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PRIMARY ANALYSIS ON GROUNDWATER, SOIL MOISTURE AND SALINITY IN FUKANG OASIS OF SOUTHERN JUNGGAR BASIN

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ABSTRACT: Soil salinity is the most important factor affecting vegetation distribution, and the secondary salinization has affected the development of oasis agriculture. In arid areas the spatial variation of soil moisture and salt content is markedly affected by groundwater, irrational irrigation in artificial oasis. By analyzing the soil moisture, salt content and groundwater table in different areas of old oasis, new oasis and desert in Fukang Oasis, it is shown that topography and land use are main factors affecting the change of groundwater table, the redistribution of soil moisture and salt content. When undisturbed by human, the groundwater table rises from mountain to belt of ground water spillage, the groundwater table rises mightily in plain because of the artificial irrigation, and the secondary salinization of soil is very serious. In oasis the groundwater table raises compared with that in the natural desert at the same latitude. In old oasis of upper reaches of river salt has not been concentrated too much in rhizosphere because this area is the belt of groundwater drainage, soil texture is coarse, the groundwater table is very low, and the salt in soil is drained into the groundwater. The new oasis has been the areas of salt accumulation because of the artificial irrigation, the salt content in soil is higher than that in old oasis, so some cultivated fields here had to be thrown out because of the serious secondary salinization.

KEY WORDS: Fukang Oasis; ground water; soil moisture; pH; electrical conductivity; spatial distribution

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1 INTRODUCTION

Soil and landform are the more important environmental factors affecting the distribution of vegetation in a basin when the meteorologic condition is similar on a large scale, especially spatial and temporal variations of the soil moisture and salt content. In arid areas the soil salinization is a major environmental factor affecting the natural vegetation development, and the secondary salinization has become a major environmental factor influencing the oasis agriculture and economy development (YANG, 1995), especially in Junggar and Tarim basins in Xinjiang. There are many factors affecting the formation and evolution of soil salinization and secondary salinization, but the most direct causes are the strong evaporation and transpiration and the groundwater table rising over the critical depth (WANG and SI, 1998; WANG and LI, 1994).

Fukang Oasis lies in the south of Junggar Basin. It is a typical temperate and arid desert climate. In the area, the main soil type is grey desert soil, of which the salinity and alkalinity are usually high. The farmland is irrigated by river water in old oasis in the upper reaches of the rivers and by the groundwater in the new oasis in the lower reaches of the rivers. The clearance of land for agricultural practice and irrigation have increased the recharge to shallow aquifers and resulted in the rising of groundwater tables. Soil salinization has been the major environmental factor affecting the agricultural development in Fukang Oasis. The analysis of spatial variation of soil moisture and salt content in Fukang is useful for learning the spatial characters of soil salinization and its

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formation mechanism, at the same time, it can provide the theoretical bases for deciding irrigation requirement and preventing soil salinization.

2 STUDIED AREA

Fukang Oasis lies in Sangonghe Basin, between Junggar Basin and Tianshan Mountains, (43°45′ – 45°29′N; 87°46′ – 88°44′E). It is the typical continental arid climate region having hot summer and severe winter, the temperature changes sharply in spring and autumn. Precipitation is very low and not evenly distributed in space and time. Because of the difference in topography, the region is characterized by vertical zonal climate. The landform is a long belt and slopes from south to north, including three types of landscape: mountain, oasis and desert. The vegetation of arid desert occupies the most part of the plain. The upper of the plain has more rough slope, the particle component of soil is mainly sand or coarse sand and the soil structure is not in, so it cannot retain much water and nutrient. The down plain has soft slope and soil with thick layer, but there are high concentrations of soluble salt in soil (GAO and ZHAO, 1990; JIANG and LI, 1990). The desert of northern plain is a part of Gurbantunggut Desert. Fukang City lies in the upper part of alluvial fan, it is an old oasis having a long reclamation history. North Fukang Farm is a new oasis which lies in the lower reaches of the basin and has been reclaimed since the 1950s.

3 MATERIALS AND METHODS

3.1 Sampling Methods

Soil samples were collected in oasis and desert, respectively. The location of plots can be seen in Table 1. Two sampling belts are basically parallel, and both were sampled from south to north, from foot of mountain to desert, from high landform to low. Soil samples were taken each 20cm from surface soil to groundwater table. The sampling depths were represented by numbers (1 represents 0 – 20cm; 2, 20 – 40cm; 3, 40 – 60cm ...).

