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The Soil Moisture and Grain Size Characteristics of Micro-area: A Case Study of Minqin Oasis – Desert Ecotone

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Abstract To elaborate soil moisture and grain size characteristics of 3 typical micro-areas in Minqin oasis-desert ecotone, samples were collected in runoff generation area and accumulated area using soil profile and multi-point sampling method, for soil moisture and physicochemical property analysis. Research results that (i) water accumulation trace of accumulated area is significant and the vegetation coverage is larger than the runoff generation area. The crust development in clay sand barrier + *Haloxylon ammodendron* forest accumulated is better than runoff generation area, while the situation is contrary in *Nitraria tangutorum* sand dune lowland and clay flat land. (ii) Moisture of accumulated area in fixed *Nitraria tangutorum* sand inter-dune lowland is better than the runoff generation area; the moisture of accumulated area in clay flat land topsoil is significantly better than the runoff generation area, while the topsoil moisture of clay sand barrier + *Haloxylon ammodendron* forest is better in the runoff generation area than in the accumulated area. (iii) Soil moisture of accumulated area in 3 types of micro-areas is in the range of 20 – 40 cm; the fixed *Nitraria tangutorum* sand inter-dune lowland is better than clay flat land and clay sand barrier + *Haloxylon ammodendron* forest, while the lowest moisture of corresponding runoff generation area is basically consistent with the depth. (iv) The topsoil clay and powder content in accumulated area of fixed *Nitraria tangutorum* sand inter-dune lowland is lower than the runoff generation area, while the fine sand content in deep layer of runoff generation area is greater than the accumulated area; soil in two areas of clay flat land mainly consists of coarse and fine sand, and clay particles are better in runoff generation area than in accumulated area. Soil in the clay sand barrier + *Haloxylon ammodendron* forest is mainly coarse sand and the structure is single. In sum, through adjusting allocation of rainfall, micro-areas influence soil moisture and grain size distribution, and further influence spatial - temporal distribution of vegetation in sand micro-areas.

Key words Runoff in micro-areas, Soil grain size, Soil moisture, Oasis-desert ecotone, Minqin

1 Introduction

Moisture is a major restrictive factor influencing many ecological processes in the desert ecosystem[1]. Especially, in arid and semi-arid areas, soil moisture is an extremely essential factor restricting restoration, reconstruction and distribution of vegetation[2,3]. Through adjusting dynamic situation of climate, soil and vegetation system, soil moisture controls distribution pattern of vegetation[4-6] and exerts important influence on physical properties of soil and growth of vegetation[7]. However, in desert areas, it is difficult for groundwater to effectively supply soil moisture in rhizosphere, and thus infiltrated natural rainfall becomes major source of effective soil moisture in this area[8]. Low precipitation, cracked land in sand dunes, clay flat land, and crust of microorganism in topsoil of artificial vegetation sand fixing area reduce the moisture infiltration and lead to water interception[9]. Numerous worm caves, cracks and root holes become seepage passage of runoff water and some runoff water directly enters deep layer soil without entering the crust layer[10]. Runoff water resulted from high precipitation flows through micro-areas and infiltrates to supply soil moisture, so the distribution and growth of vegetation in accumulated area (low-lying land) are significantly better than the runoff generation area. Besides, grain size as a quantitative indicator for classification of deposits and sedimentary rocks can reflect hydrodynamic feature of sedimentation, so it can be used as a basis for analyzing and comparing environment[11]. The mechanical composition of soil grain size is its natural property, coarse and fine feature of soil grain size is closely related to its physiochemical properties and biological properties, and grain size characteristics and mechanical composition can influence corrosion resistance, water retention ability and nutrients of soil, and further influence vegetation types and spatial pattern[12]. In this paper, we made comparative analysis on vegetation, soil moisture and grain size characteristics of different types of sand micro-areas in Minqin oasis-desert ecotone, and elaborated moisture distribution laws and grain size characteristics of topsoil in Minqin oasis-desert ecotone, to provide scientific basis for vegetation restoration in Minqin sand micro-areas and provide theoretical support for ecological control and degraded vegetation restoration in Shiyang River valley.

