Soil moisture enrichment under the desert shrub in the Gurbantungut desert, northwest China

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Abstract
The soil water which is transformed from precipitation is the most important water resource to maintain the growth of vegetation in desert ecosystem. Based on field experiments and observational data, the spatial and temporal distribution pattern and variability of the soil moisture in the root area of desert shrub in the Gurbantunggut Desert are analyzed. The main results are: (1) The 'soil wet island' with higher soil moisture content exists in the root area of desert shrub. The soil moisture enrichment in the dry summer is stronger than wet spring. (2) The soil moisture spatial and temporal variability is strongest in 80-180cm soil layer in the dry July. This layer is also the main root distribution layer of the desert shrub. (3) March and April after the snowmelt is the richest period of the soil water in whole year. This period is also the ephemeral plants season. It is considered that the desert shrub stem flow and high infiltration capacity in the root area are the main reason for the soil moisture enrichment in the desert shrub root area.

Key Words
Gurbantunggut desert, desert shrub, soil moisture, aeolian sandy soil, soil wet island.

Introduction
The Gurbantunggut Desert is located in the hinterland of the Eurasian continent, the central of the Junggar Basin in northwest China, covering an area of 48.8 thousands km^2. The annual precipitation is 70mm to 150 mm. It is the sole desert with a stable snow-covered for 110 to 130 days which depth is commonly between 20 cm to 30 cm in China. The snowmelt water can be storied in the soil profile efficiently and it is difficult to bring surface runoff (Zhou *et al.* 2009; Zhou *et al.* 2009). The groundwater depth is greater than 16m. The soil water which is transformed from precipitation is the most important water source to maintain the growth of vegetation in desert ecosystem. Compared with other deserts which lie in China and the world, the Gurbantunggut Desert have the best of natural vegetation cover, plant diversity and stability (Zhang and Chen 2002), and is also the one among the richest region of the spring ephemeral plants in Central Asia (Mao and Zhang 1994), *Haloxylon ammodendron* is the main species of desert shrub, which sparsely distributed all the desert and the surrounding areas. In this paper, the soil moisture characteristics in root area of desert shrub and its spatial and temporal distribution are discussed. This can help us to identify why the Gurbantunggut Desert has a good natural vegetation cover, plant diversity and stability under the limited precipitation situation.

Materials and methods
Experimental sites
The experimental sites are located in the Beishawo experiment area of National Fukang Desert Ecosystem Station at the southern edge of the Gurbantunggut Desert and the geography coordinate is 44°22′N，87°55′E. The *Haloxylon ammodendron* is distributed in the top of a semi-fixed exposed sand dune and the inter sand dune which the vegetation and biological soil crust is almost entirely covered. The annual rainfall is 150 mm, which 35.1% of the rainfall water and 81.1% of the rainfall event is less than 5 mm. The average annual temperature is 6.6℃, the maximum is 42.6℃ and minimum is -41.6℃. The desert soil is aeolian sandy soil with 1.57g/cm^3.

Experiment design
(1) Spatial distribution of the soil moisture in desert shrub plot and bare land
For getting the spatial distribution map of the soil water around the desert shrub, the desert shrub *Haloxylon ammodendron* with normal crown shape and growth in the flat topography are selected. The sample plot area is 10m×10m and the desert shrub is in the center. 1m×1m grid cross-point is as the sampling points. For the

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central 2m×2m range, 0.2m×0.2m grid cross-point is as the sampling points. A total of 246 sampling points with 11 soil layers for each point from 0 to 300cm profile are chose. The soil layers are 0-20cm, 20-40cm, 40-60cm, 60-80cm, 80-100cm, 100-120cm, 120-140cm, 140-180cm, 180-220cm, 220-260cm, 260-300cm.The soil sampled by soil drill and keep in the aluminum can, and dried the sample for eight hours at 105℃ by oven. According to the wet and dry weight of the soil sample, the gravimetric soil moisture content can be calculated. We take 2 times in July and October, 2006. As a comparison, the same sampling on the bare land with 5 soil layers from 0 to 1m profile at the same time are also scheduled.

(2) Dynamically monitor of volumetric soil moisture content in root area of desert shrub
Using the TDR-100 with 32 probes which produced by Campbell Ltd. Company, the soil moisture monitor system in the *Haloxylon ammodendron* root area are established. 6 soil profiles are selected and the distance from the main stem of *Haloxylon ammodendron* are 20cm, 50cm, 100cm, 150cm, 200cm and 300cm respectively. There are 9 probes in the 20cm profile from 0 to 300cm depth, 6 probes in the 50cm profile from 0 to 150cm depth, and 3 probes in other four profiles from 0 to 100cm. The volumetric soil moisture content are collected every 30min automatically for all probes.