Table 1 The features of sampling plots

Plot No.	Location (desert)	Altitude (m)	Type of community	Plot No.	Location (oasis)	Altitude (m)	Type of community
1	44°08′38″N, 87°50′34″E	531	*Suaeda physophora*	A	44°09′12″N, 88°00′48″E	577	Sunflower field in old oasis
2	44°10′22″N, 87°50′34″E	501	*Haloxylon ammodendron-Suaeda glauca*	B	44°10′32″N, 87°58′34″E	550	Sunflower field in old oasis
3	44°12′34″N, 87°50′32″E	504	*H. ammodendron + Reaunuria*	C	44°13′17″N, 87°58′12″E	496	Cotton field in old oasis
			soongorica-Bassia dasyphylla	D	44°15′43″N, 87°56′53″E	482	Watermelon field in old oasis
4	44°14′38″N, 87°51′08″E	494	*Tamarix spp. -Phragmites communis*	E	44°17′34″N, 87°56′04″E	465	Wheat field in new oasis
5	44°16′40″N, 87°52′32″E	470	*R. soogorica-B. sedoides*	F	44°19′53″N, 87°55′18″E	493	Fallow in new oasis (3 years)
6	44°19′51″N, 87°51′02″E	464	*T. spp. -B. sedoides*	G	44°20′22″N, 87°56′36″E	457	Grape field in new oasis
7	44°21′55″N, 87°55′31″E	450	*Alhagi pseudalhagi-Peganum harmala*	H	44°21′52″N, 87°55′27″E	452	Watermelon field in new oasis
8	44°22′45″N, 87°52′01″E	466	*H. ammodendron-Ceratocarpus arenarius*				

3.2 Analysis Methods

Soil sample was weighted and mixed with distilled water according to the ratio of soil weight to distilled water (1: 5 w/v), which is stirred and allowed to settle over night, then the solution is measured for Electrical Conductivity (EC), pH value. All methods are referred to *The Conventional Measurements of Soil Agricultural Chemical Analysis* (Chinese Soil Science Society, 1983).

4 RESULTS AND ANALYSIS

4.1 Comparison of Ground Water Table and Soil Moisture in Different Areas

4.1.1 Comparison of ground water table

In natural conditions, surface water percolates into deep stratum in almost whole alluvial fan, so groundwater table is very deep in upper alluvial fan. The water tables of No. 1, 2, and 3 plots are below 3m. The edge of fan is the overflow region, its water table is between 1m and 3m, the groundwater table of No. 4 plot is 2.9m. Surface water is disseminated in the plain; the groundwater tables vary in different regions and under different human influences. No. 6 plot lies in the wasteland of North Fukang Farm and No. 7 plot lies in the ecotone between the oasis farmland and sand dune. Influenced by irrigation, the groundwater table in farmland rises over the critical depth, and soil salinization becomes so serious that a large number of fields have to be abandoned. The groundwater table of No. 6 plot is 2.6m and the field cannot be used as crop field because of high salinity in soil. Although the ecotone is adjacent to the sand dune, the groundwater table is up to 4.6m because of the effect of irrigation in nearby farmland, otherwise the groundwater table in desert is very deep (Table 2, Fig. 1).

Table 2 Ground water table in different places

No.	Plot No.	Water table	Plot No.	Water table	Remark
1	1	below 300cm	A	below 300cm	Surface water leakage belt on alluvial fan
2	2	below 300cm	B	260cm	
3	3	below 300cm	C	200cm	
4	4	290cm	D	150cm	Groundwater spillage belt on the edge of fan
5	5	below 300cm	E	240cm	Groundwater dispersion belt in plain
6	6	260cm	F	280cm	
7	7	460cm	G	180cm	
8			H	320cm	
9	8	below 300cm			Sandy desert

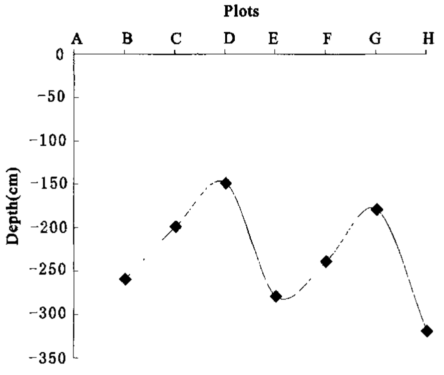

Fig. 1 Changes of ground water table in oasis

The groundwater tables of whole basin have changed much and risen all the time after the reclamation compared with that before, but the change trend from south to north and from the upper reaches of river to the lower is accordant with the trend of natural landform: groundwater table rises from the upper of alluvial fan to the edge, then goes down, it rises again in new oasis farmland affected by irrigation, then disseminates in sand desert.