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2 Materials and methods

2.1 Overview of the study area The study area is situated near Minqin National Station for Desert Steppe Ecosystem Studies (Minqin NSDSES) (102°58′E, 38°34′N)[1]. It belongs to desert-oasis ecotone and there is wide typical micro-areas such as inter-dune lowland, clay sand barrier sand fixing area, clay flat land

and cracked land, etc. The climate in this area is temperate desert climate. Its annual mean temperature is 7.7℃, the lowest temperature is −30.8℃ (on Dec. 27, 1991), the highest temperature is 41℃ (on July 22, 1999); the frost-free period is 172.6 days; the average annual precipitation is 115.9 mm (mainly in June to September); the annual potential evaporation is 2452.7 mm; the average wind velocity is 2.4 m/s with days of strong wind for 26.3 days, days of floating dust for 29.7 days, days of dusts and sands for 37.5 days and days of sandstorm up to 25.0 days; the groundwater level declines continuously from 2.21 m in 1961 to 18.4 m in 2001 at the rate of 0.71 m/a; the regional soil in this area is gray-brown desert soil and intrazonal soil includes three subtypes, namely, saline soil, meadow soil, and aeolian sandy soil. Natural vegetation is manifested in the form of Tamarix ramosissima shrubs and *Nitraria tangutorum* sand dunes, so there is grand landscape of alternate distribution of shrubs and sand dunes. In inter-dune lowland, there are many types of vegetation, such as *Kalidium foliatum*, *Limoniumau-reum*, *Eragrostis pilosa*, *Echinopilon divaricatum*, *Agriopyllum squarrosum*, *Salsola collina*, *Reaumuria soongorice*, *and Artemisia arenaria.*

2.2 Study methods In July 2013, we made a field survey in sandy areas near Minqin NSDSES where micro-areas are widely distributed. We made a record of typical micro-areas (fixed *Nitraria tangutorum* sand inter-dune lowland, clay flat land, clay sand barrier + *Haloxylon ammodendron* forest). In the runoff generation and accumulated area of each type of micro-areas, we set up sample plot (10m x 10m). Using the soil profile and multi-point sampling method, we collected samples of 0 – 10, 10 – 30, 30 – 50, 50 – 70, and 70 – 100 cm soil for making relevant analysis of soil grain size, soil moisture and physiochemical properties. Detailed information about sample plots is listed in Table 1.