Results

The intra-annual variability of soil moisture in the root area and bare land
Due to the groundwater depth is very low and no river water into the Gurbantunggut Desert, desert soil water entirely transformed from the rainfall. Figure 1 illustrated the soil moisture variation in a year from August 2007 to July 2008 in root area and bare land, based on the TDR monitoring data. The rainfall of the experimental site is also showed. The curve shows that the spring season, after snow melted, from middle march to middle May is the most abundant soil moisture period in whole year, in general, the volumetric moisture content is up to 15%. This is correspondingly with the spring ephemeral plants growth period. Many studies (Lan and Zhang 2008) demonstrate the ephemeral plants completed their life-cycle rapidly during this period in the Gurbantunggut Desert. The lowest soil moisture throughout the year is from September to the February. The vegetation growing seasons in spring and summer consumed almost all the soil water, and the volumetric moisture content is generally less than 5% in desert region.
Compared with the soil moisture in the bare land and root area, it is found that the soil moisture in bare land is lower than root area of the *Haloxylon ammodendron* except the snowmelt period. In spring, the root area can maintain a long period with high soil moisture content situation. After the May 1, the soil moisture content significantly reduced in bare land. However, in root area, the soil moisture content slowly declined after mid-May. There are better water harvesting and maintaining capacity in the root area compared with the bare land. After the high consumption of the soil water in the spring, the soil moisture content decreased. The actual evapotransration limited by the soil water supply in the summer and autumn. The soil water decrease continuously in addition to after rainfall. In the summer of 2007, the rainfall is obviously high than normal year. This is why the soil moisture maintains a high level in August and September.

The spatial variability of the soil moisture in root area of Haloxylon ammodendron
Using a principal component analysis method, factor analysis method and geostatistical method, the spatial distribution and variability of the soil moisture which is influenced by the vegetation in the Gurbantunggut Desert are studied under different micro space scale. According to the average soil moisture content, the variation coefficient and the conclusions of rotated empirical orthogonal function (REOF), It can be divided into four major layers which are 0-40cm, 40-80cm, 80-180cm and 180-300cm for the whole 0-300cm soil profile. The soil moisture variability is strongest in 80-180cm soil layer during the dry summer. The semi-variogram of soil moisture in each soil layers mainly suit spherical model and exponential model. In July, the variable-range (3.237m) and fractal dimension (1.985) in the third layer are the largest. The variability caused by random factors of the total variability of 0% to 25%. In the central region (plot 2m×2m), the second layer have the largest variable-range (1.000m), the fractal dimension of the third layer is the highest (1.883). There is the similar changing tendency and the variability is lower in October. Comprehensive analyzed the growth conditions of the desert shrub and the water consumption characteristics in different periods, the majority of *Haloxylon ammodendron* and other desert shrub roots distributed in the 60-200cm layer (Xu and Li 2009), which is correspondingly the soil moisture content change rapidly in 80-180cm soil layer. That means the vegetation has a significant impact on soil moisture.

The characteristics of soil moisture enrichment in root area of Haloxylon ammodendron
Measured data shows that the soil moisture content in all soil layers is relatively high in the vicinity of the

Haloxylon ammodendron. The measurement points which have great contribution for the soil moisture variability are mostly located near the root area of *Haloxylon ammodendron* by the conclusions of REOF. Figure 2 is vertical variation of average soil moisture content for 3 different plot size around the *Haloxylon ammodendron*. It can be seen the smaller distance from the *Haloxylon ammodendron* roots the higher soil moisture content. Looking the three-dimensional map of soil moisture content, the phenomenon of soil moisture enrichment in the root area of *Haloxylon ammodendron* are better visual displayed (Figure 3), due to its shaped like an island, we can call it "soil wet island" .

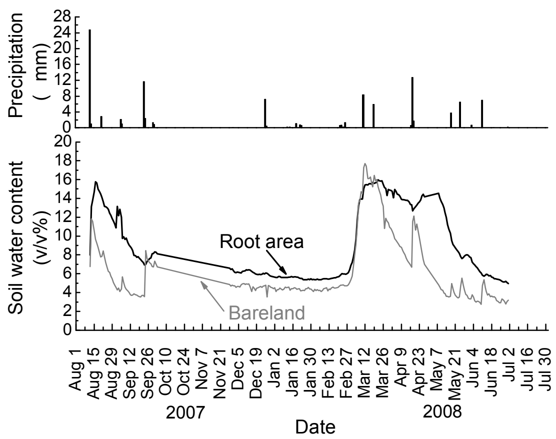

Figure 1. the annual change curve for volumetric soil moisture in the Gurbantunggut desert.

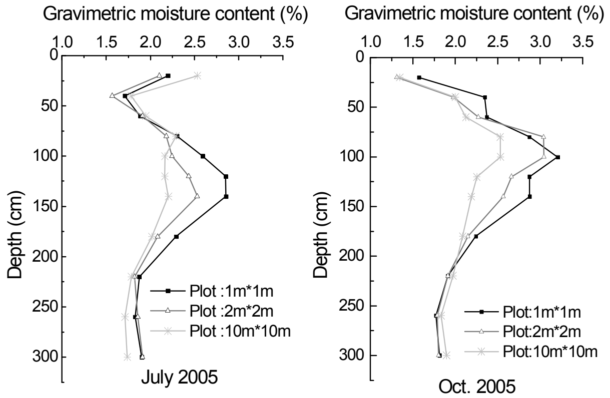

Figure 2. The average moisture content in different layer of soil profile for different root plot size.