4.1.2 The vertical change of soil moisture in different areas

The soil is dry in the whole profile in desert, the vertical change of soil moisture is in three types: first is that the water content in soil quickly increases from the surface to the bottom soil, and reaches the maximum at a layer of 40 – 60cm, then the level of water content slightly fluctuates, for example, the curves of water content in soil of No. 5, 3, 2 and 1 plots (Fig. 2) are all close to mean value. All plots lie in the percolation belt of surface water, the groundwater table is very deep and below 3m. The water content of topsoil is very low because of dry air, and the subsoil becomes wet because it is supplied by precipitation and ground water, but the influence of ground water is so small that the water content in soil below the layer of 40 – 60cm changes little and is not obvious in increment.

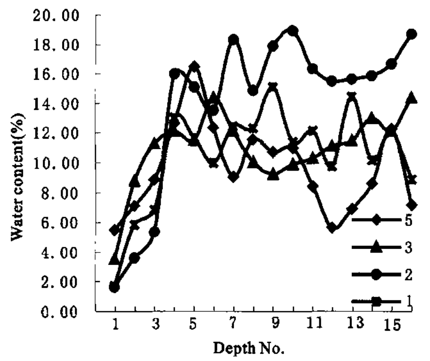

Fig. 2 The first type of the vertical changes of water content in soil in desert(depth unit is 20cm)

Second is that the soil becomes wetter from surface to ground water table, for example the plots of No. 7, 6 and 4(Fig. 3). These three plots lie in groundwater spillage belt, wasteland in new oasis farmland and ecotone, their groundwater tables are near the surface soil. The changes of soil moisture are affected by the spatial and temporal variation of ground water, so the water content in soil is constantly increased in all profiles.

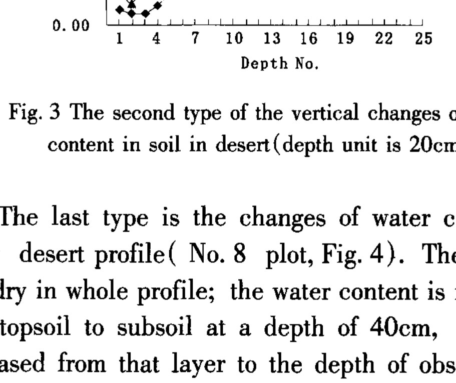

Fig. 3 The second type of the vertical changes of water content in soil in desert(depth unit is 20cm)

The last type is the changes of water content in sandy desert profile(No. 8 plot, Fig. 4). The soil is very dry in whole profile; the water content is increased from topsoil to subsoil at a depth of 40cm, and then decreased from that layer to the depth of observation. The water table is very low in sandy desert; the soil capillarity is very weak because of the sandy texture and loose structure, so changes of water content of soil at a depth of 3m are weakly influenced by groundwater. It becomes a barrier preventing the water evaporation from subsoil after the topsoil water is worked out by solar evaporation, so there is a wet soil layer under the dry sand containing the residual rainfall. Below the wet layer the soil has not any surplus of water and becomes dry again.

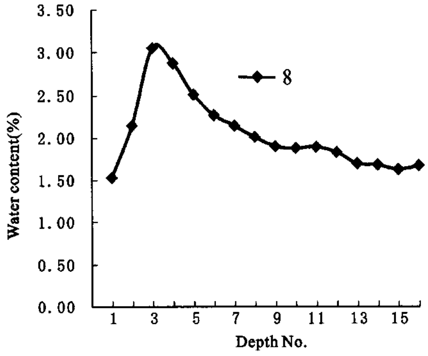

Fig. 4 The third type of the vertical changes of water content in soil in desert (depth unit is 20cm)

The horizontal changes of soil moisture from south to north are similar to the changes of groundwater table because the water content of subsoil is influenced by groundwater, and the deeper soil profile, the more similar the change trends of curves (Fig. 5). It can be seen through analysis of the law of vertical and horizontal water changes that water contents in different soil layers are all influenced by the spatial and temporal variation of groundwater, it is clear that soil water is mainly supplied by groundwater but not rainfall in natural condition in arid areas.

Influenced by irrigation, the soil moisture in oasis changes greatly compared with that in desert. First, the water content in soil is higher than that of the same soil layer in desert plots at the same latitude, especially the water content in topsoil is markedly increased. Second, the curve type changed also, all curves of vertical change of soil water in oasis belong to the second type of desert described above (Fig. 3), that is, the water content in soil is constantly increased from topsoil to the observation depth. Finally, the difference between the topsoil and subsoil is not as remarkable as the plots in desert soil because the topsoil has been wetter after irrigation (Fig. 6).

