Difference in Undulation Causes Different Moisture Regime, Thermal Environment and Evaporation in Saline Soil

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Abstract: The study was carried out in order to investigate the change in soil temperature and evaporation under undulation surface conditions (C+ site, 50cm high from the reference level C site, and C- site, 50cm low from reference level C site, respectively) which were treated for determine the reason for the difference in the soil temperature and the evaporation in saline soil. The results indicated the fluctuation of soil temperature was more dynamic in surface than the deeper layers and decreased with depths for all of treatments. The average difference in maximum surface temperature was 5.4℃ lower in the C- site than the C site, 1.0℃ higher in the C+ site than in the C site during a day (28 August 2009). The average evaporation was 41.4% to 94.1% higher in the C- site than in the C site and the C+ site during observations (from 27 August to 4 September, 2009). The average thermal conductivity was 0.29 W/m℃ larger in the C- site than the C site, 0.02 W/m℃ lower in the C+ site than in the C site. Analysis of variation showed there was significant ($p<0.05$) difference in soil temperature and evaporation due to the difference in soil water content affected by the undulation soil surface. [Nature and Science 2010; 8(10):112-116]. (ISSN: 1545-0740).

Key words: saline soil, soil temperature, evaporation, undulation surface, arid area.

1. Introduction

Soil moisture content and soil temperature are major factors affecting the growth of the plant, and also are important aspects of soil environment. The changes in soil water content and temperature in soil are influenced by lots of environmental factors. The soil surface configuration is one of major factors influencing soil environment (Hanks, 1961; Potter, 1985; Kaspar, 1990).

In irrigated agricultural land, the uneven distribution of soil surface is mostly affected by human activities, i.e. irrigation and tillage. The tillage has been considered as a prevalent method of planting for agricultural land. The tillage can not only create a suitable environment for growth of crops but also affect the soil water loss (Jalota SK, 1990) and some soil properties (Hay, 1978; Johnson, 1985; Potter, 1985; Zhai, 1990; Arshad, 1996) by changing the shape of soil surface.

In arid irrigated region, soil evaporation not only takes water loss may but also induce secondary salinization in soil, such as Hetao Irrigation District, is located in the arid area, there is a contradiction of water supply and demand due to a more rapid development of local economy and water intake reduced from Yellow River in recent years. (i.e., the water intake was 5.1 billion m^3 in 1999, 4.8 billion m^3 in 2000, and 4.6 billion m^3 in 2001).

To avoid the salt accumulation in soil, the leaching irrigation (named locally autumn irrigation) needs to be implemented at October every year. Now, the district is facing the water resources shortage and the soil salinization problems. For sustained development of irrigated agriculture, some studies (Shi HB, Akae T, et al. 2002; Akae T, et al. 2004, 2008; Li RP, Shi HB, et al. 2009) have concerned with these aspects in district.

However, at the present, the effect of soil surface shape on soil properties (i.e. soil temperature, soil water content and soil thermal properties) still is scarce in the district. Because these aspects are important parts of soil environment, and influence greatly the growth and yield of crops. On the other hand, taking into account the effect of soil surface shape on soil temperature, soil moisture content and knowing of the evaporation from saline soils also are helpful to effective utilization of water resources and salt management in the district.

In the aspects, the objectives of this study are (1) to measure and compare the change in soil temperature and evaporation in saline soil under the undulation surface and (2) to evaluate the influence of undulation surface on soil temperature and evaporation.

2. Description of studied area and processes

This study was conducted on an undulation salt-affected soil (C-, C, and C+ sites) at Hetao Irrigation District (40º19′~41º18′ N, 106º20~109º19′ E) (Figure 1) situated in the middle of Yellow River Basin (96º~119ºE, 32º~ 42ºN, 1,900 km from west to east, 1,100 km from north to south and with area of 752,443 km2). It is a typical arid region with continental monsoon climate. The district is 250 km long from west to east and 40~50 km wide from north to south.

The average annual precipitation is about 136.8~213.5 mm; average annual potential evaporation is about 1993~2372 mm; mean annual temperature is 6.3~7.7 ℃. The precipitation is mainly occurred between May and September in every year.

The studied site C (named as capital letters) has been built since 1996. The experimental treatments were constructed by artificial excavation of 50cm (C-) lower than reference level; and pile up of 50cm (C+) higher than reference level, and reference level, respectively. Each experimental plot is 10m long by 10m wide. The soil textures are typical silt clay loam (Akae, T., et al. 2008).

