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Discussions

Interactive comment on "Climate-driven interannual variability of water scarcity in food production: a global analysis" *by* M. Kummu et al.

M. Kummu et al.

matti.kummu@aalto.fi

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We are very grateful for the thoughtful and constructive comments submitted by the reviewer. We will take all the comments carefully into account when revising the paper, as specified below.

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Major comments

Reviewer's comment 2.1: With interest, I have read the manuscript by Kummu et al. They globally estimated blue/green water availability and water requirement to produce 3000 kcal per capita per day of food for 309 food production units. They analyzed the

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geographical distribution and the temporal variability of the blue/green water scarcity. They finally proposed some countermeasures for water scarce regions.

Although a number of reports on water and food have been published, integrated analyses on water and food are still lacking. The authors addressed this problem with a series of simple but effective numerical simulations in this study.

The findings of this study sometimes seem oversimplified and require readers' attention because the authors set a lot of assumptions. For example, the authors fixed population and agricultural technology at the year of 2000, but they have substantially grown in the study period. The authors also set the globally uniform numbers for daily caloric intake and the ratio of vegetable and animal caloric consumption, but in reality, there are substantial regional differences. Nonetheless I believe this study is important, because it would be a good starting point toward more sophisticated studies.

The manuscript is quite well structured and written. The tables and figures are excellently prepared, which are clear and informative. I don't have to comment much except some items shown below.

Authors' response 2.1: We thank the reviewer for the supportive comments on the importance of the paper. The assumptions, to which reviewer is referring to, have well justified reasons:

- Most existing water scarcity studies use average climate conditions over 10-30 years (Rockström et al., 2009; Gerten et al., 2011). This evens out the natural variability in water availability and water requirements (i.e. agricultural water productivity) for a reference diet. Our aim is to analyse the impact of hydroclimatic variability on food production and related water resources, i.e. to look into these 30 years that are normally averaged for this kind of studies. In so doing, we need to keep the other factors (e.g. population, agricultural technology) constant. In much more comprehensive future studies, as specified in the Discussion (p 6947, lines 19ff), it would be important to include the analysis of these processes for the historical evolvement of the green-blue

HESSD

10, C4423–C4428, 2013

water scarcity.

- It is true that there are regional differences in caloric consumption. We do refer, however, to a reference diet (i.e. production level) that follows the recommended diet of WHO and FAO (WHO, 2003; FAO, 2013) and thus our aim is to estimate whether, hypothetically, there would be enough water to produce such a diet in an area (country, FPU) in question. The diet does, nevertheless, vary in the model on how (with which crops and livestock) each country fill these requirements. More explanations can be found in Author response A1.3 to Reviewer #1.

In the revised manuscript, we will take care that these issues are more clearly stated and that our aim and methods are explained with the required depth.

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Minor comments

R2.2: Page 6934, line 10, "blue water scarcity (Wada et al., 2011; Hoekstra et al. 2012)": Also Hanasaki et al. (2008) devised an indicator for average seasonal (and partly inter-annual) blue water scarcity.

A2.2: Thank you for pointing out this article; it will be cited in the revision.

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R2.3: Page 6935, line 17, "Crop management is. . .": Throughout the text, it is not clearly mentioned that the crop yield was estimated by LPJmL and the temporal variability in yield is a modeled product. This should be mentioned here.

A2.3: We agree that this was not mentioned in the text, and it will be clearly stated in the revised manuscript.

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R2.4: Page 6935 line 25, "crop water productivity (water consumption per unit of

HESSD

10, C4423–C4428, 2013

biomass produces)": It should be clarified either the total biomass or the edible parts of crop is discussed here.

A2.4: We will clarify that it is the total biomass production, not the (manageable) yield.

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R2.5: Page 6936, line 17, "statistical weather generator": Statistical weather generators generally produce precipitation independently from that of surrounding grid cells. This makes spatially and temporary (sub-monthly) uniform distribution in precipitation over the basins, hence, it might underestimate the intensive severe drought and flood. A short note should be added to this issue.

A2.5: We will briefly discuss this issue in the revised manuscript.

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R2.6: Page 6938, line 14, "resulting GBW scarcity": The term should be clearly defined in text. Does it mean if the GBW availability falls below the GBW requirements, the region is categorized as "GBW scarcity"? The gap between the availability and requirement would be tiny for some regions while huge for others. Are these significances of shortage distinguished?

A2.6: Yes, an area is considered to be GBW scarce if GBW availability falls below the GBW requirements. We do agree that this was not adequately defined in Section 2.3, this will be fixed in the revised manuscript.

It is true that for some areas the gap, in either direction (below or above GBW scarcity), might be tiny while large for others. The frequency of GBW scarcity (i.e. counting the years that fall below the scarcity level) points this out compared to approaches where only an average value is used, as then the areas close to the threshold are classified to be under occasional water scarcity (see Section 2.4 of the article). Figure 6 further gives a good overview of the areas that are close to that threshold. We will highlight this in the revision.

HESSD

10, C4423–C4428, 2013

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R2.7: Page 6940, line 16, “on-farm management”: It would be helpful for readers if the authors specify what the key items are. Does it mainly indicate the difference in crop yield?

A2.7: Right, we will be more specific about this in the revision. It is basically about soil conservation and water harvesting.

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R2.8: Page 6946, line 3, “the model assumptions”: It should be discussed the uncertainty in crop yield simulation. As far as I know, it is still a big challenge to reproduce the historical inter-annual variability of crop yield with macro-scale crop growth models. It is even more challenging when the models cover multiple crops for small regions. Because the GBW requirement is quite sensitive to model estimated crop yield, the uncertainty should be discussed here.

A2.8: It is totally right that it is very challenging to model yields. Therefore, the management in our model was calibrated to match best the FAO reported yields for year 2000. We did not attempt to reproduce the historic yields, as the purpose of the study is to investigate the climate-only effect on those yields and on the blue-green water limitations if they were up- or downscaled to the 3000 kcal level, respectively. We will make this explicit in the revision.

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HESSD

10, C4423–C4428, 2013

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