Hydrol. Earth Syst. Sci. Discuss., 9, C4351–C4359, 2012
www.hydrol-earth-syst-sci-discuss.net/9/C4351/2012/

Hydrology and Earth System Sciences Discussions

Interactive comment on "Climatic controls on diffuse groundwater recharge across Australia" *by* O. V. Barron et al.

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Received and published: 25 September 2012

1. The paper is well written and thoughtfully prepared. The topic of the paper is appropriate for HESS and treats an important scientific issue. The use of recharge elasticity values is an interesting and novel aspect of this paper. It helps in better getting grip on the importance of CC on groundwater.

We greatly appreciate your comments, and would like to let you know that we are currently working on a paper solely related to recharge elasticity as we strongly agree with you: it is an importance parameter particular when climate change is concerned.

2. The main problem which I do not understand in the paper and which should be

resolved is the conclusion with respect to the comparison of R2pi and R2p (see comment -p6038, L13-16 and Fig 12). This is a very essential point as this conclusion with respect to the comparison is the central issue of the manuscript. There is also an important issue with respect to -p6038, L4-6: Fig 11a; it seems to me that the correlation is worse. But maybe there is an error in the graph? Some of the graphs and captions can be improved.

We agree with your view that this is an important point of the paper, and we need to clarify that the has been in error in artwork: the Y-axis titles in Figure 12 should be R2(Pi)-R2(P). We hope that proposed editing of the text will provide a better description of the relations between recharge, annual rainfall and rainfall of high intensity.

Based on the carried out analysis, recharge shows a greater level of dependency on the portion of annual rainfall which have high intensity, than on total annual rainfall. We also show that there are exceptions to this, which are associated with the regions where R2(P) is particularly high or particularly low:

âĂć R2(P) is particularly high in the regions where the majority of rainfall event are of high intensity (tropics) and

âĂć R2(P) is particularly low in the regions where the majority of rainfall event are of low intensity (BSk) and where the recharge occurs under particularly heavy soils

For those conditions, the analysis of the effect of rainfall intensity on recharge is not likely to be require.

3. The term 'diffuse' in the title and in the manuscript is not defined. As this term is not uniquely known it would be good that the authors define this term.

Following your comments we made these changes: 6024, line 22: Diffuse recharge, as recharge related to rainfall percolation across the landscape (and opposite to localised recharge, associated with water leakage from surface water features, e.g. rivers or lakes), is strongly influenced....

4. p6027, L15: point and continental scale; why these scales and not e.g. regional?

This sentence was poorly worded and will be changed in the next version of the manuscript. It was not intended to suggest that point scale results would be upscaled to the continental scale. The point scale results will be aggregated to the climate zone scale and then the continental scale.

5. p6027, L17: is there an argument why these param's are selected and others not? Or is this made later explicit?

The climate variables were selected to represent the "input" (as rainfall) and "output" (as losses to evapotranspiration), and when combined both "input and output" define the recharge. The characteristics of rainfall such as total rainfall (Crosbie et al., 2010), rainfall intensity (Owor et al., 2009) and rainfall seasonality (Petheram et al., 2002) are expected to influence the amount of recharge so were each investigated. WAVES (Zhang and Dawes, 1998) is using the Penman-Monteith (Monteith, 1967) equation to model evapotranspiration, the climate variables necessary for this modelling are the minimum and maximum temperatures, vapour pressure deficit and solar radiation (windspeed is not used because it is generally not available). Through the water balance any climate variable that effects evapotranspiration will also effect recharge.

Following your comment we made these changes (point 1): ... examine the influence of rainfall.... as these climate parameters are considered to be the most influential in recharge estimation (Crosbie et al., 2010, Owor et al., 2009 and Petheram et al., 2002)

Following your comment we made these changes (point 2)... examine the influence of other climate variables... as these parameters affect evapotranspiration and therefore indirectly the amount of rainfall which become recharge... (Zhang and Dawes, 1998, Monteith, 1967)

6. p6028, L19: How are ranges in Table 1 determined? Spatial avg? of interpolated map? or avg of stations in climate zones?

We stated in the text that Table 1 determined values as a spatial distribution of means, e.g. annual rainfall within each climate zone. Following your comment we made these changes we also added a footnote for the table: *Mean value across the climate zone, estimated using mean annual values of the relevant parameter within each climate zone **The range of mean annual values within each climate zone

7. p6029, L7: potential: please explain. Is it used as in line 15?

Since recharge values were modelled, certain assumptions were applied and recharge was considered as an amount of rainfall percolated below 4 m from the surface and no preferential flow was considered. As a result we suggested that the results are related to "potential" recharge. But to avoid confusion, we have removed the references to "potential" in this sentence and the text below provides some clarification why we considered the modelled recharge as "potential": the adapted assumptions result in overestimation of recharge where the watertable is close to the surface or underestimation of recharge where the tree roots are deeper than 4 m.

8. p6029, L16-18: The assumption: for which climate zones is it valid and for which not or less? The resulting errors from the assumption are expected for which percentage of the area?

This assumption is not directly related to climate zones, but rather to local hydrogeological conditions and aquifers settings.

9. p6030, L16: SILO: explain meaning

SILO is the Australian national climate database; following your comment we made these changes this explanation is added to the text

10. p6032, L4: Ri: not clear you should define and explain it better.

Ri or "Relative importance" refers to the quantification of an individual regressor's contribution to a multiple regression model. Each regressor's contribution is just the R2 from univariate regression, and all univariate R2 -values add up to the full model R2.

This text was added to the paragraph in question.

11. p6033, L22: not clear; sum Ri for BSk is not 0.7; what do you mean; rephrase

We agree: the remark about Ri<0.7 is confusing as low Ri values are also shown for the climate types other than BSk. The main point made in this section is that across all considered soil and vegetation types, Ri for BSk is lowest.

