Earth Syst. Dynam. Discuss.,
https://doi.org/10.5194/esd-2017-66-AC3, 2017

Earth System Dynamics
Discussions

Interactive comment on "Projected changes in crop yield mean and variability over West Africa in a world 1.5 K warmer than the pre-industrial" *by* Ben Parkes et al.

Ben Parkes et al.

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Received and published: 6 October 2017

The responses are presented as Reviewer comment, our response and the changes made to the manuscript

1. The methodology is unclear and incomplete. It lacks the necessary details to fully understand the experiment design and the results. For example, there is no explicit information about the statistical model used in the study. We don't know what form this model is and how it works in the study.

The linear model has now been described in the manuscript with the content below.

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The linear models use a design that has been used in several previous studies Estes et al. (2013); Lobell and Burke (2010); Wang et al. (2016); Parkes et al. (2017). The models in this study use the robust linear fitting tools in MATLAB (Holland and Welsch, 1977) that are less sensitive to outliers than least squares fitting. The input data for the model have been polynomially detrended before fitting and the log of the yield was taken, this means the models produce relative changes in yield instead of absolute ones. The polynomial detrending used in the models is a two degree polynomial solved for each grid cell. The models solve the equation shown in Eqn 1 where a, b and c are constants for each grid cell and T and P are the seasonal mean temperature and total precipitation respectively.

$$Y_{it} = a_i + b_i T_{it} + c_i P_{it}$$

Moreover, the interannual variability of yield is analyzed in the future based on projections from climate models. But I am not sure whether climate variability and their impacts on yield can be captured by the model's future projection, given that signals like ENSO may not be well captured.

The variability in the input data has been restricted by bias correcting the data. The models have variability that is close to the observations. The monsoon is the primarily precipitation source in the region and this is typically a weakness of models. The CORDEX simulations have been shown to perform well at replicating the large scale features including the IAV in precipitation over West Africa. Biases exist in the CORDEX output and this is one of the reasons we have bias corrected the data. To clarify this, the following text has been added.

The CORDEX-Africa simulations were found to perform well at replicating the large scale features of the West African climate including the inter annual variability in precipitation (Diaconescu et al., 2015). The precipitation in West Africa is primarily driven by the north-south motion of the monsoon (Nikulin et al., 2012). The CORDEX-Africa models were found to contain biases despite their good performance and therefore bias corrected model output were selected for further analysis (Gbobaniyi et al., 2014).

2. The analysis and results are kind of unbalanced. Three crops are included in the study, but most of the figures and results are about maize while less attention has been given to other crop and their results are placed in SI.

The figures have been consolidated and placed in the main text. An example millet figure is shown in Figure 1.

The ensemble approach using climate data of 16 combinations should help understand the uncertainty in the results. However, there is little discussion about uncertainty (e.g., from climate input data or model itself). And surprisingly, there is no error bar or confidence level reported in the results. Discussion section needs to include more content to dig into the inconsistencies and discrepancies in the results across the models and across different crop types.

We have confidence levels on the tables of results and the yield changes where discussed. We have also inserted a paragraph on the inter-model differences and the impacts of these differences. These are most clearly seen on the full updated version of the manuscript attached as a supplement to this response. Please see P6L14-24, P7L25-32, P11L3-16 and the tables on P26, 27 and 28.

3. The figures in the manuscript are poorly designed, which undermine the readability. Many figures can be combined. Results of three crops can be combined in one figure. The colormap used in the heat map is problematic. Fig 7 is hard to follow. The authors have to think about how to improve the figures to make them more effective in conveying key information and in the meantime easy to read.

New scatter plots of yield and IAV have been created and are shown below. Figure 7 has been reworked into a new box plot. See Figure 2 with the caption below.

Efficacy of adaptation methods for maize in GLAM. HTS is high temperature stress adapted crops, Rw H shows crops with rainwater harvesting, HTS and Rw H shows both adaptation methods in use. Each box shows the fractional yield change relative to the unadapted crop with the boxplots showing the range across the 6 member GCM-RCM ensemble. The pairs of boxes show the relative change in yield for the adaptation method in the historic climate (left) and the future climate (right).