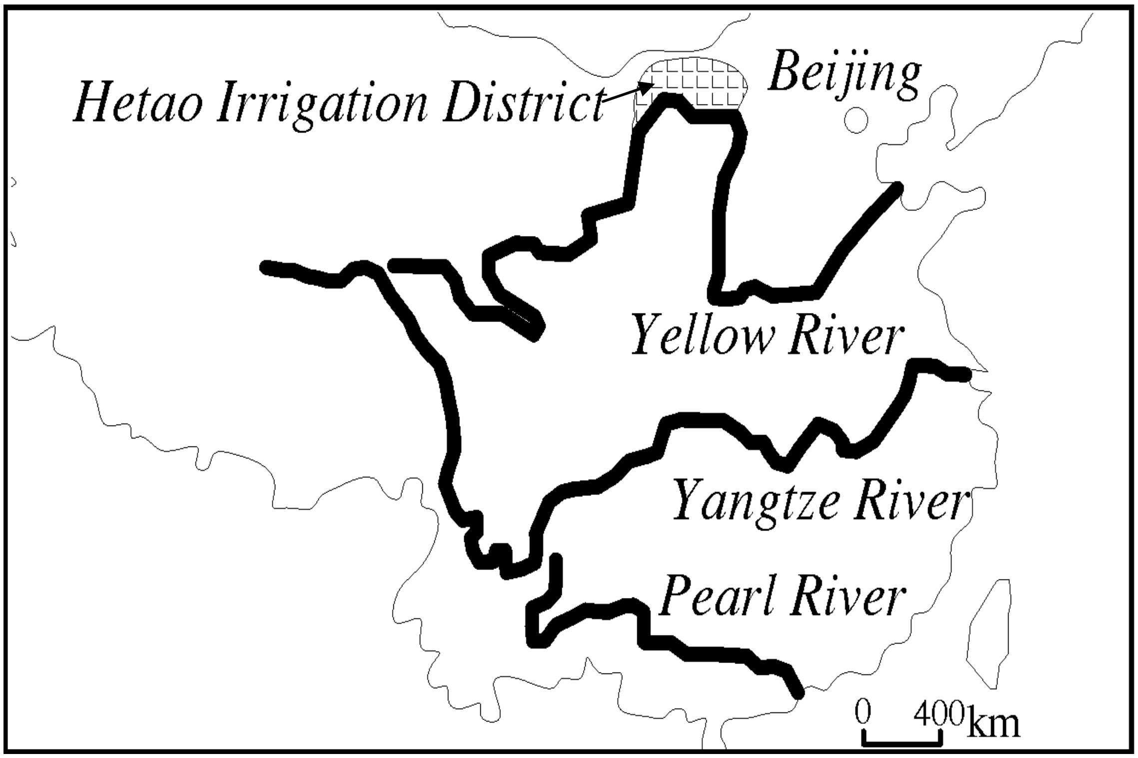

Figure 1. Schematic location of Hetao Irrigation District in China

Soil water contents were determined at 5-, 10-, 15-, 20-, 30-, 40-, and 50-cm depths by the gravimetric method. Simultaneity, the disturbed soil samples were sampled at the corresponding depths for measurement of electrical conductivity (EC) and pH of soil.

The $EC_{1:5}$ and pH of soil were determined by using portable electrical conductivity meter (B-173; Horiba Ltd.) and portable compact pH meter (B-212; Horiba Ltd.), respectively. The measured solution was consisted of air-dried soil/distilled water ratio of 1:5

Hourly soil temperature was recorded at the 10s interval by temperature data logger (TR-52S; T&D Co.) consisted of the thermo recorder and the cable. The cables were inserted carefully into the soil at 2.5-, 5-, 10-, 20-, and 30-cm depths in C-, C, and C+ sites, respectively. Surface temperature was also measured by embedding the cables close to soil surface. And then these thermo recorders were packed together using the steel case embedded in soil. Soil thermal properties (thermal conductivity and thermal diffusivity) were measured by using thermal properties analyzer (Decagon KD2; Meiwa Ltd.) at depths of 2.5, 5, 10, 20, 30, 40, and 50cm in C-, C, and C+ sites, respectively.

Soil evaporation was determined by the weighing method using the precision of 0.0001kg with electronic balance based on the micro-lysimeters. The micro-lysimeters were consisted of two steel cylinders, one cylinder was used to take soil and the anther cylinder was used to protect outer soil from disturbance.

The data were evaluated by applying the Analysis of Variance (AOV) and Least Significant Difference (LSD) methods (Gomez, Kwanchai A. 1984).

3. Result Analysis

3.1 Soil water content and $EC_{1:5}$ in soil

The measured soil water content and electrical conductivity ($EC_{1:5}$) are shown in Figure 2.

