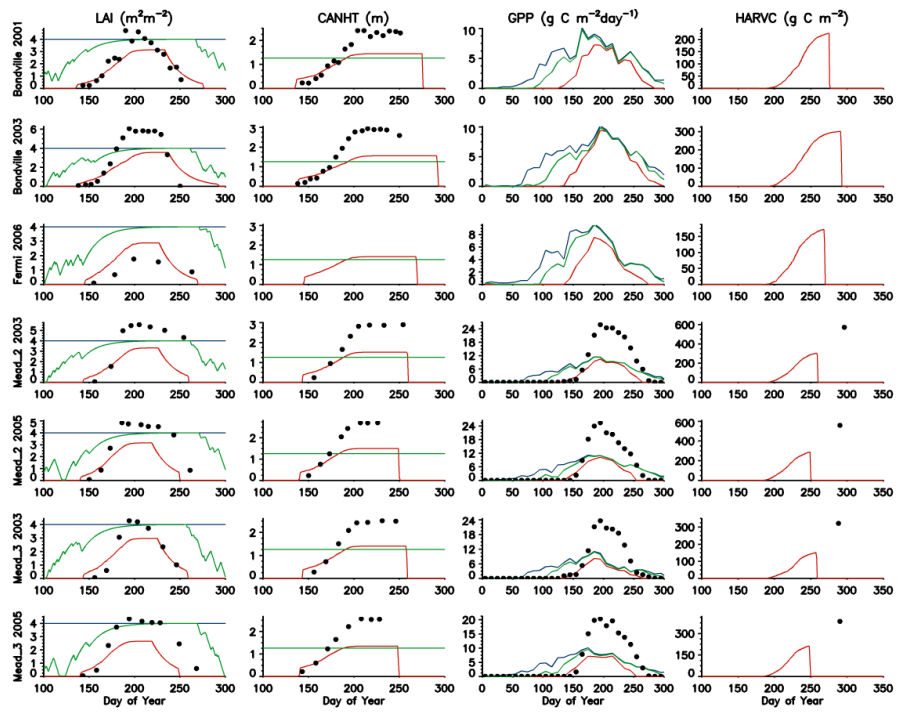
**Fig. 1.** Country crop area weighted annual cycle of crop type (top) and grid-box mean (middle) leaf area index ( $\$LAI\$$ ) and grid-box mean (bottom) Net Primary Production (NPP).

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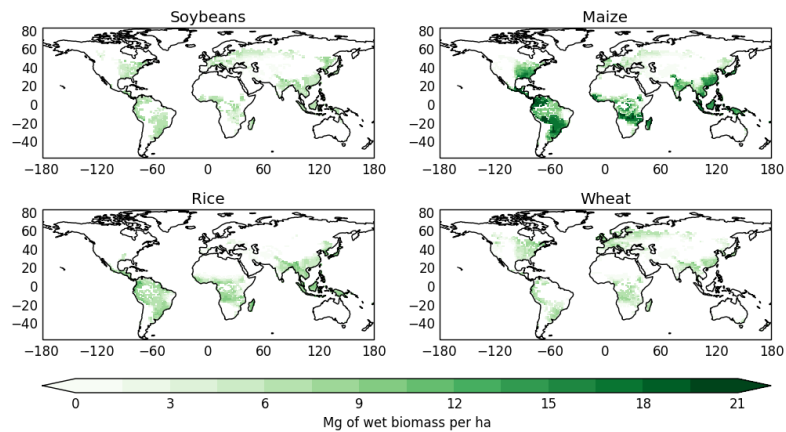
**Fig. 2.** Simulated (solid lines) and observed (dots) Leaf Area Index (LAI), Canopy Height (CANHT), Gross Primary Production (GPP) and Harvest Carbon (HARVC) at a range of fluxnet sites and years.

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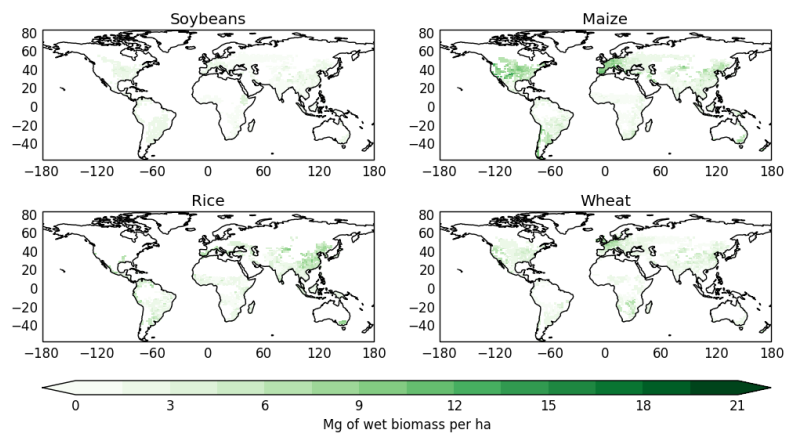
**Fig. 3.** Simulated (solid lines) and observed (dots) Leaf Area Index (LAI), Canopy Height (CANHT), Gross Primary Production (GPP) and Harvest Carbon (HARVC) at a range of fluxnet sites and years.

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**Fig. 4.** Global yields simulated by JULES-crop (Mg per ha)

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**Fig. 5.** Global yield observations (Mg per ha)

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