

Interactive comment on “Climate change impacts on river discharge in West Africa: a review” by P. Roudier et al.

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=> We thank referee #2 for its useful comments which helped us to improve the paper and to submit a new improved version of the manuscript. We answer below to each comment point by point.

General Observations:

The paper provides an in-depth analysis of the available studies related to the effect of climate change on the runoff behavior of the Sahelian, Sudano-Sahelian and Sudanian rivers in West Africa. The effect of changes in land use, water consumption and higher carbon concentrations on the hydrograph of the rivers in this region of the African continent, due to the limited number of available studies focusing hereon, is

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less developed. Although future predictions suggest an increase in precipitation (referred in this paper and elsewhere as the main factor affecting runoff) in the study area, the results evidence contrasting findings and therefore a lack of a clear tendency for most of the rivers or subzones. The manuscript not only stresses the need to assess the uncertainty bounds on the predictions of future scenarios, particular in view of decision-making, but also provides where possible uncertainty ranges. The paper is well written and concrete; the methodology is simple and easy to follow.

=>Thank you.

However, I would suggest the following minor changes before final publishing in order to improve the comprehension of the reading:

1. Page 2488, Line 23: Consider adding an explanation (after Section 2.3), including some references, on the type of scenarios considered in the database, at least the most common ones, their evolution and considerations (for instance, from the IPCC92 type scenarios until the more recent RCP scenarios). Besides it would be good to include a comparison of two or more common contrasting scenarios like A1F (or A2) vs. B1 (which we believe are available in the authors database). The better understanding of implications/considerations of each scenario is a key to understand discordances (lack of a clear trend, or uncertainty) between results of different studies. Different climate change scenarios can yield large and contrasting differences in the estimated impact on discharges (e.g., Arnell and Reynard, 1996).

=>We modified this section in order to provide more information about GHG emission scenarios:

“Many different types of scenarios are available and are clustered in three main groups, that were created in chronological order and used for the different IPCC reports: the early IS92 (Leggett et al., 1992) including for example scenario IS92a or IS92c, the SRES (Special Report on Emission Scenario, see Nakicenovic and Swart (2000) for a description) with for example scenarios A1B, A2 or B1, and the RCPs (Representative

Concentration Pathways, Moss et al. (2010)) used in the fifth IPCC report (e.g. RCP 2.6, RCP 4.5, RCP 8.5). Each group constitutes a range of possible emission scenarios, from low (e.g. for the SRES, scenario B1 that leads in 2100 to an average warming of +1.9°C) to high levels of GHG emissions (e.g., A2, that leads to +3.1°C by 2100, see Meehl et al. (2007))”

2. Page 2489, Lines 14-18.: This affirmation is not completely correct. If correctly understood the studies to which the authors refer are primarily based on the SRES and the IS92-type (IPCC 92) GHG scenarios. Just one research paper, the database, is using the lastly developed RCP scenario.

=>Referee #2 is right, we added a reference about IS92 scenarios (see point number 1).

Specific Comments:

1. Page 2485, Line 8: “and especially in rainfall, plays a significant role in flow variation in WA”. Suggest to delete “WA”, because the statement is true not only for WA, but many other regions.

=>We deleted “WA” in the sentence

2. Page 2485, Line 9: This sentence needs a reference (e.g., IPCC report or Wuebbles and Ciuro, 2013).

=>We added the Wuebbles and Ciuro (2013) reference

3. Page 2485, Lines 18-19: Why not referring to one of the recent and widely known IPCC evaluations of climate change, which contains trends of some hydrological parameters at regional scales?

=>The point is that the AR4 and AR5 do not provide a lot of information about the impact of future climate changes on runoff in West Africa specifically, but more for Africa as a whole, for East Africa or for past changes in WA. For example, in the AR5

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(WG II, chapter 22), the only results quoted for the Niger River are for a tributary (the Bani).

4. Page 2486, Line 20: “some rivers in WA can be very large”,...are not all of the rivers considered in the study large?

=>We mean here that not all studied rivers are very large like the Niger or the Nile River. Even if the Sassandra is not a small river, its size is still much below the Niger's.

5. Page 2487, Lines 19-20: Are the ranges over a specific period of time, for example a year, and for which scenario? For instance: the average annual range specified in the mentioned document is between 1.8 and 4.7C for the A1B scenario using a set of 21 global models. The authors could also specify the range for future evolution of precipitation mentioned in the same report (from -9% to 13%). Instead referring to the ranges cited in Christensen et al. (2007), why not mentioning the new ranges mentioned in the last IPCC 2013 report?