Table 1 Basic information about sample plots of 3 types of typical micro-areas

Type of micro-area	Position of sample plot	Type of crust	Crust thickness // mm	Landform characteristics of sample plot	Description of vegetation
Fixed *Nitraria tangutorum* sand inter-dune lowland	Accumulated area	Physical crust	2 – 3	The sample plot is situated in the lowest area of two *Nitraria tangutorum* sand dunes (with slope foot 18 m apart), low runoff generation area 2 – 2.5m, trace of withered thing and accumulated water; the surrounding area is fixed *Nitraria tangutorum* sand dune shrubs	Some *Nitraria tangutorum*, *Eragrostis pilosa*, companied with some *Limoniumau-reum*, *Bassia dasyphylla*, *Salsola collina*, and vegetation coverage is 2.88%
	Runoff generation area	Biological crust accounting for 3/4 and physical crust accounting for 1/4	Biological crust accounting for 4 – 6 and physical crust accounting for 2 – 4	The sample plot is situated in one side fixed *Nitraria tangutorum* sand dune (20x25m, 3.5 m high, and slope close to 15°) slope side near slope foot; the surrounding area is the same as above	The vegetation is mainly *Nitraria tangutorum*, companied with some *Salsola collina*, *Eragrostis pilosa*, and vegetation coverage is 1.64%
Clay flat land	Accumulated area	Physical crust	2 – 4	The sample plot is situated in the closed micro-area bottom surrounded by *Nitraria tangutorum* sand dune, the terrain is flat, about 0.8 m lower than the runoff generation area, and has trace of accumulated water; the surrounding area is semi-fixed *Nitraria tangutorum* sand dune	There is no arbor and the shrub is single plant *Nitraria tangutorum.* Herbs include *Limoniumau-reum*, *Eragrostis pilosa*, *Salsola collina*, and vegetation coverage is 6.20%
	Runoff generation area	Biological crust	8 – 10	The sample plot is situated at slope foot of *Nitraria tangutorum* sand dune, with slope of 2°-6°; from south to north slope, the soil is clay; the surrounding area is the same as above	There is no arbor and shrub; there are few herbs such as *Limoniumau-reum*, *Eragrostis pilosa*, *Bassia dasyphylla*, and vegetation coverage is 0.81%
Clay sand barrier + *Haloxylon ammodendron* forest	Accumulated area	Biological crust	5 – 9	The terrain is low, *Haloxylon ammodendron* degrades seriously, plant is withered, and there are traces of withered thing, rabbit manure, and accumulated water; The surrounding area is 1960s clay sand barrier + *Haloxylon ammodendron* forest	There is no arbor and shrub, the superior herbs are *Eragrostis pilosa accompanied* with *Halogeton glomeratus and Limoniumau-reum*, the vegetation coverage is 3.20%
	Runoff generation area	Biological crust	4 – 6	The sample plot is situated in clay sand barrier + *Haloxylon ammodendron* forest built by Minqin NSDSES, the sand barrier is parallel to contour line, 3 m wide and 3° – 6° slope, the terrain of surrounding area is flat, 1 – 1.5 m higher than accumulated water area. The surrounding area is the same as above	The arbor is *Haloxylon ammodendron* (canopy 18.2%), there is no arbor, and superior herbs include *Bassia dasyphylla* accompanied with Eragrostis pilosa and *Limoniumau-reum*, and the herb coverage is 0.65%

2.3 Lab analysis We adopted Malvern 2000 laser diffraction particle size analyzer to measure particle size of soil, used drying

method (*DHG-9055A Stainless Steel Air Blast Drying Oven*) to measure soil moisture, and made statistical analysis using Excel 2010 and SPSS 17.0.

3 Results and analyses

3.1 Characteristics of soil moisture changes in accumulated area and runoff generation area of micro-areas

3.1.1 Changes of soil moisture in accumulated area and runoff generation area of the same type micro-areas. From Fig. 1, it can be known that soil moisture in accumulated area and runoff generation area firstly increases, then drops, and finally becomes stable with increase of soil depth. Soil moisture of corresponding layer is better in the former than the latter. The corresponding depth of lowest moisture runoff generation area (20 cm) is shallower than accumulated area (35 cm); there is less change in soil moisture in 0 – 20 and 20 – 40 cm accumulated area compared with runoff generation area. On the whole, soil moisture of accumulated area is better than runoff generation area in fixed *Nitraria tangutorum* sand inter-dune lowland. In the runoff generation area (biological crust 3/4, physical crust 1/4, biological crust 4 – 6 mm, physical crust 2 – 4 mm), the soil crust development is better than accumulated area (physical crust 2 – 3 mm). Crust has certain interception and absorption function for natural rainfall. It stores rainfall in topsoil, so it is difficult to supply water for deep soil. In addition, high intensity rainfall will produce surface runoff. Much accumulated water will permeate and thus supply soil moisture in this area. Further, *Nitraria tangutorum* is more in runoff generation area than accumulated area. The distribution of shrub root system in soil also influences level of soil moisture. In all, in the action of various comprehensive factors, moisture in accumulated area is better than runoff generation area.