P1 L4-5: Please specify recent historical and near term future.

The dates have been added for the historic time period, we have instead specified the temperatures as this manuscript is based on SWLs.

An ensemble of near term climate projections are used to simulate maize, millet and sorghum in West Africa in the recent historic (1986-2005) and a near term future where global temperatures are 1.5 K above pre industrial.

P1 L6: "The mean yields are not expected to alter significantly". Where does this expectation come from? This contradicts the results of this study.

This line has been removed and the abstract reworked the full abstract is shown in the comment below.

The abstract needs more work. Please clearly define the science question, explain the methods used and the results.

The abstract has been developed and is shown below.

The ability of a region to feed itself in the upcoming decades is an important question. The West African population is expected to increase significantly in the next 30 years. The responses of crops to short term climate change is critical to the population and the decision makers tasked with food security. This leads to a three questions, How will crop yields change in the near future? What influence will climate change have on crop failures? Which adaptation methods should be employed to ameliorate undesirable changes?

An ensemble of near term climate projections are used to simulate maize, millet and

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sorghum in West Africa in the recent historic (1986-2005) and a near term future where global temperatures are 1.5 K above pre-industrial to assess the change in yield, yield variability and crop failure rate. Four crop models were used to simulate maize, millet and sorghum in West Africa in the historic and future climates.

Across the majority of West Africa the maize, millet and sorghum yields are shown to fall. In the regions where yields increase the variability also increases. This increase in variability increases the likelihood of crop failures, which are defined as yield negative anomalies beyond one standard deviation during the historic period. The increasing variability increases the frequency of crop failures across West Africa. The return time of crop failures falls from 8.8, 9.7 and 10.0 years to 5.2, 6.2 and 5.8 years for maize, millet and sorghum respectively.

The adoption of heat-resistant cultivars and the use of captured rainwater have been investigated using one crop model as an idealised sensitivity test. The generalised adoption of a cultivar resistant to high temperature stress during flowering is shown to be more beneficial than using rainwater harvesting.

The first paragraph needs to have more references and to be better organized. Some content such as monsoon is irrelevant to the topic of this study.

The monsoon is the primary water source for the crops grown in West Africa is therefore important to the study. The introduction has been reorganised to flow better, we now discuss the large scale problem, and the challenges faced in the region. This is followed by an introduction to the regional climate, the adaptation methods that people may use and then introduced the carbon dioxide fertilisation effect. We have also added a number of references.

P2 L4 heat- and drought-resistant

This has been corrected

P2 L19-20: references

Reference to Rippke et al added

P3 L23-25: If 10 out of 16 combinations are based on RCA4. Why is it designed this way? My concern is that the results from the ensemble experiment would largely depend on the performance of RCA4, making the results biased to RCA4.

The experiment uses the full set of CORDEX data that were subsequently bias corrected as part of HELIX. We use the full ensemble as subsampling was considered to be less optimal. The CORDEX simulations are not k-complete and we used every experiment that we had access to. The alternatives are, using only RCA4 to remove the RCM as a source of variability, or restricting to the GCMs that used multiple RCMs but only CNRM-CM5, MOHC-HadGEM2-ES and MPI-ESM-LR used both RCA4 and CCLM.

P3 L30-33: The varying CO2 levels could affect the mean yield response as well as the variability under warming. This needs to be discussed.

This is now discussed in the results section

ORCHIDEE-Crop and GLAM simulate responses to carbon dioxide fertilisation. Both models project a small reduction in yield in future climates, the magnitude of which has been reduced by the increase in yield from carbon dioxide fertilisation. Carbon dioxide fertilisation increases the yield when the crop is limited by carbon dioxide. If the crop is water limited then the carbon dioxide fertilisation will have a smaller effect on yield.

Section 2.2: more information about the four crop models need to be provided. For example, at least to differentiate process-based crop models and the statistical models. Another question is if the results from the statistical model are comparable with that from the process-based models, as the mechanisms drive the change could be different. This needs to be discussed.

