REVIEW ON "RECONCILING THE DYNAMIC RELATIONSHIP BETWEEN CLIMATE VARIABLES AND VEGETATION PRODUCTIVITY INTO A HYDROLOGICAL MODEL TO IMPROVE STREAMFLOW PREDICTION UNDER CLIMATE CHANGE" BY Z.K. TESEMMA ET AL.

Summary

The paper describes the implementation of a simple model for estimating changes in leaf area index (LAI) into the Variable Infiltration Capacity (VIC) land surface model to improve catchment stream flow prediction under a changing climate. This is an important study because the indirect effects of changes in precipitation and temperature as inputs into vegetation productivity on hydrological response at catchment scale has been rarely studied. Due to the changing climate it is important to see how the LAI will react and what differences this can make for the runoff in a catchment. The combined model is applied to thirteen gauged sub-catchments for the Goulburn-Broken catchment in Australia with three different land cover types (crop, pasture and trees). In this study three different periods were chosen the baseline period (1981-2010) and two future periods (2021-2050 and 2071-2100). For all these periods runoff values are modeled with the historical LAI values and the new simulated LAI values. These new LAI values are calculated using the 38 Coupled Model Inter-comparison Project Phase 5 (CMIP5) simulations from 15 Global Climate Models (GCMs) and for two emission scenarios (RCP4.5 and RCP8.5). These results are compared to see what the influence is of including the changing LAI due to climate change in the VIC-model on runoff. The results of this study show that due to climate change main annual runoff reduces by between 6 and 31% in the Goulburn-Broken catchment with the standard LAI values incorporated in the model. When the new LAI model is included in the VIC-model the decline in runoff is reduced to between 2 and 22% in comparison to the historical LAI input. These results show that it is indeed important to include a model that takes into account the changing LAI values to predict runoff in the future. This study takes ecological subjects into account combined with atmospheric changes on the hydrology of an area. The fact that this study touches upon 3 different scientific fields makes it a potentially relevant contribution to HESS. This article is well written, I could not detect any major flaws. However, I have a few suggestions and minor comments which I believe, can improve the clarity of the paper. I have some comments on the following points: choice of the baseline period, RCP choices, choice of the LAI model, include a hypothesis, calculation of the PET, anthropogenic influences, sub-catchment choices and presentation of the results. I therefore recommend a minor revision before publishing.

General comments

Choice of the baseline period

The first comment that I have on this paper is the choice of the baseline historical period which is from 1981-2010. This baseline period is used to compare the future climatic and modelled stream flow results with the results of this period. This baseline historical period contains a large overlap with the millennium drought period which is from 1997-2009. I doubt if this baseline period is representative for the southeast Australian region. According to Chiew et al., 2011, the period 1895-2012 is a good long term mean for the southeast Australia region. He stated that: "The 1895–2008 period offers a suitable long sequence for this region as (i) it encapsulates a large range of likely hydroclimate conditions, (ii) it covers three prolonged drought periods (around 1900, around 1940, and the current drought) and (iii) it has a similar mean annual rainfall and mean annual runoff as the past 30 years (1979–2008)". Here clear arguments are given why

this particular period is chosen, which is lacking in the manuscript. It is important to motivate the choice for the baseline period because this will influence the results. So a good argumentation or at least a discussion is needed for the choice of this period. This argumentation may be included after introducing the baseline period for the first time in the text. Or it could be included in the discussion part of the paper.

Choice of the RCP climate scenarios

In this article the RCP4.5 and the RCP8.5 climate scenarios are used as future scenarios. According to Taylor et al., 2012 there are four climate scenarios, only two of them are used in this article. The explanation for the use of these two scenarios in section 2.2.1 is: "In this study two emission scenarios were chosen: a midrange mitigation scenario, referred to as RCP4.5 and a high emissions scenario RCP8.5 (Meinshausen et al., 2011)." In the article of Meinhausen et al, 2011, I could not find a reason why only the RCP4.5 and RCP8.5 scenarios should be used in this type of studies. So a good argumentation for the choice of these two emission scenarios is missing. Also in the discussion of your article it is stated that it would be better to apply the downscaled climate change scenarios of several CMIP5 runs from selected GCM models individually to the study area to get a sense of the possible range of climate change impact on both LAI then into stream flow. With this sentence you are stating that the range of climate change impacts is important to study. If this range is important to study why not include the RCP2.6 and RCP8.5 scenarios as future climate scenarios, and maybe use fewer GCMs. These are the lowest and the highest climate scenarios and will give a broader overview of what could happen with the LAI and the runoff in the future. It was also possible to consider all the four climate scenarios, then the results would be more complete. The fact that the RCP2.6 scenario is maybe a little bit unrealistic or outdated could be used as an argumentation to exclude this climate scenario from your study.