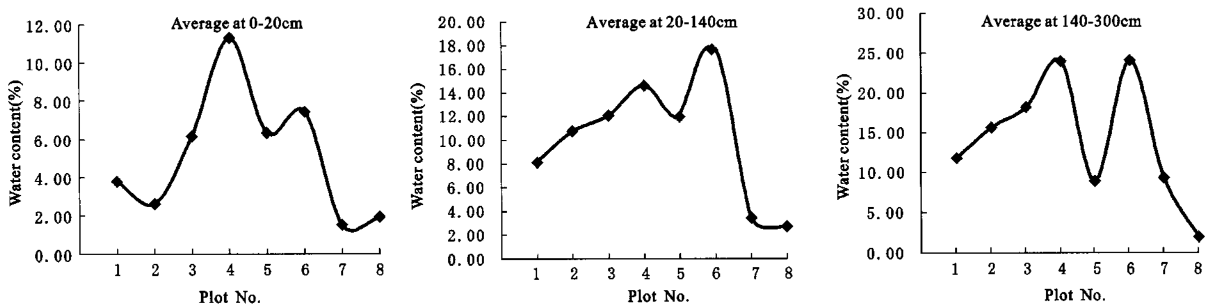

Fig. 5 Horizontal changes of water content from south to north in desert

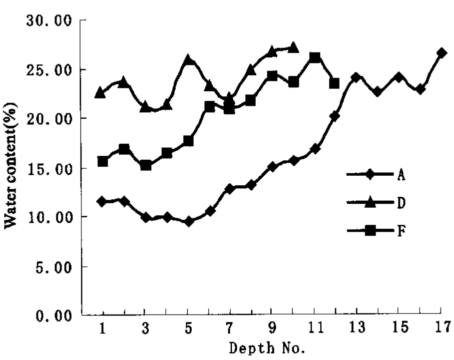

Fig. 6 Vertical changes of water content in oasis (depth unit is 20cm)

The horizontal changes of soil moisture in oasis from south to north are similar to the changes of groundwater table just like the changes of soil moisture in desert. The soil water in oasis is supplied not only by groundwater, but also by irrigation water, and at the same time the groundwater table is affected by irrigation, so the water content in oasis soil is increased in whole profile.

By the analysis of soil moisture changes it can be seen that it is true that soil moisture changes in oasis (artificial oasis) are affected by artificial irrigation.

4.2 Comparison of Soil pH Values in Different Areas

4.2.1 Changes of soil pH values in desert

The soils in desert are all alkaline or slightly alkaline, the absolute range of soil pH is between pH 7.7 and pH 10.0. Variance analysis shows that the difference in soil pH values is not significant between different layers of soil (Table 3), but it is the most significant between different observation plots. The vertical change trends of soil pH values vary in the different

Table 3 Variance analysis of pH between plots and layers in desert

Difference source	SS	df	MS	F-value	Significance
Depth	1.41	7	0.20	1.65	Not significant
Plot	6.07	7	0.87	7.07	Most significant($\alpha = 0.01$)
Error	6.01	49	0.12		
Total	13.49	63			

plots and the variation in soil pH value is great in horizontal direction. The change trend of average soil pH values of whole 0 - 300cm profile from alluvial fan to sand dune is shown in Fig. 7, although soil pH values in different layers are different, their trends are close to the average values.

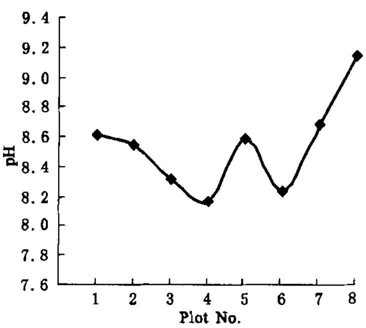

Fig. 7 Changes of average pH value

4. 2. 2 Changes of soil pH in oasis

The difference in soil pH value is significant between plots in oasis. By variance analysis it is shown that the difference in soil pH value is not significant between layers (Table 4). It is clear that the soil pH is affected by irrigation and has changed greatly in all plots of oasis.

Table 4 Variance analysis of pH between plots and layers in oasis

Difference source	SS	df	MS	F-value	Significance
Depth	0.86	5	0.17	2.52	Not significant
Plot	1.81	3	0.60	8.89	Significant($\alpha = 0.05$)
Error	1.02	15	0.07		
Total	3.69	23			

4. 3 Comparison of Soil Salt Content in Different Areas

4. 3. 1 Changes of soil salt content in desert

Soil salt content in desert is high, the electrical conductivity(EC) of soil of all plots is over 0. 1mS/cm, and the total salt content is over 0. 5g/kg, soil salinization is widely distributed in the lower reaches of river. By variance analysis it is shown that soil salt content is different in different plots and layers(Table 5).

