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

Received and published: 22 August 2014

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.

Anonymous Referee #2
Received and published: 19 September 2014

Reaction to the interactive comment by Anonymous Referee #2

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).

RC: The MS tries to identify and discuss drivers of spatial and temporal variability of stream flow in the Incomati - a trans-boundary basin shared between South Africa, Mozambique and Swaziland. The MS uses statistical analyses and IHA approach based on long term rainfall and stream flow records respectively to achieve this. The methods used are standard and straight forward but have not been used in this basin. This is an interesting area of study whose results could be used to improve management of the shared water resources. One of the biggest issues with this MS is that it is rather verbose and in some places poorly written. The use of the comma particularly needs to be improved throughout the MS.

AR: The authors thank the reviewer's comments and recommendations. The manuscript was revised based on the recommendations given. Special attention was given to make language related corrections. Most of the reviewer's comments were very useful improve the clarity of the manuscript.

RC: The authors seem confused about what exactly their paper is about. The link between the title of the MS and the goal of the paper (Page 8882, Line 19) needs to be made stronger. Either a rewording of the title or a rephrasing of the goal is necessary so that the two are closely aligned.

AR: The objectives and contents are clear to authors and we think these are presented in a reasonable good manner. Changes were made on the manuscript to strengthen the link between title, goal and results.

1. Introduction:

RC: Page 8881 Line 14 – what are these data that are scarce. There is need to qualify this.

AR: The data referred in the sentence is water resources data. It was clarified on the manuscript.

RC: Page 8882 Line 5 – delete 'dramatic'

AR: The word 'dramatic' was deleted.

RC: Page 8882 Line 20 – delete 'dynamics'

AR: The word 'dynamics' was deleted.

RC: Page 8882 Line 27-28 – this is not specific and therefore does not do anything to improve the MS at this introduction stage. The last part of the sentence from '... as well as ...conducted in the area.' could be deleted without affecting the MS.

AR: The sentence was deleted.

2. Methodology

RC: Page 8883 Line 14 – Since the MS is quite detailed about where the mouth of the river is, one would be expected to be specific about where the river's source is rather than just saying 'in the west of the basin.' Surely it is not difficult to get this information.

AR: We believe we have given enough information about the source and mouth of the river for the readers to understand basic landscape features. The source of the main tributaries (Komati, Crocodile and Sabie) is on Highveld and Escarpment in South Africa. This explanation was added to the manuscript.

RC: Page 8883 Line 21 – high escarpment not high-lying escarpment

AR: Corrected.

RC: Page 8884 Line 7 – rewrite the statement to read; 'the geology is complex, characterized by....'

AR: Re-written.

RC: Page 8885 Line 5 – rewrite to read; 'Annual, monthly and daily data for southern ...'

AR: Re-written.

RC: Page 8885 Line 10-14 – Sentence is difficult to read. Rephrase

AR: The section was reworded to improve clarity.

RC: Page 8885 Line 14 – It is meaningless to say 'good observed data'. What is 'good'? How is it measured? Good for what or for whom?

AR: The word good was removed from the sentence.

RC: Page 8885 Line 15-16 – Poor expression. Rephrase

AR: It was rephrased to read: *"Eight of the 20 stations' time series were extended up to 2012, using new data collected from the SAWS."*

RC: Page 8885 Line 19 – there is need to briefly explain why two intersecting periods were chosen. This is for readers who may not be familiar with the method.

AR: This question was also raised by Referee 1. The following sentences were added to explain the choice of periods. *"Two intersecting periods were chosen, to evaluate the consistency of the trends. Due to natural climatic variability, there are sequences of wetter and drier periods, so some trends appearing in a specific period might be absent when a longer or shorter period is considered."*

RC: Page 8885 Line 21 - change to 'The test determines the timing of a change in a time series...'

AR: Changed.

RC: Page 8885 Line 21-25 – this does not read well and is therefore difficult to follow. Rephrase.

AR: The paragraph was rephrased to read: *"The Pettitt Test (Pettitt, 1979) is used to detect abrupt changes in the time series. Potential change points divide the time series in two sub-series. Then the significance of change of mean and variance of the two sub-series is evaluated by F and T-tests. Potential change points were evaluated with a 0.8 probability threshold and significance of change was assessed with F and T-test at 95% confidence level."*

RC: Section 2.2.1 – there is generally no adequate description of the techniques and no attempt is made to justify the choice of these methods.