12. p6034, L25-26: for the most northern...for the most southern...: this cannot be deduced from fig 4.

The text was changed to make the point more clear:

For instance, temperate climate Cfa covers the eastern regions of the country stretching from the north-east to south-east. It is characterised by the greatest variation in rainfall and its relative importance in recharge estimation. The higher values are related to the most northern modelled points that are similar to in tropical climate (Aw), while the lowest values are found for the most southern modelled points that are similar to under arid climate (BSk) (Figure 4).

13. p6035, L3-5: I do not see this in fig 4. I think there is no increase for sure not for trees: K=1, delta Rip=0.6; K=0.01, delta Rip=0.4

We hope we understand this comments currently, but this section is stating that the variability of Ri increases, but it does not refer to Ri value.

14. p6035, L5: not clear, reformulate; the point is what about the soil influence? Also valid for K=0.01?

Soil type seems to have lesser effect and the sentence was changed to: For all soil types the annual rainfall, which corresponds to the minimum , is lower under tree land cover, which is about 400mm against 500mm under annuals.

15. p6035, L14: Fig 5 is not referenced/discussed.

The reference to Fig 4 on p6035 line 10 is actually a reference to Figure 5.

16. p6036: fig 7 is not referenced (line 5 and further?)

The reference was missed, and it is added to p6036 line 8.

17. p6037, L17: 'often weaker': this is a misleading phrase; more often the correlation between annual rainfall-recharge is higher.

The main message from this section was not to suggest that the correlation between annual and rainfall and recharge is weak, but to indicate that high intensity rainfall, summarised on annual basis has the higher coefficient of correlation for the majority of the considered conditions

Following your comment we made these changes: Though there exist overall high correlation between annual rainfall and recharge, the correlation between recharge and the sum of high intensity rainfall on an annual basis is stronger.

18. p6038, L1-2: I do not see this better correlation from the fig.

This section was not clear, and the following changes were made: It was found that for 99 percentile daily rainfalls on annual basis is lower than for the majority of cases but under arid climate types and under highly permeable soils and tree land cover in Csa and Cfb. and are more comparable, but application of 99 percentile daily rainfalls on annual basis does not lead to a better predictability of the recharge.

19. p6038, L4-6: Fig 11a yellow points many are below the bisectrix i.e. worse correlation. Hence, I do not understand this conclusion.

The point in this sentence should be illustrated by the following Figure (Figure 12), which shows that when a daily rainfall thresholds are concerned, only a daily rainfall thresholds greater than 20 mm was identified as having higher than : for some conditions within Aw and Bsk climate types. We will reword this sentence and the reference to the figure in the manuscript.

20. p6038, L13-16: Hence for all combinations R2pi < R2p: so the exercise failed! L20: I do not see this from 13a, you mean 13b? L22: 13a?

We agree that this section was not clear, and the following changes were made:

Under soils with lowest hydraulic conductivity (K=0.01md-1) the effect of high rainfall intensity on recharge estimation diminishes and and are largely similar for all climate types and vegetation covers. For other soil types the least difference between and (on averaged <5%) is under annual vegetation (with exception of Csa climate zone), but also under tropical Aw and arid BSk climate types (Fig. 12a, b). The latter represent the extremes in rainfall intensity across the continent with the highest intensity being typical for the tropic Aw climate type (most dally rainfall is of high intensity), and the lowest – for the arid BSk climate type (most daily rainfall is of low intensity) (Fig. 13a). This also reflects a general trend in reduction of rainfall intensity from the north to the south of the country (Fig. 13b).

21. p6042, L14-16: I do not follow this conclusion, maybe I miss something but for me it should be opposite as it appears from the paper.

We hope that the proposed changes to this section make the point more clear:

Annual rainfall is a major factor influencing recharge. However, for the majority of the considered climate types recharge shows a greater dependency on the rainfall parameters reflecting higher rainfall intensity, reflected by a stronger correlation between annual recharge and those parameters rather than between annual recharge and total annual rainfall.

22. Fig 2: modelled recharge: is that potential? What is the difference between the 3 sub figures, explain in the caption a, b, c. I hope the explanation given under point 7 is applicable here. Fig 3: –> rich soils are not presented). Fig 4: caption is not correct. I see annuals and trees presented in the fig as well, as well as K 0.10 and 0.01. Correct caption. Fig 9: what is R2 for sub fig b and d?

All charges are made

25. Fig 11: the dots are too small, the color is hardly visible.

We will need to explore is we can change the plots to make them more readable. There are about 4000 points at each dataset, so larger dots may make the image even less informatives.

26. Fig 12: in caption: (a) K=0.001. Add also in the caption an explanation for AP, PP and TR. Sub-fig b: So whatever aggregation method always R2p>R2pi: Hence aggregation is not successful; see also remark -p6038, L13-16.

Thank you for pointing out to this inconsistency, which has resulted from an error in artwork. The Y-axis title should state: R2(Pi)-R2(P). The figure legend was changed to annual, perennial and trees

27. Fig 13: Caption is not good, describe sub figure a and b separately and not within one confusing sentence.

Figure 1 plots were switched (a becomes b and n becomes a) and the caption was changes to

(a) A proportion of high intensity rainfall in total annual rainfall for all point locations used for analysis and (b) changes in this proportion from north to south of the continent

Technical corrections: all technical correction will be addressed

Relevant references Crosbie, R. S., Jolly, I. D., Leaney, F. W., and Petheram, C.: Can the dataset of field based recharge estimates in Australia be used to predict recharge in data-poor areas?, Hydrol. 15 Earth Syst. Sci., 14, 2023–2038, doi:10.5194/hess-14-2023-2010, 2010a.

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