Review#3

Review of HESSD-9-4777-2012 L. Wang et al. Dryland ecohydrology and climate change: critical issues and technical advances

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Part 1: Reviewed prior to reading comments from other reviewers

General Comments In this paper, the authors present a set of critical issues and technical advances related to the water resources, hydrology, and ecohydrology of drylands. The manuscript presents a thoughtful review of some key issues and questions and raises some compelling challenges. The paper also provides a nice review of two categories of recent advances: remote sensing and the use of stable isotopes. The paper is well written and organized and covers a number of engaging topics. At the same time, the paper is a bit lacking in its coherence and comprehensiveness, and I offer a few suggestions for improvement. The manuscript begins with the articulation of seven "critical issues" – some topical (such as woody plant encroachment and population growth) and some tied to scale (such as what is our understanding of hydrology at the plot and regional scales). This list may not be exhaustive, but it presents a range of challenging issues for consideration. The paper then continues to articulate three technical advances. The selection/organization of these advances is a bit unclear. Are they presented to address the aforementioned critical issues? Or presented more generally? For example, the use of NDVI and RESTREND to separate the effects of climate change and human-induced land degradation relates directly to critical issue #4 (human versus climate-induced desertification). And, remote sensing of the hydrologic cycle (technical advance #2) could be related to regional hydrology (critical issue #7). The use of isotopes to partition ET into E and T seems to be solving a problem not presented as a critical issue. Is this included primarily because of the authors' familiarity with these techniques? I recommend that a more explicit connection be made between this technical advance and the critical issues (perhaps plot-scale hydrology). And what of technical advances not included? On par with the development of isotope techniques has been the development of distributed-temperature sensing (DTS). This fiber-optic instrument offers great opportunity to provide high-resolution data on field- scale hydrology – perhaps potentially addressing the critical issue of the plot-scale spatial distribution of infiltration. Why is this not included? And why not other measurement advances (e.g., strain gauges to measure interception, sap flux to determine transpiration)? And what of modeling and representational advances? This, of course, opens a whole other can of worms – perhaps the focus is on measurement advances (rather than technical advances). In any case, some explanation for why certain ad- vances are included or not seems appropriate and would enhance the paper.

We added a perspective in the beginning of the technical advances section and added a summary to link the critical issue and technical advances at the end of the manuscript.

Newly added perspective:

"As already noted, the variability and distribution of water availability in the landscape is of paramount importance for drylands. There are a number of exciting developments in monitoring tools useful for ecohydrological research over the last decade. For example, field deployable laser based spectroscopy approaches that determine the ratios of hydrogen and oxygen isotopes (Lee et al., 2005; Wang et al., 2009d; Wang et al., 2012a), cosmic-ray (Zreda et al., 2008) and electromagnetic imaging (i.e., EMI) based plot to watershed scale in situ soil moisture monitoring, development of distributed-temperature sensing (DTS), and remote sensing based estimates of key hydrological variables such as soil moisture, ET and water level (Alsdorf et al., 2000) are revolutionizing the scales and precision of information sources to inform ecohydrological measurement and investigation. The modeling and conceptual advances in soil moisture (Rodriguez-Iturbe et al., 1999; Guswa et al., 2002), scale and scaling (Blöschl and Sivapalan, 1995; Rodriguez-Iturbe et al., 1995; Wilcox et al., 2003) also enhance our understanding of dryland ecohydrolocial processes. It is impractical to exhaust all the advances and here we select remote sensing and stable isotopes as examples and discuss three areas in details. First we discuss recent methodology advances to differentiate human vs. climate induced desertification using remote sensing product and time series analysis, corresponding to the critical issue 2.3; the second and third parts focus on using remote sensing and stable isotope based techniques to better characterize the water budget at various scales, which apply to all the critical issues. Remote sensing has the advantage in temporal and spatial duration and stable isotopes have the advantage in detecting mechanisms."

Newly added summary:

"In this synthesis, based on hydrological principles and published literature, we highlight current critical issues in drylands ecohydrology ranging from societal aspects such as rapid population growth and the resulting food and water security implications, development issues, and natural aspects such as ecohydrological consequences of bush encroachment and differentiation of human versus climate induced desertification. We identify a number of research priorities to better address knowledge gaps. It should be noted that while some of the issues identified are not necessarily unique to drylands themselves (e.g., food and water security), the level of severity and urgency is certainly higher in drylands and deserves focused attention.

