Interactive comment on "Drivers of spatial and temporal variability of streamflow in the Incomati River Basin" by A. M. L. Saraiva Okello et al.

Anonymous Referee #1

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Reaction to the interactive comment by Anonymous Referee #1

We would like to thank this referee for his/her interesting comments and suggestions that contributed to improve our paper and to clarify specific points. Hereby we present the authors reply (AR) to the referee's comments (RC).

General comments:

RC: Saraiva Okello et al., attempt to assess the drivers and implications of significant changes in streamflow dynamics for the period of 1970 to 2011 in the Incomati River Basin. While the topic is relevant and matches the scope of the journal of Hydrology and Earth System Sciences, they should address the following comments before the paper is published:
(1) How was the rainfall data checked for consistency and patched? In their results section, the authors state:"... the trend identified could be affected by data infilling procedures."

AR: The data from the period 1950-2000 was extracted from the Lynch (2003) database. This database was thoroughly checked and patched using various techniques, such us expectation maximization algorithm, median ratio method, inverse distance weighing, monthly infilling technique, geographic weighed regression (Lynch, 2003). Only rainfall stations with high reliability were used. Where the time series was extended the extension was also checked using standard rainfall screening procedures. Daily time series were used to check maximum and minimum values for monthly and yearly totals. Daily rainfall was checked for maximum values. Double mass plots were used to assess reliability of data.

RC: (2) Why are they using three different time periods (rainfall: 1950-2000 and 1950-2011; streamflow: 1970-2011)?

AR: The use of different periods was to allow comparison between shorter and longer time series, as some of flow gauge stations present trends when analyzed from 1950-2011, but have no trends when only the period of 1970-2011 is taken into account. Moreover, majority of flow data is consistently available for the period 1970-2011. Some rainfall stations were closed shortly after 2000, so the only data up to 2000 was available for such stations. For clarity sake, table 5 was modified to illustrate more clearly the extent of time series available and used. The description is added to clarify why different time periods were analysed. The period of 1970-2011 is the main analysis period, for the sake of consistency of trends mapping.

RC: (3) What do the authors qualify as "major abstractions"?

AR: The authors qualify as “major abstractions” in comparison with the abstractions on the Komati and Crocodile sub-catchments, as can be seen on table 1. The expression was re-worded for clarity to “fewer abstractions”.

RC: (4) Flow gauge X2H012 drains a very small portion of the upper Crocodile sub basin. It is therefore misleading to refer to a table that presents changes in land and water use for the entire Crocodile sub basin. The author should check orthophotos, etc, to understand the changes in land use of the area drained by X2H012.

AR: We thank the reviewer for the suggestion. In our view, even though the gauge X2H012 drains an area of 91 km^2, the purpose of our analysis was to map overall changes in the streamflow regime across the entire basin. It was therefore important to include all gauges that had reliable flow information. It was not possible to check orthophotos for the gauge X2H012 in particular, but reports about land use change at quaternaries catchment level were checked and compared. The results compare changes in the streamflow observed at the gauge X2H012, which were mainly attributed to land use change. At one hand, these observations apply specifically to this sub-catchment but also remain a contributing factor while explaining the observed changes further downstream of this gauge.

RC: (5) South Africa has a number of strategies on water demand management and water conservation. How can they be better implemented in the area in light of the results of this study? Be specific.

AR: The results of this study illustrate some hotspots where more attention should be put in order to ensure provision of water to society and environment. For example, where many trends of decreasing flow were identified, water managers should engage in discussions regarding development directions.

RC: (6) The authors state that water demand management and water conservation should be alternative options to the development of dams. Are the countries planning to build more major dams? Is there a viable dam site? If not, the comment is at best irrelevant. If yes, does it make sense for the countries not to build that dam? This should not be brushed over. It requires a robust discussion.

AR: As far as we know, the countries have strong plans of building new dams. In Mozambique, sluices are presently being added to raise Full Supply Level of Corrumana Dam. There is also news that the Moamba-Major Dam construction would start in 2014. Studies in South Africa also recommend construction of new dams. Therefore, the following paragraph was added to the discussion section:

“Dams provide storage, generate hydropower and attenuate floods in the basin, but have impacts downstream, such as the change of mean monthly flows, the reversal of seasonality and the trapping of sediments, which can all hamper the health of downstream ecosystems. The recently concluded Mbombela Reconciliation Strategy (Beumer and Mallory, 2014) strongly

recommends the construction of new dams in South Africa, including one at Mountain View in the Kaap subcatchment. The plans of these developments happen when Swaziland is not yet fully utilizing its allocation under the Piggs Peak Agreement and Interim IncoMaputo Agreement (TPTC, 2010). Experiences of other countries around the world shows that dam construction has many, often wide-ranging and long-term social and ecological impacts that often are negative and that frequently are irreversible, including the social upheaval caused by the resettlement of communities, loss of ecosystems and biodiversity, increased sediment trapping, irreversible alteration of flow regimes and the prohibitive cost of decommissioning (see for an overview (Tullos et al., 2009;Moore et al., 2010)). It is therefore important to fully explore alternative options before deciding of the construction of more large dams. So alternative possibilities of restoring natural stream flows and/or increasing water storage capacity should be further investigated and adopted. These alternatives could include aquifer storage, artificial recharge, rainfall harvesting, decentralized storage, and reducing the water use of existing uses and users, including irrigation, industry and forest plantations. The operation rules of existing and future dams should also include objectives to better mimic crucial aspects of the system's natural variability."