=> Point well taken. We updated the projections following results of the last IPCC report (WG I, chapter 14), that are, according to 42 climate models and scenario RCP 4.5 and for 2100: - Temperature: from +1°C to +3.2°C - Rainfall: from -8% to +8%

6. Page 2488, Lines 19-22: Are the rising CO2 concentrations not inherently considered in the climate change scenarios? What you are referring to in this paragraph is the effect of rising CO2 on PET and leaf area index; which on its turn indirectly might affect runoff. Would it more appropriate to rename this paragraph to “Carbon effect on plant water use”, as used in Section 3.4.

=> We followed referee #2 advice and renamed this section

7. Page 2489, Line 8: “19 peer-reviewed papers, Ph.D thesis or”...Do you mean 1 Ph.D thesis or more than 1 Ph.D theses?

=> We mean: 16 papers, 1 PhD thesis and 2 official reports. Changes were made in the text.

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8. Page 2489, Lines 23 and 26: Might be appropriate for the readers not familiar with the topic to define the acronyms RCM (Regional Climate Model) and GCM (General Circulation Model). 9. Page 2493, Line 1: All these results show that futures studies.... “futures” should be replaced by “future”.

=> Corrections made as recommended by referee #2

10. Page 2493, Section 3.2. The fact that precipitation is the major driver for changing trends in discharge, compared to the effect of PET or temperature, should not come as a surprise as stated by Dai et al. (2009) and Gerten et al. (2008). Although the fitting of the discharge values with rainfall is rather moderate ($R=0.49$), most likely the consequence of the diversity in methodologies, hydrological models and scenarios used in the different studies, the conclusion that rainfall is the main driver is still an acceptable conclusion.

=> We agree with referee #2 on the fact that this result is not a surprise, as we precise in the manuscript: “These results are in accordance with earlier findings in the literature which underline the major role played by rainfall on future runoff changes (Kundzewicz et al., 2007)”. However, we believed it was still interesting to study this point (i) considering many studies and (ii) focusing on West Africa. Moreover, we did not quote Dai et al. (2009) and Gerten et al. (2008) as they are dealing with past streamflows and as the range of future temperature increase is much larger than past changes.

11. Page 2498, Line 17: Here, and elsewhere in the text, change the reference of the discussion Paper of Aich et al. (2013) to the final revised paper (Aich et al., 2014).

12. Page 2493, Line 24: (e.g., Guimbertau et al., 2013) instead of (Guimbertau et al., 2013).

=> Corrections made as recommended by referee #2

13. Page 2494, Line 23: Did you mean...the trend for higher return periods (or more extreme floods) is not consistent

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=> We modified this phrase: “whereas the trend for higher return periods floods (i.e. more extreme) is not consistent”

14. Page 2494, Line 25: Probably you did mean “Fig. 1b” instead of “Fig. 1a”.

=> Indeed. Thanks.

15. Page 2496, Lines 24-26: For sure changes in the behavior of runoff is the combined result of changes in rainfall, land use, water consumption and carbon concentrations. Given the lack of knowledge of the mutual interactions, studies that analyze the integrated effect of the different drivers are needed. Should here or somewhere else in the manuscript (e.g., the Conclusions) not be given a hint in what direction such studies should be conducted? Most of the time researchers study the combined effect of climate change and CO₂ enrichment, or climate and land use change, or climate and water consumption change on the runoff behavior. Can those studies [such as Murray et al. (2012); Zhu et al. (2011); Liu et al. (2012); Cornelissen et al. (2013); just to name a few] be indicative how the interaction between the different drivers ought to be analyzed?

=> we agree with referee #2. Studies typically have focused on the effects of climate change only or include just one of the additional drivers and evaluate its marginal impact. Instead an integrated approach (either within one model or through two-way coupling of different models) is needed that simultaneously includes the driving processes that link climate, carbon, water, and terrestrial vegetation dynamics. We have made this clearer in the Conclusions section and furthermore refer to the paper of Gerten (2013), who analyses the effects of and interactions between vegetation, water, climate and human activities with the process-based LPJmL global biosphere model.

“There is also an urgent need to take into account the other factors influencing runoff, especially water and land use changes, in order to get a more comprehensive assessment and to guide the elaboration of sound adaptation strategies. This can be achieved through the use of integrated process-based models that simultaneously in-

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clude the driving processes that link climate, carbon, water and terrestrial vegetation dynamics (Gerten (2013); Guimberteau et al. (2014)).”

