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Interactive comment on "Analysis of soil moisture condition under different land uses in arid region of Horqin Sandy Land, northern China" *by* C. Niu et al.

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Thank you very much for your constructive comments on our manuscript. The following are responses to your comments:

1. Response to General comments: The manuscript was revised as your constructive comments. The sections were improved. Results were re-arranged.

2. Response to Specific comments:

Q1: Page 1984-line3 and 4. Please be consistent with the order in which you present the 5 different land uses.

A1: The order was consistent with the presentation of five different land uses in the paper.

Q2: SI units need to be used instead of other metric systems such as acres.

A2: The SI units were used in the paper.

The following are the list of Response to Specific comments:

Page 1980, Line 7: "water" and "precipitation" were deleted.

Page 1980, Line 10: "land" was corrected as "soils".

Page 1980, Line 11: The sentence of "The order of soil moisture (from high to low) among different land uses was grassland, cropland, poplar land, inter-dunes and shrub land" was corrected as "The higher soil moisture content among different land uses was exhibited by the grassland, and followed by cropland, poplar land, inter-dunes and shrub land".

Page 1980, Line 15: "difference" was corrected as "differences".

Page 1981, Line 16: "Additional" was corrected as "Additionally"; "Land" was corrected as "land".

Page 1981, Line 17: "process" was changed as "processes".

Page 1981, Line 27: "Land" was corrected as "land".

Page 1982, Line 12-19: The sentences "Horqin Sandy Land is located in the semi-arid environmental region of northern China. Due to the long-term influences of human activities (e.g., extensive firewood consumption, heavy grazing and land reclamation for agriculture) and climate changes (e.g., changes of precipitation regimes and temperature), this region has suffered serious desertification over recent decades, resulting in the scattered tree grassland to be the Horqin sandy grassland (Zuo et al., 2009). To date, most sandy grassland have degenerated into fixed, semi-fixed, semi-mobile and

mobile sandy lands (Liu et al., 2009; Zuo et al., 2009)" were moved to "Study area" in the section of "material and methods".

Page 1982, Line 28: "in Horqin Sandy Land" was deleted.

Page 1983, Line 20: The reference of "(Alamusa et al., 2014)" was added after the sentence of "and drought is serious in the spring".

Page 1983, Line 24-26: Sorry for the ambiguous. Here the sentence “Soil texture consists of aeolian sandy soil, meadow soil and saline soil ” changed to “Soil properties are characterized by their coarse texture and loose structure with high proportion of sand (85–95%) and low organic matter content (0.15–0.5% organic C) (Su et al., 2004). The soils are vulnerable to wind erosion, particularly after cultivation.”, the sentence “Flora mainly consists of Mongolia flora, North China flora and Changbai flora, where the most widely distributed species are plants of Mongolian flora.” changed to “ The most widely distributed sandy vegetation type was Mongolian flora including grasses(e.g. Pennisetum centrasiaticum L., Cleistogenes squarrosa L., Phragmites australis L.), shrubs(e.g. Caragana microphylla kom, Salix gordejevii, Hedysarum fruticosum pall.), and subshrubs (e.g. Artemisia halodendron L., Artermisia frigida L.).”

Page 1984, Line 3-4: The sentence of " including woodland (Poplar), shrub land (Caragana korshinskii kom), grassland (fenced grassland), farmland (maize) and inter-dune lowland, respectively (Fig. 1)" was corrected as" including poplar land (Poplar), grassland (fenced grassland), cropland (maize), inter-dunes and shrub land (Caragana korshinskii kom), respectively (Fig. 1)". Yes, I had showed the cropland and inter-dunes in Figure 1.

Page 1984, Line 8: "6000 acres" was changed as "2.4$\times$107m2".

Page 1984, Line 12-14: The sentences of " Cropland was located in the flat sandy land based on the grassland decades years ago, where the main crop was annual maize with fertilization during growing seasons but without irrigation in the whole seasons"

were changed as "Cropland was located in the flat sandy land with the area of about 5.0$\times$104m2. Cropland was reclaimed from grassland over the past decades. The annual maize was the main crop in this rainfed cropland".

Page 1984, Line 20: "400-600 acres" was changed as "1.6-2.4$\times$106m2".

