

We thank the reviewer for considering our manuscript and our response (in blue) to their comments (in black) are provided below. We propose to implement most of the major changes suggested by the reviewers. In the few cases where we do not agree we explain our reasoning.

Responses to major comments of Reviewer #1

General Comments: The authors have attempted to tease out the influence of vegetation adaptation to drought and future climate change in order determines the impact evapotranspiration will have on the catchment water balance. The paper lacks some of the specifics needed to determine the impact of some significant assumption made in the downscaling of GCM output.

Agreed. We will revise the manuscript to provide more details about the downscaling of GCM output to the catchment scale.

Additionally, how these downscaled datasets were then applied to VIC needs elaborating.

The delta change values were applied to all VIC grid pixels separately assuming the same spatial distribution in the climatic variables (precipitation and temperature). We will revise the manuscript accordingly.

The paper focuses on deviations from ‘mean’ conditions for the majority of the result reporting; however runoff processes are often triggered by precipitation events on the edge of the distributions. Without further statistical analysis it is impossible to determine how significant the modelled results are. There is no discussion on the precipitation characteristics of the region, and how these characteristics are predicted to change, which arguably might have the greatest impact on the partitioning of precipitation.

We agree with the reviewer that runoff processes are influenced by precipitation events on the edge of the distribution and that this issue would be important for studies that focus on the impact of climate change on runoff generation mechanism. However in this study we are interested in the impact of including climate induced LAI change on the runoff results. In the study area, the monthly LAI is strongly related to three month and or nine month moving average moisture state (precipitation – potential evapotranspiration) in this region (Tesemma et al., 2014). Therefore, consideration of extreme precipitation events is less important in this study. Therefore, so long as the precipitation is consistent between the two runs we can assess the importance of the change in LAI modelling.

Responses to specific comments (S.C) of Reviewer #1

S.C1: Pg 10598 “statistically downscaled using the delta change method” citations would be appropriate, Chen Fowler.

Agreed. We will cite Fowler et al., 2007 in the revised manuscript.

S.C2: GCM output has known difficulties with regions of high relief. How different are the 4 grid cells chosen for this study from each other? The authors aim to capture a precipitation gradient across several catchments, is this possible given the granularity of the GCM output?

Partially Agree. We will revise the manuscript to provide more detail about the observed data used to drive VIC and the spatial resolution of VIC. The mean elevation of the four GCM grid cells is 172.3m, 347.7m, 83.3m and 128.5m above mean sea level respectively, which is not representative of the catchment relief. However, since we use the delta change method to statistically downscale the GCM output, the observed spatial variation of the climatic variables is maintained in the future projected climate. The GCM data only provide the degree of scaling up or down of the observed spatial pattern in the future projections.

S.C3: Pg 10599 downscaling precipitation has several pitfalls. In particular the ‘wet bias’ due to the size of the gcm grid cells. When averaging 4 cells, this problem will be exaggerated. Based on equation (3) and (4) I see no methodology to solve the ‘a little rain all the time’ problem.

Agree, but not relevant. The delta change downscaling technique takes the spatial variability and the temporal sequence of the observed baseline period re-scales it for the future projection, so the drizzle, or little rain all the time, problem is not relevant here. The delta change is calculated from 30 year monthly mean values so any GCM daily drizzle issues are aggregated. We will revise the manuscript to reflect this discussion.

S.C4: There are no descriptive statistics examining the performance of the downscaling methodology. A validation/calibration test of the ability of the downscaling methodology to accurately capture the seasonality and the magnitude of precipitation is at the foundation of this study.

Agreed. We will revise the manuscript to include the figure showing the seasonality between the GCM and observation in the historical period.

S.C5: Pg 10600 What method was used for the calculation of PET? The calculation of future PET was undertaken by only varying temp and precipitation patterns. Vapor pressure deficit is a critical component to evapotranspiration and in this case is kept constant. Some sensitivity analysis of this assumption would put the readers at ease that the results obtained are not just a function of the assumptions made in the paper.

Agree. The PET calculation method used is the FAO56 Penman-Monteith. We will do a sensitivity analysis of this assumption and revise the manuscript to inform the readers of the importance of this assumption on the overall results.