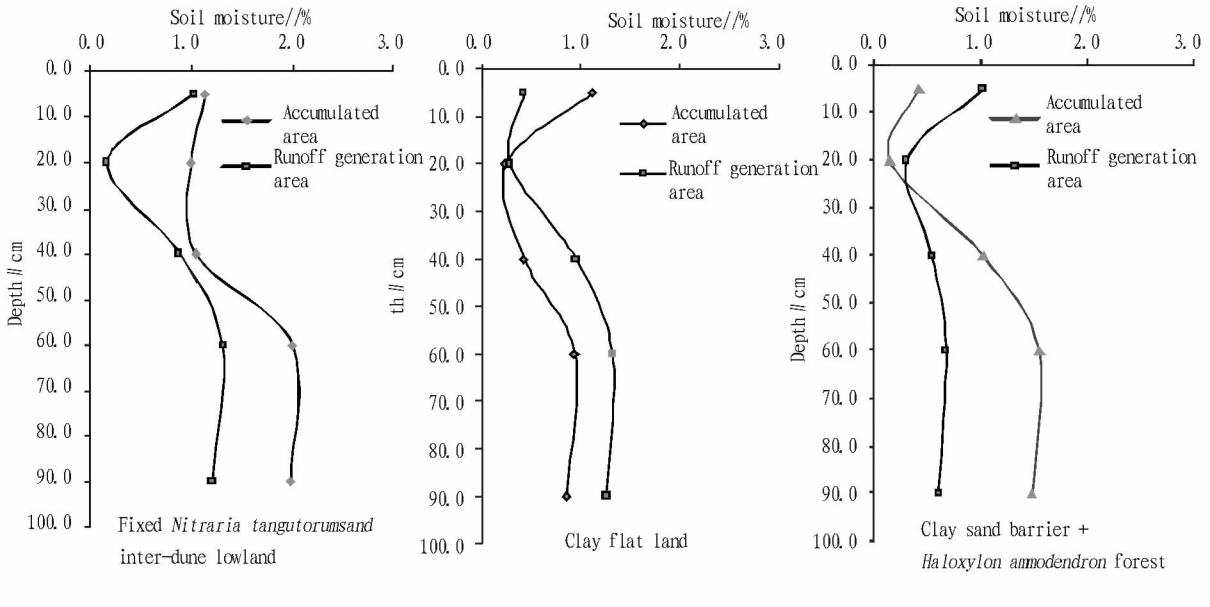

Fig. 1 Soil moisture of accumulated area and runoff generation area in 3 types of micro-areas

Fig. 1 indicates that the soil moisture change is similar to that in fixed *Nitraria tangutorum* sand inter-dune lowland. The 20 cm topsoil moisture is significantly higher in accumulated area than runoff generation area and the corresponding moisture change is great. For soil layer below 20 cm, the moisture is better in runoff generation area than accumulated area. In the runoff generation area, there are herb plants such as *Salsola collina*, *Eragrostis pilosa*, and *Echinopilon divaricatum* (the vegetation coverage is 0.81%) and there is heavy biological crust (8 – 10 mm). In accumulated area, there are *Nitraria tangutorum*, *Eragrostis pilosa*, *Salsola collina*, and *Limoniumau-reum*, and physical crust (2 – 4 mm). Runoff generated from rainfall is gathered in accumulated area, permeates downward and makes 0 – 20 cm topsoil moisture higher than runoff generation area. For accumulated area below 20 cm, soil moisture is influenced from shrub (*Nitraria tangutorum*) root system and other factors, so the moisture of clay flat land is as shown in the figure. This is close to conclusions of Wang Fanglin *et al*[13] and Chang Zhaofeng *et al*[14].

In clay sand barrier + *Haloxylon ammodendron* forest sample plot (see Fig. 1), the soil moisture of 0 – 25 cm topsoil in runoff generation area is better than accumulated area; for the soil below 20 cm, the accumulated area is better than runoff generation area. The lowest soil moisture and depth in accumulated area is lower and shallower than the runoff generation area; for soil layer below 25 cm, the moisture change in runoff generation area is smaller than accumulated area. This is because there is *Haloxylon ammodendron* forest (canopy 18.2%) in sample plot. Under the forest, there is well developed biological crust (4 – 6 mm), which increases resistance of water permeation and sand in deep layer fails to obtain water supply[15]. Root system of *Haloxylon ammodendron* mainly uses 60 – 120 cm soil moisture[14], and it exerts high influence on moisture of deep layer soil in runoff generation area. In

accumulated area without arbor and shrub, biological crust (5 – 9 mm) is well developed, root system of vegetation (coverage 3.20%) such as *Halogeton glomeratus*, *Eragrostis pilosa*, and *Limoniumau-reum* mainly influences 0 – 20 cm soil moisture[14] but has little influence on deep layer soil moisture.