RC: (7) There is no mention of the proliferation of small farm dams in the basin. Do they have any impact on streamflows?

AR: it is very likely that they have some impact on the streamflow, but it should be much minor, compared with that of the large dams. The small dams provide additional storage, which is more easily managed at local scale, and also reduces the demand on the large irrigation systems (Schreider et al., 2002;van der Zaag and Gupta, 2008).

Specific comments:

RC: (1) Put the references in chronological order

AR: This has been changed on the current manuscript.

RC: (2) Page 8882, remove the last (the) of the last sentence.

AR: Corrected.

RC: (3) Page 8883, 5.5 +33.2 +61.4 = 100.1%

AR: Corrected. The area of South Africa corresponds to 61.3%.

RC: (4) Page 8884, the Kruger National Park is part of the Greater Limpopo Transfontier Park.

AR: The reviewer is correct, but because the Greater Limpopo Transfontier Park was just recently established, most documents refer only to the Kruger National Park, and thus we decided to mention it explicitly. The sentence has been rephrased to: *"A substantial part of the basin has been declared a conservation area, which includes the recently established Greater Limpopo Transfrontier Park (the Kruger National Park in South Africa and the Limpopo National Park in Mozambique are part of it)(TPTC, 2010)."*

RC: (5) Page 8885, section 2.2.1. The main custodians of the rainfall…

AR: Corrected on current manuscript.

RC: (6) Page 8885, section 2.2.1. Eight of the 20 time 15 series were extended up to 2012,..

AR: Corrected on current manuscript. *"Eight of the 20 stations' time series were extended up to 2012"*

RC: (7) Page 8887, section 2.2.3. …in order to access (assess) impacts on streamflow caused by anthropogenic drivers

AR: Corrected.

RC: (8) Page 8887, section 2.2.3. …was compiled for the various hydrological indicators and plotted spatially (mapped), using ArcGIS 9.3

AR: Corrected.

RC: (9) Page 8887, section 2.2.4. Provide the references of the NLC 2004 and 2011 you mention.

AR: References added. *"a map of current land use (2011) (Jarmain et al., 2013) and land use of 2000 (Van den Berg et al., 2008)"*

RC: (10) Page 8887, section 2.2.4. (last sentence). …by looking at (the) temporal evolution on (of) the land use change.

AR: Corrected.

RC: (11) Page 8890. This means that along (across) the entire basin…

AR: Corrected.

RC: (12) Page 8891. The annual flow duration curve for the periods 1949–1974 and 1978– 2011 shows a dramatic decrease in annual flows. [[[Either show the graph or delete the sentence.]]]

AR: The sentence was deleted from the manuscript, given that the point about reduction of the flow between the two periods is already clearly illustrated on Figure 10.

RC: (13) Page 8894, Section 4.1. [rephrase the last sentence]: An analysis of the best quality stations and a number of stations in the same system was conducted, to avoid this pitfall.

AR: The section was reworded.

References

Beumer, J., and Mallory, S.: Water Requirements and Availability Reconciliation Strategy for the Mbombela Municipal Area. Final Reconcialiation Strategy, Department of Water Affairs, South Africa, 2014.

Jarmain, C., Dost, R. J. J., De Bruijn, E., Ferreira, F., Schaap, O., Bastiaanssen, W. G. M., Bastiaanssen, F., van Haren, I., van Haren, I. J., Wayers, T., Ribeiro, D., Pelgrum, H., Obando, E., and Van Eekelen, M. W.: Spatial Hydro-meteorological data for transparent and equitable water resources management in the Incomati catchment, Pretoria, South Africa, 2013.

Lynch, S. D.: The Development of a Raster Database of Annual, Monthly and Daily Rainfall for Southern Africa., Water Research Commission, South Africa, Rep. 1156/1/04Rep. 1156/1/04, 2003.

Moore, D., Dore, J., and Gyawali, D.: The World Commission on Dams+ 10: Revisiting the large dam controversy, Water Alternatives, 3, 3-13, 2010.

Schreider, S. Y., Jakeman, A. J., Letcher, R. A., Nathan, R. J., Neal, B. P., and Beavis, S. G.: Detecting changes in streamflow response to changes in non-climatic catchment conditions: farm dam development in the Murray–Darling basin, Australia, Journal of Hydrology, 262, 84-98, http://dx.doi.org/10.1016/S0022-1694(02)00023-9, 2002.

TPTC: Tripartite Permanent Technical Committee (TPTC) between, Moçambique, South Africa, Swaziland, 2010. PRIMA : IAAP 3 : Consultancy Services for Integrated Water Resources Management. Baseline evaluation and scoping report: Part C. Report No.:IAAP 3: 03C - 2010. Prepared for TPTC by Aurecon, Pretoria, 2010.

Tullos, D., Tilt, B., and Liermann, C. R.: Introduction to the special issue: Understanding and linking the biophysical, socioeconomic and geopolitical effects of dams, Journal of Environmental Management, 90, Supplement 3, S203-S207, http://dx.doi.org/10.1016/j.jenvman.2008.08.018, 2009.

Van den Berg, E., Plarre, C., Van den Berg, H., and Thompson, M.: The South African national land cover 2000, Agricultural Research Council (ARC) and Council for Scientific and Industrial Research (CSIR), Pretoria. Report No. GW/A/2008/86, 2008.

van der Zaag, P., and Gupta, J.: Scale issues in the governance of water storage projects, Water Resources Research, 44, W10417, 10.1029/2007wr006364, 2008.