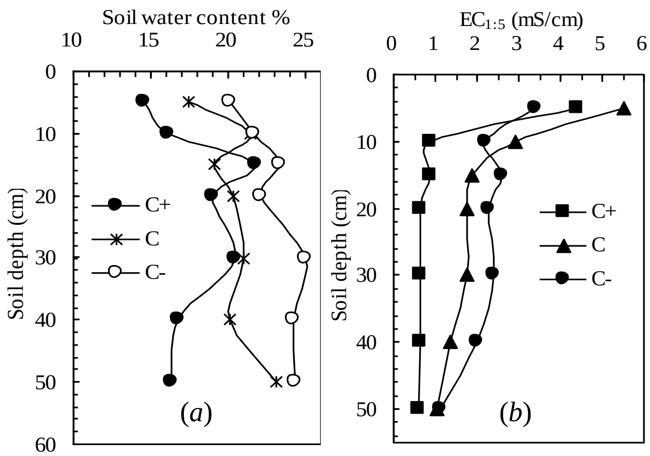

Figure 2. Soil water content (*a*) and $EC_{1:5}$ (*b*) at soil profiles in C+, C, and C- site (27 August, 2009).

The soil water content at profiles was higher in the C- site than in the C site and the C+ site, and was in the order of C->C>C+ expect for at 15-cm depth. The average soil water content (from 5-cm to 50-cm depth) was 22.9% in C-site, 20.3% in C site, and 17.8% in C+ site (Figure 2*a*). The average difference in soil water content was 12.8% higher for C- site than C site, 12.3% lower for C+ site than the C site. The analysis of variance (AOV) showed the higher significant ($p=0.00092<0.01$) differences in soil water content among treatments (C-, C, and C+ sites) (Table 1).

The $EC_{1:5}$ of soil are given in Figure 2*b*. From the surface to 10-cm depth, the $EC_{1:5}$ were decreased abruptly and then the $EC_{1:5}$ values gradually decreased with depths. The $EC_{1:5}$ values at 5-cm depth was 5.5mS/cm in C site, 4.4mS/cm in C+ site, and 3.4mS/cm in C- site. The average $EC_{1:5}$ of soil from 10-cm to 50-cm depth in C- site was 2.11mS/cm, 1.78mS/cm in C site and 0.71mS/cm in C+ site. It is obvious that salt accumulation has occurred in soil surface and sub-surface layers. Again, the salt content of soil in lower soil surface (C-site) was larger than the reference (C site) and the higher soil surface (C+ site), which may be attributed to the C- site collecting the runoff with salt from surrounding soil.

3.2 Soil temperature in saline soil

Figure 3 shows the hourly soil temperatures under undulation of surface C-, C, and C+ sites.

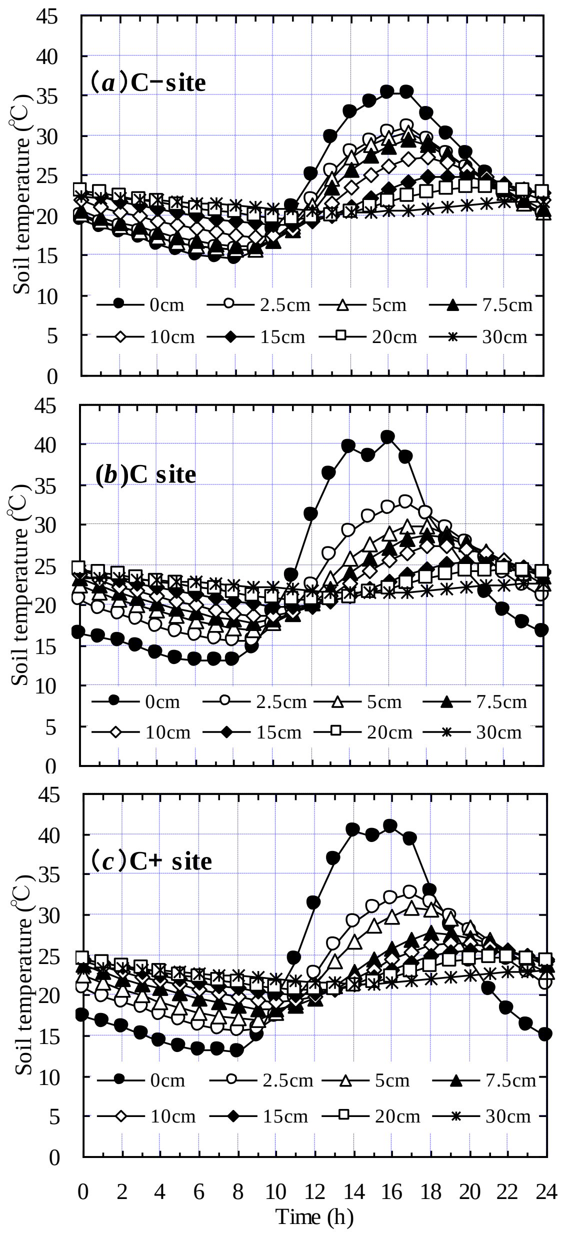

Figure 3. Mean hourly soil temperature in C- (*a*), C (b), and C+ (*c*) sites (28 August, 2009).

