Interactive comment on "Analysis of water use strategies of the desert riparian forest plant community in inland rivers of two arid regions in northwestern China" *by* Y. N. Chen et al.

Anonymous Referee #2

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The authors of this manuscript tried to describe "comprehensively" the water use characteristics of desert riparian plants in typical arid regions of northwestern China. Their attempt itself is important in terms of raising fundamental information on tree ecology and hydrology of the wood lands in arid environment. However, this manuscript is not sufficiently describing those information "comprehensively", and does not consists of complete structure as an original scientific paper in terms of following points.

1) They chosen two different study sites: "Lower reaches of the Tarim River" and " Lower reaches of the Heihe River". However, substantial reasons of this selection were not described apparently. Also, an implication of the comparison between these two sites should be mentioned with explaining the geographical differences including the vegetation history etc. of those sites

2) Only two species of trees were selected for the investigation. The reasons and adequacy (how typical? why are those selected as representative trees?) of those selections should be explained. The implications of the comparisons between those two species were also not described explicitly.

3) Two of above points should have been described in the introductory section. Discussions and conclusion must be answers for the questions on those comparisons (between sites and tree species).

4) Moreover, in the introductory section, it was necessary to be described what kind of originalities were involved in their investigations of this manuscript, compared to the previously reported studies on similar subjects. Current citations in Introduction were just a list of previous studies.

5) Some of the observed data were presented only for Populus euphratica.

6) Many sentences in the Discussion and conclusion were redundant. Many of cited literatures did not have a point, in terms of direct discussions of their observed results.

7) As a consequence, it was unclear whether water use strategies and life mode that they determined from the results were unique in this study sites or generally found phenomena.

Individual points: Table 1: "Average precipitation" => "Average annual precipitation" "Average evaporation" : Is this potential evaporation rate? How did they estimate?

Figure 1: Scales of Y axes are different between (a) and (b). Those should be justified.

Figure 4: Scales of Y axes are different between (a) and (b). Those should be justified.

Figure 5: "…. in the desert riparian forest" => "….in the study sites"

Figure 6: Explanation of "PLC" is needed in the caption.

Figure 7: Are those error bars needed?

Figure 10: Scales of Y axes are different among (a) - (d). Those should be justified.

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Response：

1) According to the reviewer's comment, we made a major revision in the introductory section. We add a paragraph for describing the reasons and comparative implication why we selected the lower reaches of the Tarim River and Heihe River as the study area. Moreover, we have more detail describe about the geology, soil, groundwater and vegetation of both of the two areas in the section of study area. The detail revision about introduction are as follow:

1 Introduction

Water is the most important limiting factor of plant distribution and growth; thus, plant water sources and use strategies are one of the major concerns of ecologists (Pausas and Austin, 2001; Cheng et al., 2006; Zhou et al., 2011), especially for the arid and semiarid ecosystems due to the rare rainfall. In the global terrestrial ecosystem, arid and semiarid ecosystems cover about 50% of the earth's surface (Bailey, 1996). In China's terrestrial ecosystem, arid and semiarid ecosystems, mainly located in northwestern China, account for 52% of the national land surface (Wang, 2007). Typical studies on plant water sources and use strategies have been conducted of tropical forest ecosystems (Meinzer et al., 1999), temperate forest ecosystems (White, 1985), riparian ecosystems (Snyder et al., 2000), coastal ecosystems (Dawson, 1998), desert ecosystems (Ohte et al., 2003), and semiarid areas (Willams and

Ehleringer, 2000, but few was carried on the extreme arid regions. Therefore, the exploration of plants' water use strategies in extreme arid regions is important to the conservation and restoration of the fragile ecosystems in the arid systems.