AR: The techniques used are standard, and brief explanation of methods was added for clarity. Readers were referred to literature were the methods are explained more in detail.

RC: Page 8886 Line 8 – How is the 'quality' of the data defined? There is nowhere else in the MS that this data 'quality' issue is discussed, so it would need to be qualified here. See my comment on 'good' data.

AR: The flow data quality was defined using the definition of the Department of Water Affairs (DWA), the main custodian of data. Data of a flow gauging station was considered of good quality when the number of missing data was less than 5%, and most of the data was qualified by DWA as good continuous data. The quality of rainfall data was addressed in response to a comment from referee 1, and a sentence was added to the manuscript describing data quality.

RC: Page 8886 Line 11 – change to '....very few stations could be considered not impacted by human interventions.' Why is it necessary to use data from stations that are 'least' impacted by humans? There is no justification or explanation for this.

AR: Corrected on the current manuscript. The following sentence was added to justify the use of data from pristine catchments: *"Data from pristine catchments can reveal the dynamics of natural variability of streamflow, and isolate the impacts of climate change on streamflow.*

RC: Page 8886 Line 13 – delete 'and summarized'

AR: Deleted.

RC: Section 2.2.2 – are there no stations in Swaziland? This needs to be explained.

AR: There are few stations in Swaziland, but the data was not freely available as in South Africa and Mozambique. Also, for this study we were interested in long term patterns, thus long time series; some of Swaziland's gauging stations are only operational from 2000's. Furthermore, as the focus of the study was the entire river basin, and the portion of the basin in Swaziland is just 5.5% of total basin area, we assumed that the stations downstream of Swaziland would serve as surrogate of changes occurring in Swaziland.

RC: Section 2.2.3 – the whole section is poorly written and needs to be rewritten. The MS does not adequately and clearly explain the IHA method. Some mistakes are pointed below:

AR: The section was revised and a paragraph was added to better explain the IHA method.

RC: Page 8887 Line 1-3 – I can hardly follow what the authors are trying to say.

AR: The sentence was rephrased to read: *"33 selected gauges from the Incomati Basin were analysed with this method using daily flow data."*

RC: Page 8887 Line 7 – what does 'water conditions' mean?

AR: We refer to river flow; the expression was replaced on the current manuscript.

RC: Page 8887 line 10 – which flow metrics are these?

AR: We refer here to the IHA hydrological indicators. We replaced the word 'metrics'.

RC: Page 8887 Line 11 – does the software only analyse 'linear' trends? Why not just say 'trends'? Whether or not these are linear is immaterial, I presume.

AR: The word linear was removed.

RC: Page 8887 Line 12-13 – this trend is evaluated with the P value.... What is the p value? What does it represent? What is the range of values for P? Why choose P<=0.05? The explanation and/or justification for method are missing.

AR: The p-value is the probability of obtaining a test statistic result at least as extreme as the one that was actually observed, assuming that the null hypothesis is true. A researcher will often "reject the null hypothesis" when the p-value turns out to be less than a predetermined significance level, often 0.05 or 0.01. Such a result indicates that the observed result would be highly unlikely under the null hypothesis. Many common statistical tests, such as chi-squared tests or Student's t-test, produce test statistics which can be interpreted using p-values. Most authors refer to statistically significant as $P < 0.05$ and statistically highly significant as $P < 0.001$. In the current study, the hypothesis tested was if there was a trend on the time series of IHA parameters or not. So a p-value<= 0.05 means that there is strong evidence that there is a trend on the time series.

RC: Page 8887 Line 20-24 – this should be made more concise.

AR: We believe that the explanation provided is important to understand how the comparison of indicators with land use was made. The paragraph was rephrased to improve clarity.

3. Results

RC: Page 8888 Line 6-7 – '...due to the elevation gradient.' Firstly, change to '... as a result of elevation' if you want to use this. Secondly, is this the reason for variability? How was this determined? Sounds like guessing to me.