Page 1984, Line 25-Page 1985, Line 3: The sentences of "Precipitation of June, July and August was higher than the other months in 2002 and 2003, and evaporation was always higher than precipitation each month; moreover, based on the meteorological data recorded in previous years, the annual precipitation from June to August was over 70% of the whole year, and the annual evaporation (2300mm) was 6.6 times of precipitation (Fig. 2)" were moved to the section of "Results". Page 1985, Line 6-10: The sentences of "A sample point was designed at each plot for measuring soil moisture at depth of 0-120 cm and profile was divided into 0-20, 20-40, 40-60, 60-80, 80-100 and 100-120 cm at 20 cm increments and 3 repetitions each layer and soil moisture was measured through drying method" were corrected as "Soil moisture measurements were designed at depth of 0-120 cm at each plot and profile was divided into 0-20, 20-40, 40-60, 60-80, 80-100 and 100-120 cm at 20 cm interval. Soil samples were taken out by a drill and soil moisture was measured gravimetrically (the soil samples were oven at 105 for 12-14 hours based on oven drying method). At each plot, three points were randomly chosen to calculate the average value of soil moisture".

Page 1985 Line 8: The Figure 5 was redrawn.

Page 1985, Line13-15: The sentences of "The groundwater table was at 1.6-3.5m in poplar land, inter-dunes, grassland and cropland based on the flat sandy land in these plots. While, the groundwater table was over 8m in shrub land based on mobile dunes with a slope of 30° approximately" were moved to the section of "Result".

Page 1985, Line 14: All land uses were shown in the Figure 1.

Page 1985, Line 23-28: First, we wanted to figure out how rainfall events affected

infiltration depth, including low rainfall, medium rainfall, high rainfall and extreme-high rainfall. Second, the high and extreme-high rainfall event often occurred in July or August based on the local records of weather station. Third, the larger precipitation often need a long time to runoff and infiltrate. Thus, we chose this different time spells to see infiltration depth in different land uses after different precipitation.

Page 1987: Results were described. The revised results as followed:

3.1 Rainfall and evapotranspiration

Precipitation of June, July and August was higher than the other months in 2002 and 2003, and evapotranspiration was always higher than precipitation for each month. Moreover, according to the meteorological data recorded for each month, the annual precipitation from June to August was over 70% of the whole year, and the annual evapotranspiration (2300 mm) was 6.6 times of precipitation (Fig. 2).

3.2 Comparisons of vertical soil water in different land uses

Significant differences of soil water were observed among three layers in five land uses (Table 2). First, the soil water content of grassland was significantly ($p<0.05$) higher than that of the other land uses in comparison of surface soil water, while, in cropland and poplar land, surface soil water was markedly higher than that of inter-dunes and shrub land. However, there were no considerable differences on surface soil water between inter-dunes and shrub land. Second, soil moisture of grassland was also remarkably higher than the other land uses in root zone, while the shrub land was evidently lower than that in the other land uses. Furthermore, soil water of grassland and inter-dunes were conspicuously higher than the other land uses in deep soil layer, while shrub land was significantly lower than the other land uses patterns in deep soil layer, too.

3.3 Temporal variations of soil water in different land uses

First, the poplar land soil moisture content was increasing after rainfall and was con-

sistent with the temporal variations of rainfall (Fig. 3). Second, grassland soil water variations showed two and three peaks in 2002 and 2003, respectively, and the peaks appeared at May, August and May, July, September, respectively, which was not synchronous with the rainfall temporal variations. Third, cropland showed two peaks at May and September, respectively, which was not concurrent with rainfall in 2002, the only peak appeared at August due to the lack of relevant data in 2003, which was accordant with rainfall. Forth, the inter-dunes soil water variations showed two peaks at the beginning of June and August, which was consistent with rainfall changes; inter-dunes soil moisture showed a decreasing trend in 2003. Moreover, shrub land soil water variations showed single peak both in 2002 and 2003, and appeared in July and June with a value of 2.42 and 2.38 %, respectively, which was consistent with rainfall.