The Tarim River and Heihe River, respectively, are the largest and the second largest inland rivers, located in northwestern China. Both of them belong to typical extreme arid desert regions. The common points between the Tarim River and Heihe River are as follows: 1) Water resources form from the ice-snow melting water and rainfall. In the middle stream oasis region, the surface water is exploited in large quantity for agricultural irrigation (Chen et al., 2004; Bai et al., 2008). 2) The geological environment, soil-forming process (Liu et al., 2005; ; Zhao et al., 2010), precipitation and evaporation (Fu et al., 2006; Yao et al., 2006) in the river downstream region are basically similar. The river downstream dried up for a long time and the underground water level falls, the desert riparian forest declines and even dies off in a large area, presenting desert landscape. 3) Both sides of the downstream of rivers also distribute similar desert riparian forest, in which *Populus euphratica* is the only arbor, *Tamarix ramosissima* is the dominate shrub, and *Alhagi sparsifolia* and *Karelinia caspia* is the main herb species (Fu et al., 2014). All of the plant communities in both of the areas have the same constructive species- *Populus euphratica* and *Tamarix ramosissima.* 4) Since 2000, ecologic water transport has been applied in the downstream dried-off riverway, aiming at lifting the underground water level and saving increasingly declining desert riparian forest. The differences between the Tarim River and Heihe River lie in that: 1) In the past 13 years of the ecological water transport process, linear water transport occur following the artificial levees in the downstream of the Tarim River channel for. Therefore, only the underground water level near both sides of the riverway is lifted (Chen et al., 2003). However, almost every year the waterhead reaches the tail Lake-Dongjuyanhai Lake (Tang and Jiang, 2009), and when the water transfer quantity is huge, many overflows occur in the downstream. 2) The mean underground water level of both sides of the downstream of the Tarim River is 6-8 m, and some sections reach over 10 m (Chen et al., 2004). However, the mean underground water level of the downstream of the Heihe River is 3-4 m (Jiang and and Liu, 2009). In summary, the lower reaches of the Tarim River and Heihe River could be favorable experimental sites for testing response of plants to long-term different drought stresses (different groundwater depths).

Most studies indicated that plant water sources and use strategies varied in different ecological environments. For example, in Utah's southern desert in the U.S., its annual and perennial succulent plants completely depend on summer rains, while herbaceous plants and perennial xylophyta simultaneously use summer rains and winter rains (Ehleringer et al., 1991). In the Mu Us Desert in Northern China, it is easy for alien species, *Saliz matsudana*, to use underground water; whereas, native species*, Sabina vulgaris* and *Artemisia ordosica*, tend to store water (Ohte et al., 2003). Moreover, in southern Florida in the U.S., the tropical and sub-tropical hardwood species (e.g., *Coccoloba*) of coastal plants mainly use fresh water (rainfall and runoff), while salt-tolerance species (e.g., *Slicornia*) almost all use seawater. On the other hand, Redwood forest can use both of these kinds of water sources (Sternberg et al., 1987).However, they still are not clear about the water sources of dominant species of desert riparian forest, water use strategies of plants resisting different long-term drought stresses in the extreme arid areas. Combined with stable isotope technology (Drake et al., 2003; Duan et al., 2007; Zhou et al., 2011), trunk sap flow technology (Ma et al., 2013), water potential (Fu et al., 2012), root water redistribution (Hao et al., 2012), etc., this paper comprehensively compared and analyzed the water use efficiency, source, distribution, and strategy of dominant species of desert riparian forest-*Populus euphratica* and *Tamarix ramosissima* in two typical extreme arid regions, the downstream of the Tarim River and the Heihe River Basin, and explored the relation between the long-term drought stress and plant water use strategy. The ultimate aim of our research is to perfect studies on plants' water physiological ecology and provide a scientific basis for the restoration and reestablishment of desert riparian forests of inland river basins in arid regions.