More detail about the crop models have been added to the text in both the methods and the discussion

Differences in the crop models Both GLAM and ORCHIDEE-Crop were used to simulate maize, SARRA-H and the generalised linear models were used to simulate maize, sorghum and millet. GLAM and ORCHIDEE-Crop both respond to carbon dioxide fertilisation and ORCHIDEE- Crop has nitrogen fertiliser inputs as part of the simulated crop growth. The crop models all simulate crops based on a single planting and harvest without multicropping. GLAM and the linear models use observational yield as an input, in both cases the input yield is detrended using a two degree polynomial before use. This detrending removes consistent trends such as management changes and technological improvements. GLAM unlike the other models was calibrated specifically for these simulations whereas ORCHIDEE-Crop and SARRA-H used pre defined parameter sets. The SARRA-H parameters were based on a study area in Burkina Faso. The process based models are time dependent and respond to the arrival of the monsoon, the linear models however only use the seasonal total precipitation. Linear models suffer with reduced accuracy outside the parameters space used to train them. In the short term linear models are not notably worse than process based models (Lobell and Asseng,2017).

The differences in the crop models and inputs have an influence on the results. From Figure 1 GLAM shows a greater spread of yield change with climate change than the other models whereas ORCHIDEE and SARRA-H are more consistent under climate change. The yield changes in ORCHIDEE and GLAM are also influenced by the carbon dioxide fertilisation effect and in its absence the projected yields are expected to be lower. The IAV results show greater spread in the linear models than the process based models, this is a result of the simple parameters in the linear models. The results in Figure 5 show that GLAM has a stronger negative response to precipitation loss than the other models. The temperature results for all models show a downward trend in yield with increasing temperatures. The lack of variability in the linear models is shown in Figure 4 where they consistently underestimate crop failure rates. ORCHIDEE has a smaller IAV than the other process based models which means the crop failure limit is much higher than in the other models. This results in ORCHIDEE finding a significant increase in the number of crop failures. As the ORCHIDEE IAV is closest to the observed IAV (Table 3,this indicates that GLAM and SARRA-H are likely to underestimate the number of future crop failures. For Figures 2 and 3 the country scale yields in the historic inputs can be clearly seen in the linear models as opposed to the spread of yield values in SARRA-H.

Figure 1: (1) Since the red and blue color already represent negative and positive changes, it may not necessary to use symbols (cross and dot) to denote agreement for negative and positive changes separately. (2) Fig 1 and 2 and be combined to include both mean change and IAV. (3) I would suggest trying to include all four crops in the figure using 8 panels.

The plots have been reworked into new panels to give even attention to all three crops. We have 3 crops and show 3 figures containing 4 panels each. The new panels are maps of yield and IAV along with scatter plots coloured by model. An example of the new figure layout is already shown in Figure 1 of our responses.

P4 L24-25: Unless those place names are shown on the map, they make little for people like me who is not familiar with the geography of West Africa. And this might be the case for most readers.

A figure has been added to the SI and referenced in the results section.

An annotated map of the analysed area is shown in SI Figure 1.

P4 L26: Avoid placing the results in SI unless there is a strong reason to do so. Since millet is one of the three crop types in the study, the results should appear in the main text.

As part of earlier responses we have moved several millet and sorghum results into the main text, and an example figure has already been shown.

Fig 3-6: (1) the current blue-to-red contrast type of colormap is problematic. It is not suitable to display a continuous range of yield value (not yield change). It creates unnecessary visual confusions. For example, What is the white color? Does it mean no value or the value around 1700? Please use other colormaps, there are plenty alternatives to choose. (2) Heat map here may not be a good choice to represent quantitative information . . . The difference between history and future is very hard to see. The authors should consider redesigning this figure or at least display the exact number in the heat map.

The yield and IAV heatmaps have been replaced by new figures and tables. See Figure 1

P5 L11: Please specify the results from Knox and Challinor results? Is that a model result, empirical study, field experiment, or meta-analysis? What did they find and how their results are connected here?

This has been expanded and clarified

The yield losses in GLAM and ORCHIDEE-Crop are smaller than the mean reported in the meta-analysis by Knox et al. (2012). The Knox et al. (2012) results are for crops in the 2050s and therefore our results are expected to be smaller as they are for a closer time horizon. A second meta-analysis by Challinor et al. (2014) presents results by temperature change, our results at 1.5 K are within the range of results found in their analysis.