Table 5 Variance analysis of EC in desert

Difference source	SS	df	MS	F-value	Significance
Depth	62	7	8.86	3.68	Most significant
Plot	274	7	39.1	16.2	Most significant
Error	118	49	2.41		
Total	454	63			

Average EC in 0 - 300-cm profile rises gradually from south to north and up to the maximum in fallow field of new oasis, but then fall in ecotone and sandy desert (Fig. 8). Salt in sandy soil profile is little accumulated because the capillarity of soil is too weak to carry ground water from deep soil to the surface, and water is mainly moved by gaseous status in topsoil. No much salt will be accumulated in rhizosphere by irrigating saline water, because the sandy soil is charactered by the good infiltration (GU *et al.*, 2000). So it is a good way to increase the vegetation coverage in sandy desert by irrigating drainage water in oasis farmland (JI *et al.*, 2000).

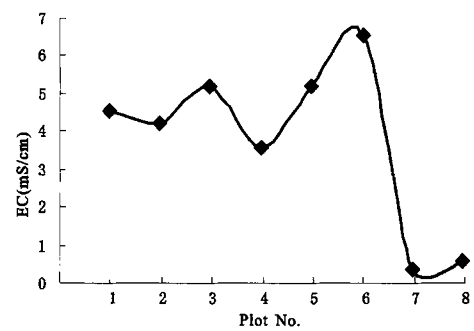

Fig. 8 Changes of average EC in desert

4. 3. 2 Changes of soil salt content in oasis

The salt content in oasis soil is different from that in desert. The salt content of soil in the upper reaches of river, which is salt percolation region, is lower than that in desert, but in the overflow belt of ground water spillage and new oasis, the salt content in soil is higher than that in desert, especially in the fallow field much salt is concentrated. Variance analysis (Table 6) shows that the difference in dissolved salt content is ultimately notable between different plots but it is not significant between different layers, because both irrigation and groundwater influence the salt content in soil in oasis farmland. The salt content in soil constantly rises from surface to subsoil in oasis cultivation fields, there is no much salt concentrated in rhizosphere and the plant growth would be not hurt. In fallow soil salt is much more concentrated on surface of land, then rises con-

Table 6 Variance analysis of EC in oasis

Difference source	SS	df	MS	F-value	Significance
Depth	1.5	5	0.3	0.35	Not significant
Plot	125	3	41.6	48.2	Most significant
Error	13	15	0.86		
Total	139	23			

stantly and up to the maximum content in the layer of 60 - 80cm, from that layer the salt content falls near to salt content in the ground water. In wasteland the groundwater table is very high and the soil exposes to solar radiation directly, the salt is carried from deep soil layers to the surface by rising groundwater and accumulated in the rhizosphere and surface soil.

5 CONCLUSSIONS

(1) When undisturbed by human beings, the ground water table rises from mountain to belt of ground water spillage, the groundwater table rises mightily in plain because of the artificial irrigation, and the secondary salinization of soil is very serious.

(2) The water content is very low in topsoil. There are three types of water content in soil in desert, which are affected by the change of groundwater table.

(3) The pH value and salt content in soil with natural vegetation are high, the change of pH and electrical conductivity from south to north (from mountain to desert) is affected by groundwater, too.

(4) There are remarkable differences in water content, pH and electrical conductivity between oasis and land with natural vegetation. The groundwater table rises in oasis because of irrigation, and the water content in topsoil increases too, and the types of water content change in oasis are different from those in natural conditions.

(5) In old oasis of upper reaches of river the salt content in soil is not very high in whole profile because this area is the leakage belt of groundwater. The soil texture is coarse, and the groundwater table is very low, therefore, the area is the belt of salt washing and the soil salt is washed into the ground water.

(6) The new oasis has been the area of salt accumulation because of artificial irrigation. The irrigation water is mostly from ground water, so the soil salt content is higher than that in old oasis. Much farmland had to be abandoned because of the serious secondary salinization.

(7) In natural status the salinization phenomena is very similar, but it is aggravated by irrational irrigation in oasis. Our research effort on the spatial variation of groundwater, soil moisture and salt content is directed at the causes of salinization and offering gist for the water resource utilization. So the spatial and temporal variation of the groundwater table is the main mechanism for the formation and development of soil salinization and secondary salinization.

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