3.1.2 Changes of dynamic characteristics of soil moisture in accumulated area and runoff generation area of different types of micro-areas. Through comparative analysis of fixed *Nitraria tangutorum* sand inter-dune lowland, clay flat land, clay sand barrier + *Haloxylon ammodendron* forest, we know that the soil moisture of fixed *Nitraria tangutorum* sand inter-dune lowland and clay flat land is basically consistent and is 1.5 times the clay sand barrier + *Haloxylon ammodendron* forest. The moisture of three types has declining trend: clay flat land > clay sand barrier + *Haloxylon ammodendron* forest > fixed *Nitraria tangutorum* sand inter-dune lowland. In inland arid and semi-arid areas, solar radiation is strong and sunshine time is long, topsoil moisture of sandy land is low. In the beginning of survey, little rainfall brought better moisture of 0 – 10 cm topsoil. At 20 – 40 cm soil layer, the moisture of soil in accumulated area is the lowest for all three types of micro-areas. The moisture of clay flat land and clay sand barrier + Haloxylon ammodendron forest is the lowest, basically consistent, and obviously lower than the fixed *Nitraria tangutorum* sand inter-dune lowland. The lowest moisture value appearance depth of the first two types is shallower than the latter. Besides, change range of moisture of fixed *Nitraria tangutorum* sand inter-dune lowland and clay flat land is smaller than clay sand barrier + *Haloxylon ammodendron* forest, indicating that restoration of 20 – 40 cm soil moisture in clay sand barrier + *Haloxylon ammodendron* forest micro-areas is better than other two types of micro-areas. In 40 – 70 cm soil, moisture of all three types is increasing and the change range is fixed *Nitraria tangutorum* sand inter-dune lowland > clay flat land > clay sand barrier + *Haloxylon ammodendron* forest. When soil layer is above 70 cm, soil moisture change of three types is gentle and relatively stable.

From Fig. 2, in 0 – 15 cm topsoil, moisture is basically consistent in fixed *Nitraria tangutorum* sand inter-dune lowland and clay sand barrier + *Haloxylon ammodendron* forest, and is about 2 times higher than the clay flat land. In 15 – 20 cm soil layer, the lowest soil moisture appears in fixed *Nitraria tangutorum* sand inter-dune lowland and clay flat land and the former is greater than the latter; in about 25 cm soil layer, the soil moisture of clay sand barrier + *Haloxylon ammodendron* forest is the lowest and the soil moisture is as follows: clay flat land > clay sand barrier + *Haloxylon ammodendron* forest > fixed *Nitraria tangutorum* sand inter-dune lowland. In 25 – 40 cm soil layer, soil moisture of three types is increasing and the level sequence is as follows: fixed *Nitraria tangutorum* sand inter-dune lowland > clay flat land > clay sand barrier + *Haloxylon ammodendron* forest, and the moisture is as follows: clay flat land > fixed *Nitraria tangutorum* sand inter-dune lowland > clay sand barrier + *Haloxylon ammodendron* forest. In 40 – 100 cm soil layer, change of soil moisture is generally gentle, and the soil moisture of clay sand barrier + *Haloxylon ammodendron* forest is significantly lower than fixed *Nitraria tangutorum* sand inter-dune lowland and clay flat land. The clay sand barrier + *Haloxylon ammodendron* forest sample plot is situated in the 1960s *Haloxylon ammodendron* forest, while the *Haloxylon ammodendron* forest root system mainly uses 60 – 120 cm soil moisture[14], which well explains the fact that the soil moisture of clay sand barrier + *Haloxylon ammodendron* forest in 40-100 cm soil layer of runoff generation area is much lower than that of other two micro-areas.