Variations of soil water profiles changed with time and were dependent on rainfall (Fig. 4a–c). Under different land uses, surface soil water varied with the changes of precipitation patterns (Fig. 4a). Surface Soil water of each land use patterns presented higher soil moisture content during the peak of precipitation between July and August. For instance, soil surface water of grassland reached a peak value (14.78 %) in August 2002 when a heavy rainfall event (112.6mm) occurred. However, soil water presented a complicated variation in root zone (Fig. 4b). For example, soil water of five land uses patterns presented an increasing trend in August 2002 due to the heavier rainfall. In the contrary, soil water presented a decreasing trend from June to September when heavier rainfall still continued during this period. There were not obviously changes in deep soil layers under different land uses with the changes of precipitation (Fig. 4c), and deep soil water presented a smooth temporal change during the whole growing season.

Furthermore, in spring (Fig. 5a), soil water in different land uses, except cropland, exhibited a low-high-low trend from 0 to 120 cm and the peak values appeared at 60 cm (grassland), 110 cm (inter-dunes and poplar land) and 40 cm (shrub land) with the value of 13.55, 17.09, 11.17 and 2.80 %, respectively. However, soil moisture in crop-

land showed an increasing trend from 0 to 120 cm. In summer (Fig. 5b), soil moisture in poplar land, grassland and inter-dunes showed a single peak with depth increasing, and the peak value appeared at 90, 90 and 110 cm, respectively. Meanwhile, in cropland and shrub land, soil water exhibited two peaks and the peak values appeared at 60, 110 cm and 20, 110 cm, respectively. In autumn (Fig. 5c), soil moisture of all the land uses were observed similar stable trend with depth increasing, except that soil moisture of grassland showed relatively smooth trend at 0–100 cm and gradually declined from 16.15% at 100 cm to 3.09% at 120 cm.

3.4 Influences of precipitation infiltration on vertical soil water changes for different land uses

Soil water infiltration after four rainfall events was different under five land uses (Table 3). Soil water at 0-20 cm of five land use significantly increased after light (2.6mm) and medium (16.2mm) rainfall. After a heavy rainfall event (40.5 mm), a significant increasing trend in soil water was observed at 0-60 cm. Remarkably, the whole profile (0–120 cm) soil water was supplied by a heavier rainfall event (102.4 mm). Different land uses showed different responds to the four types of rainfall. Under the low rainfall, the higher incremental soil water was exhibited by grassland, and followed by cropland, inter-dunes, shrub land and poplar land at 0-20 cm depth. Similarly, under the medium rainfall, the higher incremental soil water was exhibited by grassland (with the value by 5.08%), and followed by cropland, inter-dunes, poplar land and shrub land at 0-20 cm. Moreover, under the heavy rainfall (40.5 mm), the highest incremental soil water at 0-60 cm was exhibited by grassland, and followed by cropland, poplar land, inter-dunes and shrub land. Furthermore, under the extreme heavy rainfall (102.4 mm), the highest incremental soil water at 0–120 cm was grassland (with the value by 18.25%), and followed by cropland, poplar land, inter-dunes and shrub land.

Page 1990, Line 7-10:

“This is because the “dry” sequence (the term dry sequence is defined as a succes-

sion of several consecutive days without rain preceded and followed by days with rain) appeared (Fu et al., 2003), although several small rain events occurred in July 2002 and 2003, they did not interrupt the dry trend.” changed to “This is because the “dry” sequence (In arid land, the soil moisture content often reached a highest value after a heavier rain, and when the rain had stopped for a couple of days, the soil moisture content decreased sharply duo to evapotranspiration, absorbed by roots or runoff etc. While several small rain events occurred, but the soil moisture content did not increase, it kept decreasing in some land uses. Then we called the trend of not interrupted by small rain “dry” sequence) appeared (Fu et al., 2003), although several small rain events occurred in July 2002 and 2003, they did not interrupt the dry trend.”

Page 1991, line 16-17: Sorry, it’s not called the regional differences. Therefore, here “A possible explanation is that the regional differences (Gómez-Plaza et al., 2000). The differences in topography, soils, vegetation and land uses resulted in the variability of soil moisture (Fu et al., 2003).” changed to “Because most of the time soil moisture is controlled by factors such as soil texture, vegetation, aspect of the hillslope or local topography, and sometimes in semiarid land, it seems that there are other factors, such as topographical and vegetation presence, with a major influence on soil water content (Gómez-Plaza et al., 2000). Therefore, the differences of soil moisture variations between these two areas might due to the different soil texture, topography and vegetation cover. ”

Page 1994, line 1: Here “In the semi-arid and arid land, precipitation regimes have influenced by climate changes (Parry et al., 2007). ” changed to “Climate change affects the hydrological cycle (Parry et al., 2007) and is likely to reduce summer precipitation over the central parts of arid and semi-arid Asia.”

