Referee #2

General comments:

The paper well addressed the current critical issues in the understanding of dryland systems, and reviewed the technical advances also. In my opinion, it is an excellent research progress review, and I recommend the manuscript should be published after minor revisions. The suggestions are as follows.

Firstly, scale effects and scaling may be one of the important issues for "Dryland ecohydrology and climate change". In the part of " INTRODUCTION", the paper gives some sentences on scale (Page 4780, Line 17; Page 4781, Line 1); and the authors also has carried some research on upscaling (Page 4781, line 4-7). While, there are few sentences on scale effects and scaling in the manuscript. It is necessary for the paper to discuss scale effects and scaling methods for dryland ecohydrology and climate change.

We added a new paragraph to discuss scale effect and scaling issue in the revised manuscript.

“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).”

Secondly, in the parts of "2.1 Dryland population growth and water demands" and "2.2 Dryland agriculture and climate change", the paper discussed the relationships between population and water demands, agriculture and climate change". The two parts are different from each other in general; while, it seems there are some close relationships between them. With the population growth, agriculture will have to support additional people, and more freshwater resources are needs. I am not sure the two parts can distinguish from each other clearly. For example, the contents (Page 4784, line 6-11) may be suitable for "2.1 Dryland population growth and water demands" also.

In the revised manuscript, we combined these two sections and modified the text to avoid redundancy.

There are some specific comments also.

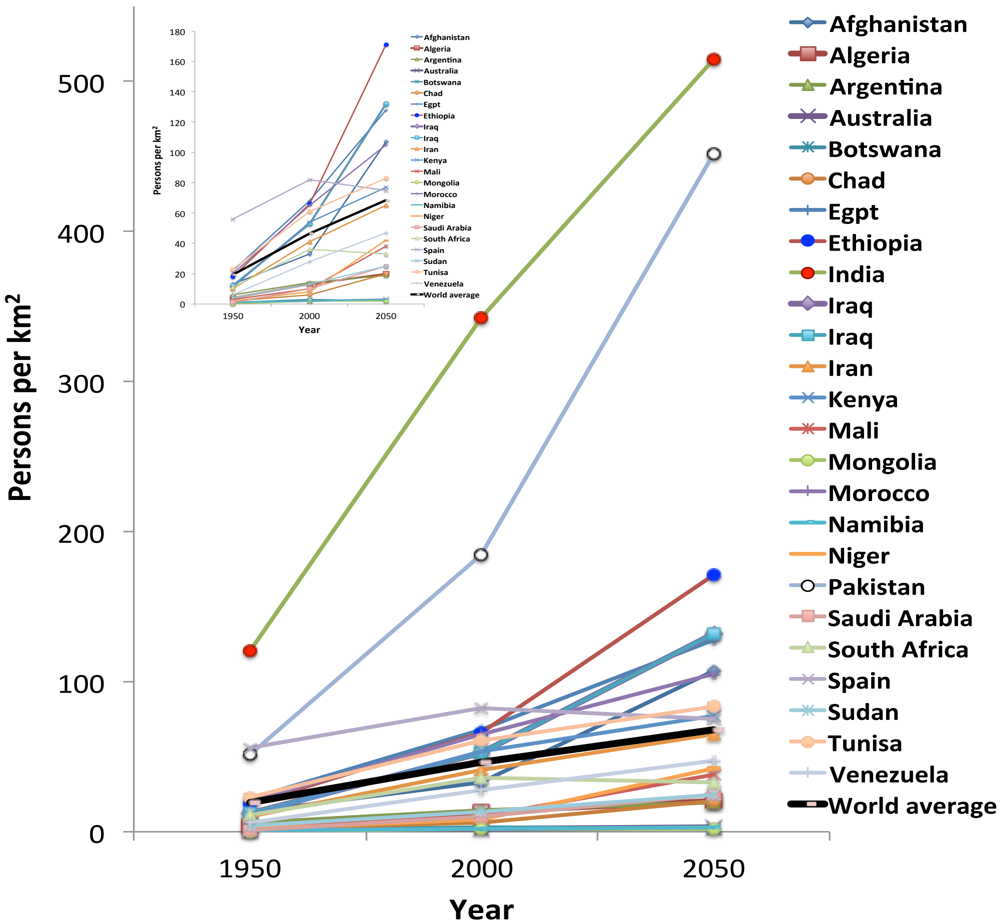
1.Page 4783, line 7-9. China and India have so many people and low economic levels(per person); it is impossible for the per-capita water footprint of China and India will reach the levels of the US. It may be difficult to turn the hypothesis into reality.

We added clarification that this scenario may not be able to reach in reality.

"…(this may not be achievable in reality due to the size of the population and low per capita economy level at these countries), "

2.Page 4783, line 4-5. The population of China and India in 2050 should be updated. See "State of World Population 2010" for the new predicted populations please. So do with Fig.1.

We updated these numbers (1.42 and 1.61 billion for China and India, respectively) according to the "State of World Population 2010". We used the same data source for Fig. 1 because it provided not only population data, but also density data which we used for Fig 1. We re-made Fig. 1 and added a new inset for better display.



3.Page 4788. In the part of " 2.4 Desertification and human vs. climate induced desertification", the authors discussed the driving factors of desertification. Maybe, some detailed data or examples, on the extent to which a region's degradation is caused by climate variations or human activities, can be given.

An example was given.

"Using this methodology Evans and Geerken (2004) identified the regions undergoing significant human caused degradation in the Syrian drylands, which account for a large portion of the total degraded areas."

4.Page 4789. In the part of "2.5 Ecohydrological consequences of shrub encroachment", the effects of shrub encroachment are discussed at plot scale and regional scale. In the revised manuscript, the scale effects or scaling may be discussed further.

The scale effects were added.

"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)."

5.Page 4794. In the part of "3 Technical advances addressing dryland issues", the de-tailed technical advances on dryland systems are discussed. In the revised manuscript, the perspectives may be added.

We added a perspective in the beginning of the technical advances section.

"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."

6.Page 4798. Different remote sensing techniques are discussed for ecohydrological investigations. If the authors give a table and list different techniques for different ecolydrological applications, it will be better.

We have tried to add a table, but realize it is hard to summarize everything without adding a gigantic table, which will be out of scope of this manuscript. Instead, we added summary in the newly added Conclusion section.

"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. "