2) Yes, we just selected two species as the study objects. The reasons are that there are no more than 20 plant species growing in the both of the lower reaches of the Tarim River and Heihe River, and *Populus euphratica* and *Tamarix ramosissima* are the dominant and constructive species in all of the plant communities in both of the areas. Moreover, both in the lower Tarim River and Heihe River *Populus euphratica* is the only arbor in the desert riparian forest, and *Tamarix ramosissima* is the dominant shrub species in the plant communites. So, we think *Populus euphratica* and *Tamarix ramosissima* could represented the main species of the plant communities in the study area. According to the reviewer's comment, we have added the explanation in the introductory section.
3) According to the reviewer's comment, we have modified the sections of introduce and discussion and conclusions. Please see the detail revision of introduce in the answer 1) and of discussion and conclusions in the answer 6).
4) According to the suggestion of the reviewer, we added the originalities of our manuscript in the introductory section. In this paper, most of the similar studies focused on tropical forest ecosystems, temperate forest ecosystems, coastal ecosystems, etc., but few studies were carried on the extreme arid regions. Moreover, although there were many studies analyzed the effects of ecological environment factor on the plant water resources or water use strategies, they still are not clear about the water sources of dominant species of desert riparian forest, water use strategies of plants resisting different long-term drought stresses in the extreme arid areas. This is our key objective for studying in our study. About the explanation, please see the first and third paragraph in the introductory section.
5) Yes, we just monitored the data of hydraulic redistribution and sap flow for Populus euphratica. And we agree with the reviewer's viewpoint that it will be more valuable if we have these data of *Tamarix ramosissima.* But you know, it need a long time (all day

and night) and continuous investigation to get these data. So, we cannot monitor both *Populus euphratica* and *Tamarix ramosissima* at the same time because we have not enough researchers and instruments. *Populus euphratica* is the most important species in the local plant communities. And we have found hydraulic lift and redistribution in the local plant communities were mainly occurred by *Populus euphratica* (see literature Hao et al., 2012). So, we only monitored *Populus euphratica.*

6) To clearly understanding, we should state the structure of the section of discussion and conclusions for reviewers. It is as follows:

The first and second paragraph in the section of discussion and conclusions state the implications of our study on the field of biogeosciences. The third paragraph in the discussion and conclusions state the substantial reason resulted in the differences of groundwater depths between the lower reaches of Heihe River and Tarim River although both of them have similar climate, soil and vegetation, which indicated the plants in the two areas experienced a long-term different drought stresses. In fact, this is the reason why we select the dominant plants in the two areas for comparing their responses to different drought stresses. 4-8 paragraph in the section of the discussion and conclusions mainly compared the differences in water resources and water absorption patterns, water redistribution, water transportation, and evapotranspiration of plants in different area, which was corresponding to the scientific questions (originalities of our study) in introduce section. The last paragraph in the discussion and conclusions section was the ending of the discussion.

According to the reviewer's suggestion, we have made a major revision in 4-8 paragraph in the section of Discussion and Conclusions, in which we streamlined the contents, deleted some unrelated references and added some related references. The detail revision please see as follows:

Different drought stresses caused the differences of water absorption pattern of plant root (Fig. 1). In an environment with limited water, plants may absorb deep soil water or groundwater by deep roots (Nie et al., 2011). According to stable $\delta^{18}O$ composition in the water of the xylem, both *Populus euphratica* and *Tamarix ramosissima* in the downstream of the Heihe River and Tarim River took deep subsoil water and groundwater as the main water source, and did not mainly rely on the surface soil water (Figs. 1 and 2). It could give a stable water source for *Populus euphratica* and *Tamarix ramosissima* in the downstream of the Tarim River and Heihe River by their deep roots to adapt drought stress. Combining $\delta^{18}O$ contents in soil and groundwater, $\delta^{18}O$ content in the soil below 175 cm of the downstream of the Heihe

River is similar to that in the groundwater, and $\delta^{18}O$ content in the soil below 375 cm of the downstream of Tarim River layer is similar to that in the groundwater (Fig. 1). These indicate that deep soil water mainly came from the supply of groundwater. Therefore, *Populus euphratica* and *Tamarix ramosissima*, the major plant community of desert riparian forests in the downstream of the Heihe River and Tarim River, actually use groundwater. This may be relevant to the deep root distribution of *Populus euphratica* and *Tamarix ramosissima* (Fu et al., 2014). However, the water use patterns of plants still are different in the two areas. The use ratio of groundwater of *Populus euphratica* and *Tamarix ramosissima* in the downstream of the Tarim River is smaller than that in the downstream of the Heihe River, and its use of soil water is relatively larger than that in the downstream of the Heihe River. Moreover, the use of soil water of the soil depth layer in the downstream of the Tarim River is also deeper than that in the downstream of the Heihe River. In other words, under long-term water stress, the water absorption of *Populus euphratica* and *Tamarix ramosissima*'s roots becomes diversified.