Page 1994, line 7-8: Sorry, I will add the results of this paper in this paragraph. Here this paragraph “Due to cropland could induce severer soil erosion and land degradation, keeping implementation of artificial forest. . .. . .In the light of high soil moisture maintained in grassland and inter-dunes, herbaceous plant is likely to be an adaptive

and stable vegetation type under this environmental condition." changed to "Because cropland could induce severer soil erosion and land degradation, other land uses in terms of artificial forest and shrub (e.g. poplar and C. korshinskii kom in our site) and natural rehabilitation (e.g. fenced grassland in our site) have been suggested to plant and protect by fence (Zhang et al., 2012). In addition, soil moisture of deep layer in shrub land was significantly lower than that in the other land uses (Table 2), soil moisture would decline in C. korshinskii kom shrub land for the reason soil water could not get the supplement from the deep soil water resulting from C. korshinskii kom had deep and enormous roots for water uptake (She et al., 2013). Moreover, surface soil water of poplar land was significantly ($P< 0.001$) lower than that in grassland(Table 2), and water consumption of poplar was higher than grassland vegetation (Kang et al., 2008), therefore, surface soil layer could be dry and deteriorate due to precipitation interruption and deep-root water uptake (Wang et al., 2013). Consequently, this would result in competitive disadvantage of deep-rooted trees and shrub. If this situation continued, "low-thin-old-trees" and further degradation might occur (Zhao et al., 2009). In the light of high soil moisture maintained in grassland and inter-dunes, herbaceous plant is likely to be an adaptive and stable vegetation type under this environmental condition." Page 1995, line 6: Yes, you are right. Here "Different land uses was the main reason that contribute to the soil moisture variations." changed to "Different land uses contributed to the soil moisture variations together with rainfall, topography and soil properties. "

Page 1995, Line 12: "difference" changed to "differences"

Page 1995, Line 14: Here, "Meanwhile, the temporal variations of soil moisture profile changed with precipitation; there was a clear lag in response to precipitation for deep layer soil water." changed to "Meanwhile, Soil water profiles under different land uses that changed with precipitation, soil water in surface, and root zone horizons were driest during April to September, and soil water lag was observed in deep soil layer."

Page 1995, line 15: Sorry for the confusion, here "Two types for the seasonal variations of soil moisture profile in five land uses were classified and the stable layer of soil

moisture was found at 80–120 cm." changed to "Vertical soil water profiles exhibited seasonal patterns for different land uses, and the stable layer of soil moisture was found at 80-120 cm."

Page 1995, line 19-20: Sorry, here "Those results give us an insight into land and water management, an irrigation scheme must be worked out to meet water requirement and then increase soil water utilization during the initial growth of crop, which could also decrease severer soil erosion and land degradation." changed to "Those results give us an insight into land and water management, an irrigation scheme must be worked out to meet water requirement based on soil water content and evapotranspiration, and then improve water use efficiency. All of this could also help to control soil erosion and land degradation better."

Page 2002: Sorry for the mistake, all the names of plants were included in the Table 1 and plant names were not abbreviated, e.g., "A. squarrosum" was changed to "Agriophyllum squarrosum".

Page 2009: Sorry for the mistake in the Figure, and the Figure 5 was redrawn.

Interactive comment on Solid Earth Discuss., 7, 1979, 2015.

Figure 5

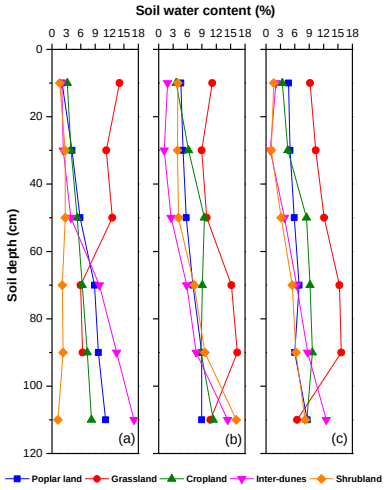

Fig. 1. Seasonal patterns of vertical soil water variations for different land uses: spring (a), summer (b) and autumn (c)