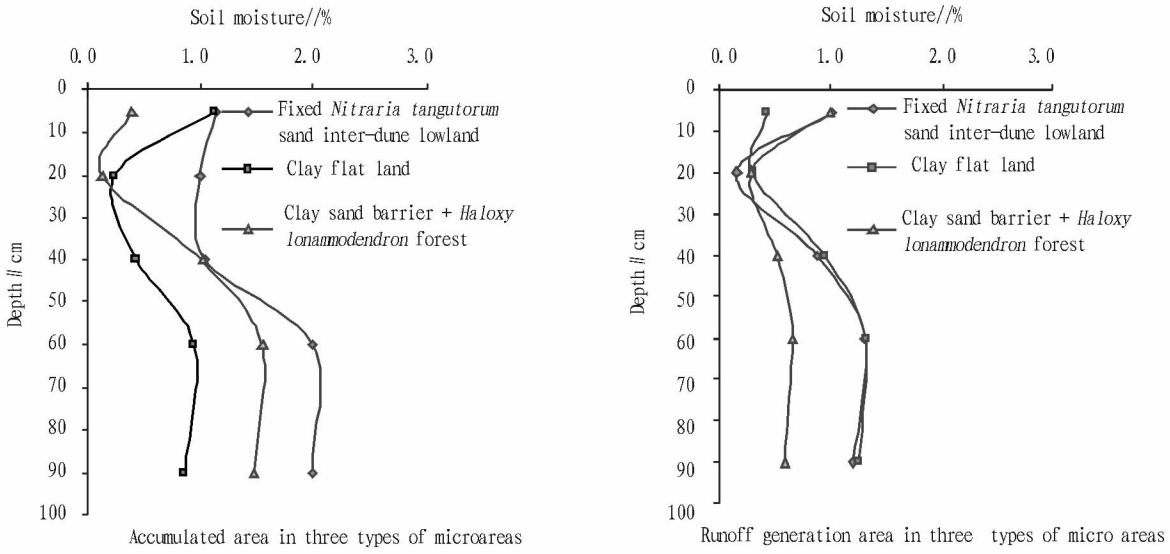

Fig. 2 Soil moisture of accumulated area and runoff generation area in 3 types of micro-areas

3.2 Distribution characteristics of soil grain size in different types of micro-areas From analysis on soil grain composition of three types of micro-areas (as listed in Table 2), we know that for fixed *Nitraria tangutorum* sand inter-dune lowland: fine sand in

accumulated area (46.02% – 68.47%) and runoff generation area (topsoil 17.69%, other layers 57.10% – 79.12%) takes up a larger portion in grain size classification. The sum of coarse and fine sand grains takes up 53.4 – 96.0% in each layer of both areas (except in 0 – 10cm of runoff generation area, the content of coarse and fine sand grain is 20.7%), which is basically consistent with researches of other scholars in inter-dune lowland. In 0 – 10 cm topsoil accumulated area, the content of clay and powder grains (1.42% and 3.83%) is much lower than runoff generation area (17.90% and 61.38%); for 10 – 100 cm soil layer, the situation is opposite. The development of surface crust (biological crust 3/4, physical crust 1/4, biological crust 4 – 6 mm, and physical crust 2 – 4 mm) in runoff generation area is better than accumulated area (physical crust 2 – 3 mm). In the study area, plant growing in sand dunes blocks foreign dust and withered things and forms crust in the action of microorganism decomposition[16]. Formation and existence of biological crust greatly increase content of clay and powder grains in the runoff generation area. In 10 – 50 cm soil layer accumulated area, the content of clay and powder grains is obviously better than runoff generation area, so leaching only occurs in shallow layer of soil (0 – 40 cm)[17]. Short and heavy rainfall in deserts can generate runoff, gather and permeate downward, thus powder and clay grains in topsoil of accumulated area will be leached to deeper layer soil.

