Earth Syst. Dynam. Discuss.,
doi:10.5194/esd-2016-58-RC3, 2017


Earth System Dynamics
Discussions
Open Access

# *Interactive comment on* "Future supply and demand of net primary production in the Sahel" *by* Florian Sallaba et al.

**Anonymous Referee #3**

Received and published: 18 April 2017

This manuscript aims to forecast the spatiotemporal supply and demand of net primary productivity (NPP) across the Sahel region for the full 21st century. The authors utilize a simple vegetation production model forced by four RCP projections and a simple socioeconomic model based on assumptions derived from five shared socioeconomic pathways to quantify spatiotemporal variability in NPP supply and demand, respectively. Results indicate widespread NPP shortfalls across the region by 2050 due to population increases and shifts toward diets rich in animal products. The authors conclude that the UN sustainable development goals for ending hunger are at high risk for failure. Overall, I feel the manuscript presents a useful framework for addressing the eminent grand challenge of meeting future demand in the face of climate change, dietary shifts, and population growth. The manuscript is well written and the methodological detail is clear and sufficient. The findings are of interest to a broad audience



including land managers and policy makers. Yet, there are apparent major flaws in the modeling approach that must be addressed before I can recommend publication of this manuscript. My main issue is that . . . I recommend ... Please find my general and specific comments below.

Major Comments: 1. The introduction is very well-written and does an excellent job of framing the question and establishing the importance of the work.

2. Page 4, line 27: It is stated that the authors used 0.5 degree climate data from five GCMs, and [CO2] based on four RCPs (Representative Concentration Pathways). The way it is phased it is unclear which RCPs were used to generate the climate projections for each GCM. The authors should have used climate data derived from runs across the 4 RCPs for each of the 5 models. Please clarify the text if this is the case. If not, please explain more fully why the climate data were not derived for all RCPs.

3. Robustly representing future NPP trajectories is challenging due to the many potential counteracting feedbacks. The authors show a good fit with LPJ NPP simulations, but do not consider observational data or alternative runs of the LPJ model itself. I recommend further comparison against both census derived yield trends (Rey et al. 2013) and satellite-derived yield trends (Running et al. 2004). For instance, the authors could consider runs in which the CO2 fertilization effect is turned off. Currently all the NPP trends considered in the paper are increasing due to CO2 fertilization (page 9, line 24). This is an area of debate and may be counter to observational data (see Smith et al. 2016, Oberneier et al. 2016, and Ort & Long et al. 2014). Thus, I wonder if a scenario in which CO2 fertilization effects are isolated and removed would be a more realistic lower boundary on what to expect for the region? I would imagine very large increases in the NPP debt (without large irrigation efforts), much larger than what is currently considered in the paper.

Running, S.W., Nemani, R.R., Heinsch, F.A., Zhao, M., Reeves, M. & Hashimoto, H. (2004). A Continuous Satellite-Derived Measure of Global Terrestrial Primary Production. Bioscience, 54, 547–560.

Ray, D.K., Mueller, N.D., West, P.C. & Foley, J.A. (2013). Yield Trends Are Insufficient to Double Global Crop Production by 2050. PLoS One, 8, e66428.

Smith, W.K., Reed, S.C., Cleveland, C.C., Ballantyne, A.P., Anderegg, W.R.L., Wieder, W.R., Liu, Y.Y. & Running, S.W. (2016). Large divergence of satellite and Earth system model estimates of global terrestrial CO2 fertilization. Nat. Clim. Chang., 6, 306–310.

Obermeier, W.A., Lehnert, L.W., Kammann, C.I., Müller, C., Grünhage, L., Luterbacher, J., Erbs, M., Moser, G., Seibert, R., Yuan, N. & Bendix, J. (2016). Reduced CO2 fertilization effect in temperate C3 grasslands under more extreme weather conditions. Nat. Clim. Chang., 7, 137–142.

Ort, D.R. & Long, S.P. (2014). Limits on Yields in the Corn Belt. Science (80-. )., 344, 484–485. McGrath, J.M. & Lobell, D.B. (2013). Regional disparities in the CO 2 fertilization effect and implications for crop yields. Environ. Res. Lett., 8, 14054.

4. Page 5, line 4: When the fractional agricultural landcover estimates from Hurtt et al (2011) were applied, was it assumed that natural and agricultural NPP were similar? If so, this assumption should be revisited after considering differences between agricultural vs. natural NPP for the region. For instance, the authors could compare census-based estimates of crop productivity with their estimates as a reality check. Smith et al. 2014 (see reference below), found that agricultural productivity for the region is significantly lower than natural productivity. If this potential reality is not considered, then the scenarios in this manuscript may be overly optimistic.

Smith, W., Cleveland, C.C., Reed, S.C. & Running, S.W. (2014). Agricultural conversion without external water and nutrient inputs reduces terrestrial vegetation productivity. Geophys. Res. Lett., 41, 449–455.

5. I would recommend revisiting all crop allocation parameters based on those reported by Monfreda et al. (2008). Given the high variability in crop specific harvest fractions,



it seems it may be necessary to parameterize the model for each individual crop grown in the region.

Monfreda, C., Ramankutty, N. & Foley, J.A. (2008). Farming the planet: 2. Geographic distribution of crop areas, yields, physiological types, and net primary production in the year 2000. Global Biogeochem. Cycles, 22, 1–19.

6. Page 12 line 24-26: This statement is not representative of the literature (see below references). I would suggest more nuanced discussion of the potential limitations of the supply approach used in this analysis. For instances, how much did CO2 fertilization drive increases? How uncertain are the precipitation estimates? Were nutrient constraints considered and if so what are the management implications? If not, how might nutrient constraints limit NPP? How will increases in atmospheric water demand (Vapor pressure deficit) affect yields and productivity? Could increased drought and desertification also represent a potential scenario had the CO2 sensitivity been adjusted? The way that this section is currently written is a gross over extension of the simplified NPP modeling that the paper is based on.

Smith, W.K., Reed, S.C., Cleveland, C.C., Ballantyne, A.P., Anderegg, W.R.L., Wieder, W.R., Liu, Y.Y. & Running, S.W. (2016). Large divergence of satellite and Earth system model estimates of global terrestrial CO2 fertilization. Nat. Clim. Chang., 6, 306–310.

Obermeier, W.A., Lehnert, L.W., Kammann, C.I., Müller, C., Grünhage, L., Luterbacher, J., Erbs, M., Moser, G., Seibert, R., Yuan, N. & Bendix, J. (2016). Reduced CO2 fertilization effect in temperate C3 grasslands under more extreme weather conditions. Nat. Clim. Chang., 7, 137–142.

Ort, D.R. & Long, S.P. (2014). Limits on Yields in the Corn Belt. Science (80-. )., 344, 484–485. McGrath, J.M. & Lobell, D.B. (2013). Regional disparities in the CO 2 fertilization effect and implications for crop yields. Environ. Res. Lett., 8, 14054.

Wieder, W.R., Cleveland, C.C., Smith, W.K. & Todd-Brown, K. (2015). Future productivity and carbon storage limited by terrestrial nutrient availability. Nat. Geosci., 1–5.

Minor Comments: 1. Page 3, Line 17: “Three different aggregation levels are considered, including Sahel, the country, and the local”. Please define what is meant by local level. Pixel level? What resolution? 2. Page 12 line 12: missing end of parentheses.

---

Interactive comment on Earth Syst. Dynam. Discuss., doi:10.5194/esd-2016-58, 2016.