Different drought stresses caused the differences of water redistribution pattern of plant root (Figs. 5 and 6). As the active adaptation strategy to drought stress, the hydraulic lift of plants plays a key role in the riparian forest in the inland river basins of arid regions (Hao et al., 2012). Research results (Warren et al., 2005; Brooks et al., 2006; Munoza et al., 2008) indicate that hydraulic lift can extend the available period of water, which is beneficial to the maintenance of physiological activity and hydraulic conductivity of plant tissue, and postpones the time of critical water potential of root embolization caused by the decrease of soil water potential. The hydraulic lift capacity of plant roots depends on plant species and meteorological factors (McMichael and Lascano, 2010; Warren et al., 2011). In the downstream of the Heihe River, the hydraulic lift of the root of *Populus euphratica* occurs at the 10-50 cm soil layer, and its capacity is usually small (0.36 mm/d), accounting for about 10% of water consumption. In contrast, in the downstream of the Tarim River, *Populus euphratica* root at night tends to release the soil water at mid-depth (10-110 cm) to the shallow layer, and the content is large (0.41 mm/d), accounting for about 32% of water consumption.

Different drought stresses also caused the differences of xylem water transport patterns of plants . Xylem hydraulic conductivity of *Populus euphratica* and *Tamarix ramosissima* in the downstream of the Heihe River is significantly higher than that in the downstream of the Tarim River. Moreover, the branch xylem in the downstream of the Heihe River is easier to embolize, indicating that the root water absorbing capacity of *Populus euphratica* and *Tamarix ramosissima* under mild drought stress is strong. In this way, the strong flow resistance in the branch xylem not only can effectively reduce the water absorption of branch, but can also be beneficial to the uniform distribution of water from root in branch, which is important for maintaining adequate water in the plant to coordinate the normal growth and development. In other words, desert riparian forest plants in the downstream of the Heihe River adapt to mild drought stress by the hydraulic conductivity limiting in the branch xylem. However, in the downstream of the Tarim River, the embolization of root xylem of *Populus euphratica* and *Tamarix ramosissima* is obviously larger than that of branch, indicating that the water transport resistance of desert plants mainly lies in root, which means the root water absorbing capacity is substantially limited. To maintain survival, the water absorption resistance must be actively reduced to compete for the extremely limited water supply and enable the water to rapidly transmit to blades. Therefore, some branches with weak competition are doomed to wither due to the water shortage. It is common to see a small part of branches of *Populus euphratica* and *Tamarix ramosissima* growing well, while the remaining branches wither to death in the downstream of the Tarim River (Fig. 11). In this way, desert riparian forest plants in the downstream of the Tarim River mainly guarantee the survival of the whole plant by sacrificing weak branches and improving dominant branches with a strong ability to compete. This is consistent with the conclusions in the study of Zhou et al. (2013)..

Furthermore, different drought stresses caused the differences of plant evapotranspiration characteristics. Root and stem sap flow of *Populus euphratica* in the downstream of the Heihe River and Tarim River at night are similar, with a non-significant difference ($P>0.05$); whereas, the sap flow of *Populus euphratica* in the downstream of the Heihe River in the daytime is significantly smaller than that in the downstream of the Tarim River ($P<0.05$). In the downstream of the Heihe River, the sap flow of the main root and lateral root of *Populus euphratica* in the daytime is fairly large, and both main root and lateral root bear the transport of evapotranspiration of *Populus euphratica*. In the downstream of the Tarim River, the shallow soil water is not adequate, and *Populus euphratica* in the daytime mainly transports water, depending on developed deep main root. At night, plant evapotranspiration reduces, and to make up for the huge loss of shallow soil water in the daytime, the lateral sap flow begins to flow negatively. Water in the plant xylem releases in the shallow soil to supply the soil water and improve the water environment of shallow-rooted plants, which is beneficial to the succession development of the plant community.