Table 2 Characteristics of soil grain size in different sample plots

Type of micro-area		Depth cm	0.01 – 2 μm (clay grain)	2 – 20 μm (powder grain)	20 – 200 μm (fine sand)	200 – 2000 μm (coarse sand)
Fixed *Nitraria tangutorum* sand inter-dune lowland	Accumulated area	0 – 10	1.423 ± 0.023d	3.827 ± 0.030e	63.217 ± 0.765c	31.533 ± 0.812b
		10 – 30	2.123 ± 0.078c	6.916 ± 0.190d	52.640 ± 1.094d	38.320 ± 1.356a
		30 – 50	9.363 ± 0.110a	37.224 ± 0.533a	46.019 ± 0.746e	7.393 ± 1.334c
		50 – 70	6.649 ± 0.026b	26.404 ± 0.105b	66.928 ± 0.116b	0.019 ± 0.016d
		70 – 100	6.581 ± 0.093b	24.941 ± 0.205c	68.467 ± 0.487a	0.011 ± 0.001d
	Runoff generation area	0 – 10	17.896 ± 0.052a	61.383 ± 0.245a	17.690 ± 0.174e	3.031 ± 0.400d
		10 – 30	1.361 ± 0.002d	3.466 ± 0.006c	66.731 ± 0.347c	28.442 ± 0.355b
		30 – 50	1.694 ± 0.030b	4.207 ± 0.070b	57.096 ± 0.824d	37.003 ± 0.922a
		50 – 70	1.538 ± 0.038c	4.044 ± 0.009b	77.123 ± 0.255b	17.295 ± 0.221c
		70 – 100	1.511 ± 0.013c	4.003 ± 0.101b	79.251 ± 0.336a	16.734 ± 0.395c
Clay flat land	Accumulated area	0 – 10	2.932 ± 0.079a	8.110 ± 0.210a	50.620 ± 1.156d	38.338 ± 1.430b
		10 – 30	1.998 ± 0.025b	5.165 ± 0.053b	51.905 ± 0.715d	40.931 ± 0.789a
		30 – 50	1.300 ± 0.007d	3.021 ± 0.013d	59.846 ± 0.338a	35.833 ± 0.357c
		50 – 70	1.610 ± 0.022c	3.913 ± 0.050c	56.211 ± 0.735b	38.266 ± 0.807b
		70 – 100	1.002 ± 0.030e	1.930 ± 0.051e	54.765 ± 0.797c	42.304 ± 0.410a
	Runoff generation area	0 – 10	2.941 ± 0.050a	8.101 ± 0.111a	64.930 ± 0.732a	24.028 ± 0.889d
		10 – 30	2.181 ± 0.062b	5.555 ± 0.142b	48.645 ± 1.323e	43.620 ± 1.525a
		30 – 50	1.415 ± 0.018bc	3.740 ± 0.029e	56.838 ± 0.449d	38.007 ± 0.484b
		50 – 70	2.108 ± 0.049c	5.249 ± 0.115c	61.263 ± 0.626c	31.380 ± 0.783c
		70 – 100	2.003 ± 0.096d	4.979 ± 0.022d	62.785 ± 0.319b	30.234 ± 0.903c
Clay sand barrier + *Haloxylon ammodendron* forest	Accumulated area	0 – 10	2.626 ± 0.150a	7.394 ± 0.410a	35.808 ± 2.045b	54.171 ± 2.603c
		10 – 30	1.009 ± 0.009b	3.835 ± 0.037b	38.066 ± 0.583a	57.090 ± 0.620c
		30 – 50	0.423 ± 0.367c	1.751 ± 1.519c	3.413 ± 1.201c	94.414 ± 3.086b
		50 – 70	0.000 ± 0.000d	0.000 ± 0.000d	1.489 ± 0.076c	98.511 ± 0.076a
		70 – 100	0.000 ± 0.000d	0.000 ± 0.000d	1.381 ± 0.015c	98.619 ± 0.629a
	Runoff generation area	0 – 10	4.909 ± 0.055a	14.055 ± 0.155a	58.734 ± 0.492a	22.303 ± 0.699c
		10 – 30	0.326 ± 0.048b	3.658 ± 0.125b	2.656 ± 0.074c	93.361 ± 0.236b
		30 – 50	0.000 ± 0.000c	0.000 ± 0.000c	3.453 ± 0.105b	96.547 ± 0.105a
		50 – 70	0.000 ± 0.000c	0.000 ± 0.000c	3.348 ± 0.013b	96.652 ± 0.013a
		70 – 100	0.000 ± 0.000c	0.000 ± 0.000c	3.214 ± 3.214b	96.786 ± 96.786a

Note: letters in the table signify Duncan multiple comparative results of soil grain size of different sample plots. Values with letters indicate significant difference ($P < 0.05$).