AR: The change was made on the current manuscript. We understand that the elevation is a major reason for the variability of the rainfall. We analyzed daily, monthly and annual rainfall records for many stations in the region, and found that the variance of the stations in higher elevations was much higher than those in lower elevations. Furthermore, Lynch (2003) reports the importance of elevation on rainfall variability in South Africa.

RC: Page 8888 Line 23 – delete 'of an increase or decrease', it is not necessary.

AR: Deleted.

RC: Page 8889 Line 18 – '....buffered due to flow regulation....' The use of the phrase 'due to' is wrong. What the authors want to say that it is a consequence of; then they could use 'as a result of' instead. The flow regulation issue is very important and needs to be discussed more.

AR: Corrected on the current manuscript. The flow regulation issue is discussed further on the context of dams.

RC: Page 8890 Line 1-4 – This explanation does not sound correct to explain the observed trend.

AR: The sentence was rephrased to read: *"October is the month of the start of the rainy season, when the dam levels are lowest and irrigation water requirements highest (DWAF, 2009d; ICMA, 2010)"*

RC: Page 8890 Line 8-10 – the concept of reversals is really interesting. It needs to be properly explained in the text.

AR: The sentence below was added to better explain the concept of reversals:

'*Reversals are calculated by dividing the hydrologic record into "rising" and "falling" periods, which correspond to periods in which daily changes in flows are either positive or negative, respectively. The number of reversals is the number of times that flow switches from one type of period to another. The observed increased number of reversals is likely due to the effect of flow regulation and water abstractions.'*

RC: Page 8890 Line 14-15 – What does 'cross-compensate' mean? How is this compensation achieved? What is the effect of this? No change at all? If there is any other effect observed, how would one confidently talk about cross-compensation? How would it definitively be determined? Maybe it's the wrong phrase used here?

AR: In the context, cross-compensate means to cancel the effect of another trend, with contrary signal. The cross-compensation happens mainly along the main river channels, because of the influence of tributaries, for example. The effect of this is a reduction, increase or cancelation of the impact of certain trends at a larger scale. The sentence reworded to read:

'An interesting aspect is that some of the trends cross-compensate each other. Some of the positive trends occurring on the tributaries of the Crocodile, for

example, the October Median Flow and baseflow are cancelled out when moving down the main stem of the river.'

RC: Page 8890 Line27-next page – The statement needs to be rephrased as it is difficult to follow.

AR: Rephrased to read: '*Thus, the trends observed in downstream Magude (station E43) in Mozambique are the result of a combination of the positive effect of the conservation approach of KNP on the Sabie, and the negative effect of flow reductions in the Crocodile and the Komati.*'

RC: Page 8891 Line 15-22 – It is inadequate to use only one rainfall station to explain the change in stream flow, as a stream flow gauge represents a summation over a catchment area, at times quite big (in this case 126 km^2). So using one rain gauge, no matter how close to the flow station, does not make sense and is not informative enough. Therefore it is not possible to conclude that the flow reduction is a result of land use change. While it is probable that land use change is the driver here, this cannot be explained by that one rain gauge.

AR: Following the reviewer's comment, the areal rainfall was computed for this sub catchment based on 3 rainfall stations. The areal rainfall also shows no significant trend of increase or decrease. This explanation was added on the current manuscript.

RC: Page 8892 Line 16 – who is 'they'? Ridell et al? Then write Ridell et al!

AR: Corrected.

RC: Page 8892 Line 18 – What is 'homogenisation of the flow regime'?

AR: the homogenization of the flow regime refers to reduction of the variability of the flow. For example, the difference between high and low flows is reduced.

4. Discussion

RC: Page 8894 Line 3-6 – this issue of problems with data on high flows in the time series was never raised earlier. What is the explanation/discussion for the analysis being uncertain? How? What is the impact? This is a discussion section; one would expect some 'discussion' to take place! In what way would the developments affect the analysis? What can be done? How about naturalisation of flows?

AR: The first part of the sentence was rephrased. The results of indicators of high flow should be interpreted with caution, in face of the uncertainty reported (limit of current monitoring network to capture extreme high flows). Developments can mask the natural variability of flow. Naturalization of flows is a common approach to overcome the limitation of developments. This can be achieved through hydrological modelling, but it can also add uncertainties to the analysis. Therefore, this was not followed on the current study; rather "learning from the data" approach was used', comparing results of stations with near natural conditions with those heavily managed. We do recommended for future studies that the trends computation is done with naturalized time series as well.