The enrichment intensity of soil moisture is different in different seasons. According to the coefficient of variation, the variability of soil water content in July is larger than in October. Otherwise, the increased soil water storage of the 0-300cm soil layer in 0.4m×0.4m plot compared with the 10m×10m plot is more predominance in July. The increased soil water storage is 16% in July and 12.3% in October. In addition, the soil moisture content is almost same between bare land and root area after snow melt completed (Figure 1). It is indicated that the phenomenon of soil moisture enrichment in the root area is not appear in the spring with the most abundant soil water. It is considered that the enrichment of soil moisture in root area is transformed by stem flow infiltration. In the summer, with the strongest evaporation, the soil moisture enrichment in the root area of *Haloxylon ammodendron* has the highest level, but in the spring, with the most abundant soil moisture, the soil moisture enrichment is the least. So, as a result of the interaction between climate and vegetation, *Haloxylon ammodendron* can adapt to the climate change. Before the dry season, the desert shrub can reserved more water in their root area than the surrounding environment. Other parallel experiment results shows that the *Haloxylon ammodendron* is propitious to generating stem flow when an average rainfall more than 0.62mm. In addition, the root area of *Haloxylon ammodendron* have better soil infiltration capacity, the stable infiltration rate declined steeply with the distance increasing from the shrub stem. The radial trend was described by a power-function model. (Tang *et al.* 2009). Changing the crown and stem shape, and the surrounding soil environment, the *Haloxylon ammodendron* can get more water. It is consider that the stem flow and high infiltration capacity of soil in the root area are the main reason of the soil moisture enriched in the root area of *Haloxylon ammodendron*.

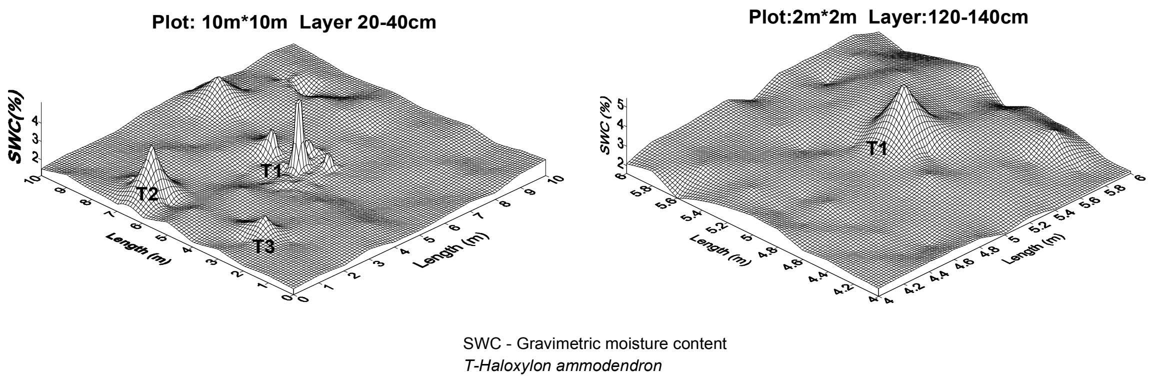

Figure 3. The moisture content map with different root plot size and soil layer.

Conclusions

(1) In the Gurbantunggut Desert, it is widespread phenomenon that soil moisture enrichment in the root area of *Haloxylon ammodendron*. The enrichment intensity is different in different seasons. In July of the summer with the strongest evaporation force, the soil moisture concentrates at the highest level. In April of the spring with the most abundant soil moisture, the enrichment intensity of the soil moisture is at the lowest level. In October of the autumn, the enrichment degree is between spring and summer. The main reason for rainfall infiltrated and enriched in root area of the *Haloxylon ammodendron* is stem flow and high soil infiltration capacity in the root area.

(2) The spring, from March to May, is the most abundant soil moisture period in the Gurbantunggut Desert. Autumn and winter, from the end of September to the end of February, soil moisture is the minimum throughout the year. Spring and summer, growing season of plants, consumed nearly all the soil moisture transformed by the summer rainfall and the winter snow melt water. From spring to autumn, the soil moisture was continuing downward trend except increase pulse after rainfall. The root area has a better water retention property than the bare soil.

(3)According to the average soil moisture, the variation coefficient and the conclusions of rotated empirical orthogonal function (REOF), the soil moisture has the strongest temporal and spatial variability at 80-180cm layer in dry summer, which is correspondingly the majority of *Haloxylon ammodendron* and other desert shrub roots distributed in the 60-200cm layer. So the vegetation has a significant impact on soil moisture. The semi-variogram of soil moisture in each layers mainly suit spherical model and exponential model.

Acknowledgements

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