Choice of the LAI model

The choice of the LAI model of Tesemma et al., 2014a is not motivated. This model is a purely statistical model that tries to predict the LAI with statistical relationships between rainfall and reference evapotranspiration. But there are also other physical models that can predict the LAI with changing atmospheric conditions (Montaldo et al., 2005 among many others). These models include more parameters and are more complex than the statistical model used in this study. But maybe these models are better in predicting changing LAI in future climate conditions. This is important to discuss, because it can have influence on the results of this study. At least the use and potential impact of other more physical LAI models could be mentioned as a discussion point in this paper.

Including a hypothesis

In the introduction a nice overview is given of what would happen with the runoff if the precipitation goes down in the future. Also the amount of precipitation reduction for southeast Australia in the future is given and is supported with references. The research question is clearly formulated and the novelty of this study is strongly highlighted. But what is missing is a hypothesis, what would happen with the runoff if this new LAI model is included? References could be given for what will happen with LAI under changing climate conditions, will it increase or decrease. With this information a good hypothesis could be formulated of what will happen with the runoff if these new simulated LAI models are included. What also would be an interesting point to mention is if the results of this study are applicable in other areas in the world. Maybe there are some other places in the world who face similar climate change conditions as in southeast Australia. If these results are somewhat the same in other places, this study increased its interest. These points could all be included in the introduction of this paper.

Calculation of the reference evapotranspiration (PET)

For the calculation of the reference evapotranspiration (PET) the FAO-56 Penman-Monteith equation is used. This is in general a very precise equation to calculate the reference evapotranspiration. However this is only true if there is reliable data available to put into the equation. In Tesemma et al., 2014a it is

stated that: “This study adopted the properties of the FAO-56 hypothetical crop of assumed height of 0.12m, a surface resistance of 70 s m^{-1}, and an albedo of 0.23 (Allen et al., 1998; McMahon et al., 2013).” This raises questions if this reference evapotranspiration calculated is also valid for trees and crops. The main land cover type in the area are trees, so these will have a great influence on the outcomes of this study. If the PET is not accurate calculated for the trees, the results on runoff could be influenced. According to McMahon et al., 2013 there are alternative reference crop evapotranspiration equations that have been developed for taller crops. This equation is maybe more suitable to use for calculating the PET for trees and crops.
Furthermore the future PET is calculated with only changing the projected minimum and maximum temperature. Also this raises questions if this is reliable. The climate scenarios indicate an increase in radiative forcing, this will influence the solar radiation term in the FAO-56 Penman-Monteith equation. So maybe this variable should also be changed in the equation for future PET calculations.
Both these points should be mentioned in the discussion part of this paper. To do the PET calculations again for trees and crops using the PET equation for 0.5m tall crops and including the solar radiation term in the equation would be the best.

Importance of anthropogenic influences

In this paper no attention has been paid to anthropogenic influences. However, a study by Gerten et al., (2008) found that human influences will probably have the greatest influence on the runoff in the future. Of course it is hard to implement these human influences in the model, but the effects can be elaborated upon in the introduction or in the discussion. Also, I wonder whether or how the harvesting of crops is taken into account in the LAI model. Maybe in the future the growing season of the trees and crops will change due to the climate change, and changes the LAI. Other examples are forest fires which are more likely to occur in the future due to drier conditions (Pitman et al., 2007). Also nutrient limitation could affect crop growth. All these factors influences the LAI and hence the runoff in the future scenarios and should at least be mentioned in the introduction or in the discussion, or both.