RC: Page 8894 Line 16-18 – It sounds like this was not a problem. So why is this reported as a limitation?

AR: The paragraph was deleted.

RC: Page 8895 Line 16 – the concept of 'reverse seasonality' would need to be explained/discussed more clearly.

AR: The sentence below was added to further explain reverse seasonality.

'Reverse seasonality is the change in timing of season flow characteristics, for example, the occurrence of low flows during wet season, or high flows on the dry season.'

RC: Page 8895 Line 21-22 – This does not read well. Rephrase.

AR: The sentence was rephrased: *'This change was compared with the increase in the area under forestry in the sub-catchment, as well as with the increase in irrigation. The comparison revealed that the land use change was the main driver of the flow alteration.'*

RC: Page 8895 Line 25-26 – Did the climate change during this period?

AR: From our analysis of rainfall records, there was no significant trend on the rainfall records.

RC: Page 8896 Line 9-11 – Rephrase.

AR: The sentence was rephrased to read: *"The Sabie flows generated in the upper parts of the catchment persist until the outlet, whilst in other rivers flows are highly modified. This suggests that the use of the conservation approach through the Strategic Adaptive Management of the Kruger National Park (KNP) and Inkomati Catchment Management Agency (ICMA), which are stronger on the Sabie, can be very beneficial to keep environmental flows in the system."*

RC: Page 8896 Line 19-21 – A good point raised that needs to be explained clearly.

AR: This point was also discussed in response to the comment of referee 1. The section was expanded to further explain the point:

"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: Page 8896 Line 28 – What does 'this' refer to in 'This is even more...'?

AR: 'This' refers to the complexity. It was rephrased in the manuscript.

RC: Page 8897 Line 5-8 – this is a big challenge and expensive. Perhaps the MS should give pointers as to how this can be achieved.

AR: We agree that this is a major challenge. However, when the impacts of lack of information derived from such monitoring network are considered, it would be worthy doing the investment. The following points were added to the manuscript:

"The improvement of the monitoring network can be achieved by various means, such as:

- *Water management institutions collaborate more intensely with academic and consultant institutions;*
- *Develop realistic plans to improve monitoring and data management;*
- *Learn from other countries/institutions that have adequate monitoring in place;*
- *Use modern ICT and other technologies, which may become cheaper and more accessible;*
- *Involve more stakeholders and citizens in data collection."*

5. Conclusions

RC: Page 8897 Line 10-11 – What does this introductory statement mean? It is not clear. Rephrase

AR: The sentence was rephrased to read: *"The research conducted reveals the dynamics of streamflow and their drivers in a river basin.*

RC: Page 8897 Line 19-21 – rephrase statement

AR: Rephrased to read: *"The study therefore recommends that strategic adaptive management adopted by the Kruger National Park and Inkomati Catchment Management Agency, should be further employed in the basin".*

RC: Page 8898 Line 7-8 – It's the Water research Commission

AR: Corrected.

6. Tables

RC: Table 1 – What are 'first priority supplies.' These are not available in the text

AR: The 'first priority supplies' are domestic and industrial supply. An explanatory note was added to the table.

RC: Table 6 – Explanation of CD is missing on the table, though its available in the text

AR: An explanatory note was added to the table.

7. Figures

RC: Figure 2 – the figures are too small and difficult to read. Also both show the same information, choose one.

AR: The figures do not show the same information, as one show the period of 1930's to 1960's and the other 1970's to 2012. But given the clarity issue, the first part was removed from the manuscript.

RC: Figure 4 – the scale of rainfall anomalies is too large and therefore masks the changes. I advise that the graphs be separated.

AR: This figure was deleted, has no trends were found on rainfall record, and results are reported on Table 5.

Anonymous Referee #3

Received and published: 29 September 2014

Reaction to the interactive comment by Anonymous Referee #3

We would like to thank this referee for the time spend in critically reading our manuscript and 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).

RC: Saraiva Okello et al. report on the drivers of spatial and temporal variability of streamflow in the Incomati River Basin in Southern Africa using rainfall and streamflow observations over a relatively long time period. The topic is relevant to a wide range of readers and fits well within the scope of the Hydrology and Earth System Sciences journal. However, important links between the research objectives and analysis of outcomes in this MS are broken and need further attention before the paper is suitable for publication. Some of the overarching issues are summarized below. In addition, the MS would benefit from a thorough edit for English language usage.