S.C6: Pg 10601 What was the initial condition for each of these simulations? Was there a spin up time? Where the periods examined assumed to be stationary?

Agree. We will revise the manuscript to provide more detail about VIC and direct the readers to the detailed discussion of VIC and our modelling procedure in Tesemma et al., (2014, HESS discussion), which is currently under review.

Most land surface models require a spin up period for stabilizing the internal equilibrium of the equations which are solved iteratively. The spin up period depends on the type of model and the purpose of the studies. In this study the VIC model was run at a daily interval for 30 years from January 1981 to December 2010 to spin up the model and produce a restart file to be used as the initial condition for experiment runs. All experimental runs were initiated with

the state produced from model spin up. The spatial resolution used to run VIC model was 5km by 5km.

S.C7: Pg 10601 The VIC model is a critical part of this work, but little detail of the model setup is given. What timestep, grid resolution etc were used? What PET method, infiltration scheme?

Agree. We will revise the manuscript to provide more detail about VIC and direct the readers to the detailed discussion of VIC and our modelling procedure in Tesemma et al., (2014, HESS discussion), which is currently under review.

We used a daily time step, a 5km by 5km spatial grid resolution and Penman-Monteith for potential evapotranspiration. The infiltration scheme varies spatially with the infiltration rate computed as the difference between precipitation (or throughfall if there is vegetation coverage) and the direct runoff. The infiltration capacity is allowed to vary spatially. The soil moisture movement is modelled with the one-dimensional Richard's equation.

S.C8: Pg 10603 “Most of the projected seasonal precipitation simulations showed a shift towards drier climates in all seasons except summer in both emission scenarios and periods. The variability in the projected mean monthly precipitation among climate models indicates great uncertainty but all climate models clearly deviated from the baseline period 20 (1981–2010), underlining the change signal (Fig. 3).” Based on figure 3 I don't see a ‘drying’ trend, the models seem to be split to me. I think just reporting the mean is not enough in this case. Perhaps a box plot or the standard deviations would help examine the change (same comment for tables 3 and 4).

Agreed. We will convert the point graph into box plot to show the trend more clearly.

S.C9: Figure 5: Caption doesn't explain the ‘proportion of LAI effect’

Agreed. We will change and explain the proportion of LAI effect in the figure caption.

S.C10: Pg 10608 “Projections of climate-induced vegetation dynamics and their hydrological impacts are influenced by various sources of uncertainties that arise from inputs from downscaled GCM outputs.” The authors discuss in depth the differences in means; however runoff processes in semi-arid catchments are rarely triggered by ‘mean’ conditions. There is no discussion on the precipitation characteristics of the regions (intensity, duration, interstorm) and how these are predicted to change. If interstorm periods are expected to increase, this will significantly alter the hydrologic fluxes even if the mean precipitation is maintained. Vegetation response to long dry periods would be more significant than response to changes in mean conditions. There is no discussion of existing models that use a more sophisticated vegetation module to model these effects. A review of these models would be useful to readers.

The main objective of this study is to investigate the indirect effect of drought and future anticipated climate change on mean monthly /annual runoff through including vegetation LAI to change with climate. Therefore, consideration of extreme precipitation events is less important in this study; so long as the precipitation is consistent between the two runs we can assess the importance of the change in LAI modelling. This is particularly important for the studies with objective of predicting flood, reservoir management and so on.

Agreed. We will have to discuss on existing models that use a more sophisticated vegetation module to model these effects for readers' interest.

References

Fowler, H. J., Blenkinsop, S., and Tebaldi, C.: Linking climate change modelling to impacts studies: recent advances in downscaling techniques for hydrological modelling, *Int. J. Climatol.*, 27, 1547-1578, 10.1002/joc.1556, 2007.

Tesemma, Z. K., Wei, Y., Western, A. W., and Peel, M. C.: Leaf area index variation for cropland, pasture and tree in response to climatic variation in the Goulburn-Broken catchment, Australia, *Journal of Hydrometeorology*, 10.1175/JHM-D-13-0108.1, 2014a.