P5 L24: Please justify the definition of crop failure using 1 and 1.5 standard deviations of yield. Is the std threshold calculated using observations?

1 and 1.5 have been used in previous studies by the authors. The standard deviation is from the historic results per model. Otherwise biases in the model results would dominate over the yield changes. A citation of Parkes et al (2015) has been added too.

Fig 7. The legend is incomplete. Please add legends for all symbols including cross, circle, etc. I don't understand how to read this figure... What is the variable on x and y axes and their units? Please add more information in the caption.

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Figure 7 has been reworked as a boxplot instead of the scatter plot and is described in Figure 2 with the associated caption.

Please also note the supplement to this comment:
https://www.earth-syst-dynam-discuss.net/esd-2017-66/esd-2017-66-AC3-supplement.pdf

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Interactive comment on Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2017-66, 2017.

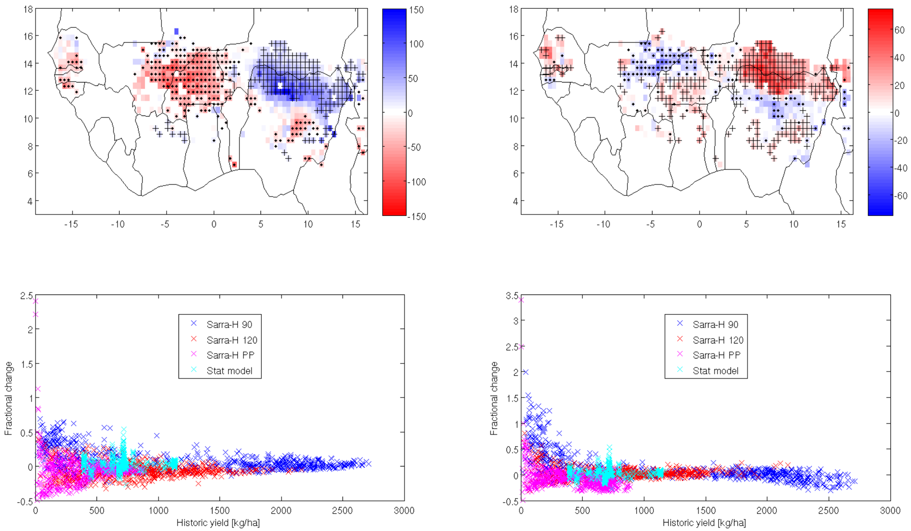

Fig. 1.

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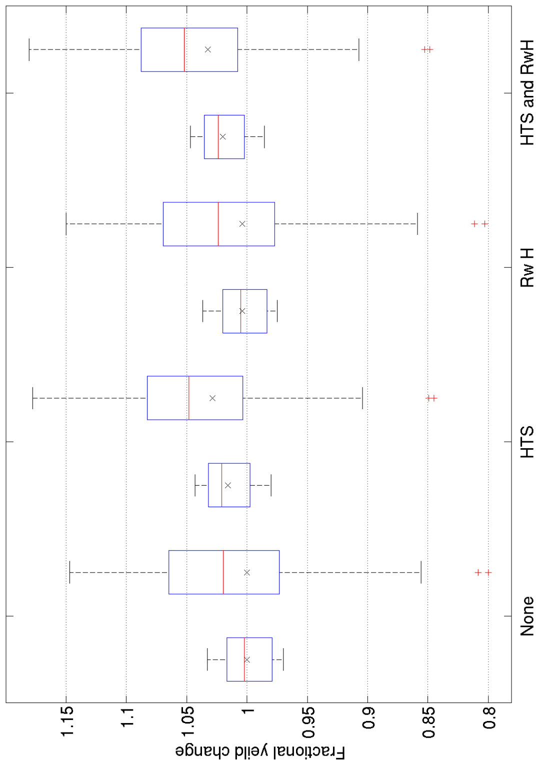
Fractional yeild change
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
None
HTS
Rw H
HTS and RwH

Fig. 2.