> AR: The authors thank the reviewer's recommendations. The article was revised to strengthen the link between objectives and analysis, and then revised on English issues. Several comments made by the three reviewers helped in this regard.

RC: 1. Page 8880, line 4 (and throughout the MS): The authors discuss natural (environmental) flows and changes to the flow regime due to water management activities in response to different human-driven demands for water across the basin. The study, however, does not succeed in isolating the impacts of one or the other on streamflow. Taking this into consideration, the MS needs a thorough revision in order to make the research objectives more focused and feasible.

> AR: In our opinion, comprehensive evidence is presented on isolating the impacts. For instance, the results are examined for sub-catchments and specific gauges and the observed changes were discussed specifically. For example, the impact of dams in Crocodile (gauge X2H013); irrigation; forestry (gauge X2H010); combined impacts (gauge X2H016). At higher spatial scales, the isolation of several human activities is not possible because of scale issues. On this issue, the discussion on re-enforcement or cancellation of impacts is given. Therefore, we consider that the manuscript does not need major revision on these points. However, the other reviewer's comments contribute to clarify these points as well.

RC: 2. Page 8881, lines 20-27: The discussion of climate change impacts on hydrology are somewhat irrelevant, as the MS does not really provide a focused

investigation of these. Investigating projected impacts such as decreased rainfall events would require analysis of sub-daily data, if the authors mean decreased rainfall duration. If number of rainy days is meant, however, this could be investigated from the relatively long time series of daily rainfall data that the authors have analyzed. However, this is not clearly addressed and instead the IHA methodology is followed without much justification on how it contributes to addressing the research questions of the study.

AR: We acknowledge that the analysis of sub-daily data on rainfall is important to further understand how rainfall intensity and other extremes have changed over time. This will be subject of further research. However, the manuscript's main focus was to understand the changes occurring on streamflow, therefore the analysis of rainfall data was conducted only at monthly and annual scales to assess if there were trends at this level corresponding to the streamflow trends. The explanation about the IHA methodology was improved in the manuscript, as well as the reason why specific methods were chosen.

RC: 3. Page 8882, lines 19-26: Generally, the research objectives then need to be followed by a focused methodology for answering these. This is not well achieved in the current MS version. What is needed is an explanation for the observed trends in streamflow, but not in rainfall. Land use changes appear to have contributed substantially to this but there is no mention of other variables such as temperature and humidity, for example, which could also have a pronounced effect on streamflow. Even the links with land use changes are not investigated in sufficient detail in order to draw the relevant conclusions and possibly this is one of the reasons for the authors struggling to interpret the outcomes from this study in the final sections.

AR: The authors have revised the manuscript, based on the suggestions of all referees to strengthen the link between research objectives, methodology, results and conclusions. The main focus of the paper is to look at drivers of streamflow trends observed. Climate can be one of the major drivers, particularly precipitation. The analysis of other climatic factors is also relevant, but was beyond the scope of the current analysis. The authors strived to establish links between trends identified and land use changes that occurred, however, some changes occurred well beyond the period of analysis (1970-2011). Therefore only secondary data about land use changes was available, but this already gives strong evidence of the importance of land use changes.

Some comments on figures and tables:

RC: - Table 3: The use of the @ symbol is inappropriate, the location could be given with either a comma or in parentheses.

AR: Revised.

RC: - Figure 2: The text is very unclear in this figure, consider revising the layout and presentation.

AR: Revised.

RC: - Figure 3: Is the N-S variability unimportant? Would it be better to present the error bars on a map?

AR: The N-S variability is also important. The graph will be changed accordingly.

RC: - Figure 9: The shaded box with trend parameters might not appear well in print, consider revising the figure.

AR: We believe the reviewer meant Figure 8, instead of Figure 9. The figure will be revised to increase the contrast between trend parameters and land-use map.

RC: - Figures 10&11: The text in the legends of these figures is too small to read, consider revising the layout and labeling of these plots.

AR: The layout and labels were revised; the font size was increased to make them more readable.

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