Sap flow is an intuitive reflection of plant evapotranspiration (Wullschleger et al.,, 1998). For the same plant, its evapotranspiration rate in water stress will be lower than that in adequate water (Ma et al., 2013). In the downstream of the Tarim River and Heihe River, the sap flow rate of *Populus euphratica* exhibits a significant difference ($P<0.01$). In drought stress, especially during the strongest evapotranspiration period at 12:00 LT, the leaf stomata reduces its opening to decrease water consumption and further reduce the evapotranspiration rate. Thus, there is a break at 12:00 LT, which is an adaption mechanism of plants to water shortage. Daily variation of sap flow rate of *Populus euphratica* in the Tarim River will have a slight decrease, which is a presentation of this mechanism. This indicates that in the downstream of the Tarim River, *Populus euphratica* is in water stress. In contrast, the sap flow rate of *Populus euphratica* in the downstream of the Heihe River presents a unimodal curve, indicating that its water status is good. The data of branch water potential also confirm this point. Both in the downstream of the Tarim River and Heihe River, the water potentials of *Populus euphratica* and *Tamarix ramosissima* obviously increase after 12:00 LT. Furthermore, when the groundwater depth varies within 3 m, the water potentials of *Populus euphratica* and *Tamarix ramosissima* at predawn have no significant difference, and neither does the soil water. Thus, it can be proven that *Populus euphratica* and *Tamarix ramosissima* do not suffer serious water stress in the downstream of the Heihe River. In the downstream of the Tarim River, the water potentials of *Populus euphratica* and *Tamarix ramosissima* at 18:00 LT are low and have no sign of lift, indicating that with the decrease of temperature, the weakening of evapotranspiration, and untimely water supply of soil to blade, the water potential of blade manifests as low. In addition, with the increase of groundwater depth, the water potentials of *Populus euphratica* and *Tamarix ramosissima* at predawn decrease obviously. Thus, these indicate that *Populus euphratica* and *Tamarix ramosissima* are suffering serious water stress in the downstream of the Tarim River. This is consistent with the conclusions in the study of Fu et al. (2006, 2014). The geological environment, climate and soil-forming process in the downstream of the Heihe River and Tarim River are basically similar. In the downstream of the Tarim River and Heihe River, groundwater is the main supply source of soil water. *Populus euphratica* and *Tamarix ramosissima* both take groundwater as the main water source. Therefore, different groundwater depth is the essential reason for the water use difference of *Populus euphratica* in both regions.

Other revisions please see the revised manuscript, which we will submit later through the Journal's website.

7) In our paper, we measured every parameter from 2010 to 2012, that is all of the data we used in the paper were the average values of three years. Moreover, we measured three different trees and shrubs in each site in ever year for each species, and most of the parameters we have measured no less than 3 replications from each tree and shrub. More importantly, both trees (*Populus euphratica)* and shrubs *(Tamarix ramosissima)* have the same responses to different drought stresses in the two sites. So, it is reasonable that we think that the results in our paper were generally phenomena.

Individual points:

1) In the Table 1, average precipitation means average annual precipitation, average evaportation means average annual potential evaporation rate, average temperature means average annual temperature, relative humidity means relative humidity in summer. According to the comments, we have added these details in the Table 1. The calculation of potential evaporation used the common methods: penman formula.
2) According to the comments, we have justified the Y axes of figure 1 into the same scales between (a) and (b).
3) According to the comments, we have justified the Y axes of figure 4 into the same scales between (a) and (b).
4) According to the comments, we have changed the caption of figure 5 "Conductivity characteristics of plant root (**a**) and stem (**b**) in the desert riparian forest" into "Conductivity characteristics of plant root (**a**) and stem (**b**) in the study sites"

5) PLC: Percentage loss of hydraulic conductivity. According to the comments, we have added the explanation in the caption of Figure 6.
6) Because the data in figure 7 we used the mean values from three different trees and different days. It may be better by using error bars. So, we did not change it in Figure 7.
7) According to the comments, we have justified the Y axes of figure 10 into the same scales between (a) - (d).

Additionally, We have some revision throughout the text for improving the clear and scientific statement. At the same time, we rearranged the references. All of the revisions will be submitted as a revised manuscript later through the Journal's website.