Soil composition in clay flat land of accumulated area and runoff generation area mainly consists of coarse sand (35.83 – 42.30% and 24.03 – 43.62%), fine sand (50.62 – 59.85% and 48.65 – 64.93%), clay (1.00 – 2.93% and 1.42 – 2.94%), and powder (1.93 – 8.11% and 3.74 – 8.10%). In vertical direction, variation of changes in different levels of grain size is significant ($P < 0.05$). In each corresponding layer, the clay grain content is better in runoff generation than accumulated area. Related researches show that if one-time rainfall exceeds 5 mm, it will generate surface runoff[18]. Since sample plots in accumulated area and runoff generation area are low (the accumulated area is 0.8 m lower than runoff generation area), the development of crust in runoff generation area is better than accumulated area (the runoff generation area is 8 – 10 mm thick biological crust; the accumulated area is 2 – 4 mm physical crust), biological crust absorbs and blocks upstream runoff to reach the accumulated area. Such hydrological process brings fine soil to low-lying land, and increases clay particle of soil to a great extent. More important, such soil and hydrological process greatly promotes growth and development of microorganisms in crust. Thus, this is possibly the

most essential factor for increase of clay particle content[16]. With wash of natural rainfall, fine soil in clay sand barrier is brought to runoff generation area but not reaches the accumulated area. In 10 – 30 cm soil layer, clay and powder particle content in accumulated area is better than runoff generation area, which is connected with permeation and leaching of accumulated water in the micro-area, and also related with *Haloxylon ammodendron* forest blocking dust in air. Various factors determine grain size distribution of accumulated area and runoff generation area in this type of micro-area.

4 Conclusions and discussions

(i) In sand micro-area, rainfall heavier than certain intensity will generate runoff and the runoff will flow to accumulated area and supply part of soil moisture. In three types of micro-areas, vegetation growth (canopy 2.88 – 6.20%) is better in accumulated area than in runoff generation area (canopy 0.65 – 1.64%). This indirectly reflects water catch function of soil moisture in micro-areas. (ii) Variation of soil moisture in accumulated area and runoff generation area of three types of micro-areas reflects water household. The level of soil moisture influences distribution of shallow root and deep root plants and crust, while moisture is also influenced by other factors, such as rainfall, vegetation, crust, and terrain, so the situation is relatively complex. (iii) Topsoil moisture of three types of micro-areas rises due to little rainfall in the early period. As a result, soil moisture in accumulated area and runoff generation area takes onan S form. In 20 – 40 cm soil layer, the lowest soil moisture of fixed *Nitraria tangutorum* sand interdune lowland is significantly higher than that in clay flat land and clay sand barrier + *Haloxylon ammodendron* forest in accumulated area of three types of micro-areas. In runoff generation area, the lowest soil moisture level (0.18% – 0.41%) and depth are basically consistent. The depth of lowest soil moisture in three types of micro-areas is closely related with vegetation growth in accumulated area and runoff generation area, and also connected with specific condition of little rainfall in sand area, and interception and absorption function of dry sand and soil crust reduces supply of rainfall for deep soil[19]. (iv) Soil grain size in three types of micro-areas is influenced by rainfall, vegetation, crust, original soil texture factors, the influence process is relatively complex and to be further studied. Besides, it is necessary to study how to promote sand under crust to change to soil and the laws of water cycle in micro-areas. (v) At present, the understanding of ecological and hydrological process is limited[20], and there are few foreign reports about moisture in sand micro-areas. Through analysis on distribution laws of soil moisture and characteristics of grain size in 3 types of micro-areas, it is hoped to fill the gap of domestic researches in this area and provide scientific basis and theoretic support for vegetation restoration and comprehensive ecological control, as well as restoration of degraded vegetation in micro-areas of northern desert in China.

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