16. The abbreviation WA is used 38 times in the text (at least if correctly counted). Wonder if this abbreviation cannot be deleted in a number of phrases!

=> We deleted “WA” when possible and replaced it by “West Africa” in the conclusion to be more understandable.

17. The text labels in some figures are difficult to read, particular in the Figs. 1 and 8 when compared to 3 or 4. Also the labels in the map (top Fig. 1), particularly the dark blue color impedes easy reading the name of the rivers. Although not a problem for a digital version of the paper, consider standardizing the size of the labels in the figures.

=> Referee #2 is right and we therefore redesigned Figs 1 and 8 to be easier to read (see attached)

=> References

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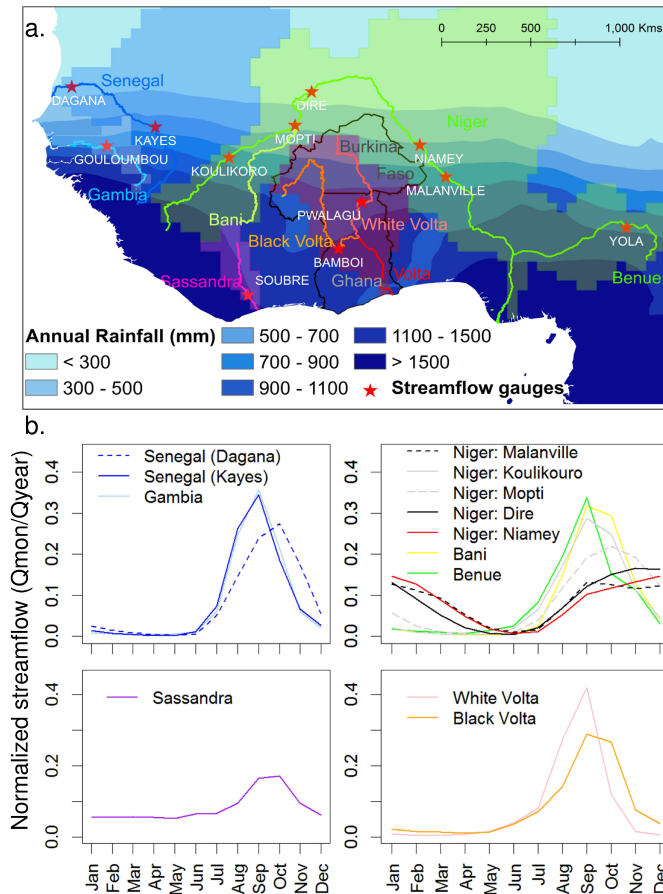


Fig. 1. Figure 1

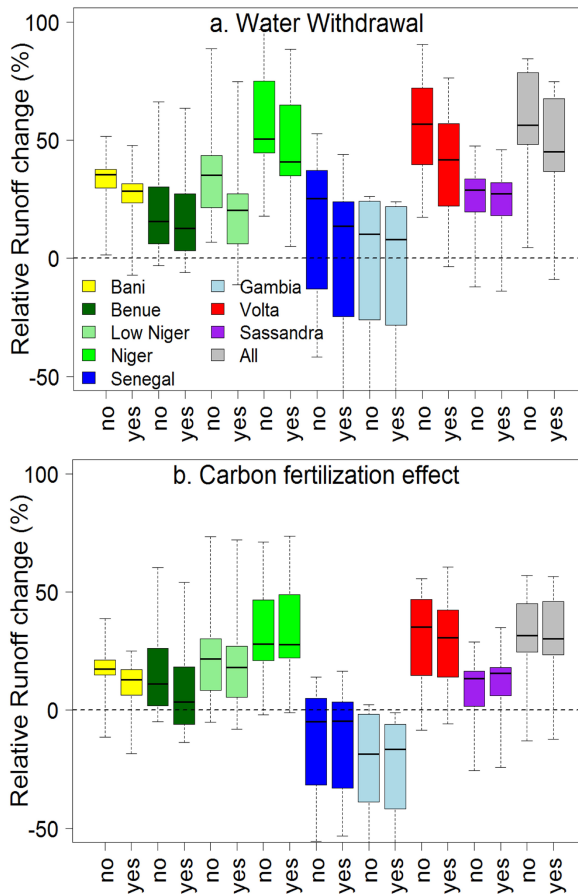


Fig. 2. Figure 8

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