Sub-catchment choices

In section 3.3.2 Future climate, tree sub-catchments are highlighted (catchment: 6, 10 and 11). It is stated that sub-catchments 10 and 11 are covered sparsely with trees. However, this seems to conflict with the data in Tesemma et al., 2014b. In this paper the same sub-catchments are used and a table is presented listing the percentage of the three land cover type’s crop, pasture and tree (table 1 Tesemma et al., 2014b). In sub-catchment 10 the tree cover is 92.38%, this means that almost the whole land cover type is trees. Also it is indicated that the precipitation in the sub-catchments 10 and 11 are low. This is really vague, because no definition is given on what is a low mean annual precipitation. For sub-catchment 10 the mean annual precipitation is 1034.81 mm/year. This is not a low annual precipitation in my opinion.
In Chiew et al., 2011 the importance of the southeastern Australian area is explained. “The southeast Australian region discussed in this article is about 1.4 million km2 (20% of mainland Australia). The region generates more than half of Australia’s agricultural income, and more than half of Australia’s population lives in the southeastern parts of the region (Australian Bureau of Statistics, http://www.abs.gov.au).” So according to this statement a lot of crops are grown in these regions. With this information I am surprised that none of the chosen catchments has a high percentage of cropland. Was there no data for such catchments available? Otherwise a nice comparison could be made between catchments that contained mostly forest, catchments that contained mostly pasture and one with mostly crops as major land cover type. This kind of information is more relevant to policy makers.

Table 1. Characteristics of selected sub-catchments for this study: mean annual precipitation (P), FAO56 reference evapotranspiration (PET), mean annual leaf area index (LAI) and the percentage of the three land cover type (crop, pasture and tree).

Catchment ID	P ($mm\,yr^{-1}$)	PET ($mm\,yr^{-1}$)	LAI ($m^2\,m^2$)	Crop (%)	Pasture (%)	Tree (%)
1	911.00	1031.13	2.72	0.57	14.4	85.03
2	1028.09	969.66	2.75	1.04	32.71	66.25
3	1121.16	947.73	3.00		3.26	96.74
4	1170.00	928.23	3.00		6.4	93.60
5	1315.17	920.63	3.35		0.92	99.08
6	1407.00	902.77	3.83		5.5	94.50
7	1258.88	930.08	3.56		9.94	90.06
8	1299.98	902.45	3.67		2.57	97.43
9	1051.09	952.44	3.03		25.93	74.07
10	1034.81	942.63	3.23		7.62	92.38
11	659.00	1046.40	1.71	1.52	63.48	35.00
12	766.00	1028.12	1.91	1.16	56.27	42.57
13	733.00	1046.19	1.85	1.15	48.78	50.07

Presentation of the results

For the presentation of the results I would suggest in figure 5 and 6 to split the two graphs, or leave some open space. Now it looks like it is one graph, but it has two different x-axes, which is a bit confusing.

In figure 3, I wonder why it starts with the month December. Furthermore this is a very good figure because it represents the uncertainty of the climate models.

In figure 9 and 10 continuous lines are used. I would suggest not to use continuous lines, because the catchments are not linked to each other. Now it looks like also a catchment 6.5 or 5.5 exists.

The large number of tables shown results in a very chaotic presentation of the results. The average change of LAI in a year for a certain catchment is enough to present. It is not necessary to present it for every month, since these results are also not discussed. This is also not done in table 1 were the impact on mean annual vegetation productivity are shown. This will lead to a better presentation of the results. I challenge the writers to come up with a nicer presentation of the results.

Specific comments

p.10595, line 9; millennium drought is different in the abstract and the introduction. Millennium drought should be 1997-2009 in the abstract.

p.10601, line 11; in section 2.2.3 the historical climate period is from 1983-1995. Here an extra sentence should be included saying that no drought years are taken into account.

P.10597, line line 1; I was looking for the results of the validation and calibration of the VIC m606odel. But these results are presented in Tesemma et al., 2014b. This is only stated in section 2.2.3 Hydrological model an experimental design, while already in section 2.2 this validated and calibrated VIC model is mentioned. It is better to put also a reference to Tesemma et al., 2014b in section 2.2.

p.10606, line 15; similar impact patterns as the “Millenium Drought”.

p.10627; in figure 4, I would suggest to change the caption. After: runs of climate projections, the years are missing (2021-2050 and 2071-2100).

p.10603, line 11; Further decline in the mean annual precipitation is projected…

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