To improve current understanding and inform upon the needed research efforts to address these critical issues, we identify some recent technical advances in terms of monitoring dryland water dynamics, water budget and vegetation water use, with a focus on the use of stable isotopes and remote sensing. Stable isotopes have proven to be a powerful tool in tracing hydrological processes and vegetation water sources. Recent developments in spectroscopy have revolutionized the temporal and spatial resolution of isotopic monitoring, providing foundations to use isotope-based techniques to partition ET and characterize large-scale vegetation water use. Similarly, rapid developments in remote sensing based hydrological monitoring provide unprecedented temporal and spatial coverage in estimates of soil moisture, ET, water level and other important ecohydrological aspects of the system. For example, both active and passive microwave based systems are available for remote estimation of soil moisture, with each representing a compromise between spatial and temporal resolution. Combing microwave-based passive and active systems with infrared-based sensors allows for the spatial and temporal resolution of precipitation structure and pattern to be significantly improved. In addition, the capacity to monitor vegetation structure and vegetation health provides additional benefits for ecohydrological monitoring using remote sensing.

Due to inherent length limitations, there are a number of related technical advances in in situ measurements, such as field portable 3D LIDAR systems for plant canopy analysis, distributed temperature sensors (DTS) for soil heat flux and connected waters measurement, and electromagnetic imaging (EMI) and cosmic ray soil moisture observing systems (COSMOS) for soil moisture that were not covered in detail. Further information of such advances can be found in a number of synthesis papers devoted to some of these techniques (e.g., Robinson et al., 2008; Zreda et al., 2012).

Overall, the analysis techniques, observation systems and monitoring advances discussed herein can all help to address some of the key ecohydrological issues of water and food security, consequences of bush encroachment and differentiation of human versus climate induced desertification. Inevitably, development issues in drylands require a hydrological, ecological and socio-economic understanding of the dryland ecosystem. An effective management of dryland systems demands that advances in monitoring, together with informative techniques for data analysis, should be linked within an interdisciplinary interpretive framework. Only then will the capacity to address the myriad issues facing dryland systems in the coming years be realized. ”

Also, what of the critical issues that are not addressed by the technical advances mentioned in the paper? As written, the paper ends rather abruptly after the presentation of the technical advances. Even if the solutions are not yet present, perhaps the authors could provide their thoughts on what might be needed to address the issues of population growth and water demands or development. Are the issues technical? Social? Economic? What is the role of the hydrologist? Can the hydrologist make a contribution to those critical issues? Since the authors take the time to present the issues, I recommend that they offer some thoughts on pathways forward.

We added a summary section and present the future challenges.

“4. Summary and concluding remarks

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Overall, I enjoyed reading this thought-provoking paper. I think it can be improved with a clearer rationale for the technical advances included (and perhaps an expansion of that section) and a concluding section that returns to the seven critical issues and offers some commentary on how the hydrologic community can contribute to each.

Part 2: Additional thoughts after reading comments from Reviewer 1 and 2

I generally concur with the comments of the two prior reviewers. I think the issues of scale and scaling are indeed "critical." Perhaps it is worth including some of the "technical advances" in this area? That is, new insights into how to represent the same processes at different time and space scales? That may lead the paper too far afield, however.

I will echo my colleagues in their general support of the paper, and (as outlined above), I think it can be improved with some reorganization and clarification.

The scale effects were added in the Introduction and the manuscript was thoroughly re-organized and revised.

“Not unique to drylands, but equivalently important in arid and semiarid landscapes, scale and scaling is another important issue in understanding and predicting ecohydrological processes (Seyfried and Wilcox, 1995; Becker and Braun, 1999). Scale is perceived differently by different researchers and for different research purposes. From the perspective of a small lysimeter study, a catchment of the size of 1 km2 may be considered large and heterogeneous, whereas a several thousand km2 basin may be considered small and homogeneous by global simulations (Bergström and Graham, 1998). In reality, processes are often observed at short time scales and small spatial scale and predictions are made for long time scales and large spatial scale. To make this link, it is essential to understand how the nature of spatial variability affects hydrologic response over a range of scales, how to link the small-scale and large-scale observations and where the uncertainty lies. Upscaling typically consists of two steps: distributing the small-scale parameter over the interested area and aggregating the spatial distribution of the parameter into one single value, downscaling, on the other hand, involves disaggregating and singling out (Blöschl and Sivapalan, 1995). Scaling can be conducted either in a deterministic or a stochastic framework and scaling methods depend on the characteristic of the interested parameters. Scale and scaling issues have been discussed comprehensively in other reviews and syntheses (Blöschl and Sivapalan, 1995) and it is still an active area for ecohydrological research (Wilcox et al., 2003; Wang et al., 2012b).”