Figure 3 shows the change in mean hourly soil temperature at eight soil depths in C- site (Figure 3*a*), C site (Figure 3*b*), and C+ site (Figure 3*c*), respectively during a day. The fluctuation of soil temperature was more dynamic in surface than the deeper layers. In the morning about 8:00 A.M., the soil surface temperature reached the lowest and the minimum soil temperature was increased with depth increasing. After sunrise, the soil temperature increased gradually and the soil surface temperature reached the highest at about 4:00P.M., and the maximum temperature of soil decreased with soil depth increasing. For example, the minimum soil temperature of C site (Figure 3*b*) the soil surface was 13.1℃ at 8:00A.M, the 2.5-cm depth was 15.7℃at 9:00A.M, 5-cm depth was 17.0℃, 7.5-cm depth was 17.9℃, the 10-cm depth was 18.7℃ at 10:00 A.M, the 15-cm depth was 19.8℃at 11:00 A.M, the 20-cm depth was 20.7℃at 12:00 A.M, and. the 30-cm depth was 21.5℃at 3:00 P.M. The difference in average maximum surface temperature was 5.4 ℃ lower in C- site than C site, 1.0℃ higher in C+ site than in C site during a day (28 August 2009). And then the AOV showed that the significant ($p=0.035<0.05$) differences in average soil temperature among treatments (Table 1).

3.3 Soil thermal properties in saline soil

The mean soil thermal conductivity and diffusivity measured are presented in Table 1. The average thermal conductivity was 0.29 W/m℃ larger in the C- site than the C site, 0.02 W/m℃ lower in the C+ site than in the C site. The reasons for the difference in thermal conductivity among these treatments are attributed to the soil water content influence. The average thermal diffusivity was 0.23 mm^2/s for the C-site, 0.19mm^2/s for both of the C+ site and C site and then there was not significant difference ($p=0.181>0.05$) in average thermal diffusivity among the three sites.

3.4 Soil evaporation in saline soil

Daily soil evaporation from the three sites is presented in Figure 4. During the observation period, the evaporation for C- site was always larger than for the C site and C+ site and was higher in C site than in C+ site (Figure 2*a*). The average difference in evaporation was 0.29mm/d between C- site and C site, 0.19mm/d between C site and C+ site, and 0.48 mm/d between C- site and C+ site.

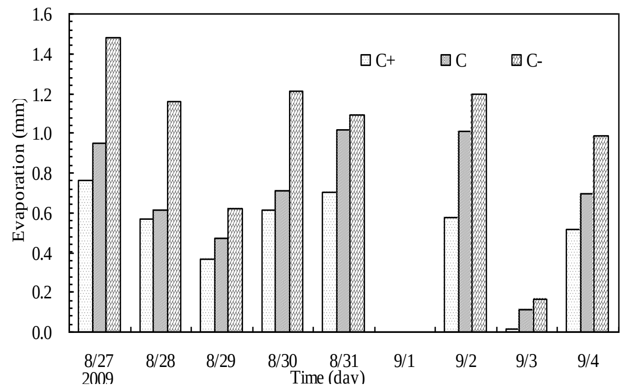

Figure 4. Daily evaporation in C+, C, and C- sites during observation

The average evaporation was 0.99mm/d in C-site, 0.70mm/d in the C site, and 0.51mm/d in the C+ site, respectively. Again, the mean evaporation was 41.4% to 94.1% higher in the C- site than in the C site and the C+ site during observations (from 27 August to 4 September, 2009). The analysis of the influence of undulation soil surface on evaporation was done by using the AOV method in Table 2. The results of the AOV showed significant ($p=0.0263<0.05$) difference in evaporation, the evaporation of C- site was significant large among these treatments. The difference in soil evaporation among treatments was induced greatly by the difference in soil water content due to the effect of undulation soil surface ($p=0.00092<0.001$).

Table 1 Mean thermal properties, soil temperature and water content in three sites

Site	Thermal conductivity (W/m℃)	Thermal diffusivity (mm^2/s)	Soil temperature (℃)	Soil water content (kg/kg)
C−	1.07±0.08&	0.23±0.02	20.16±0.75	0.23±0.02
C+	0.76±0.26	0.19±0.04	23.66±3.44	0.17±0.02
C	0.78±0.27	0.19±0.06	22.13±1.88	0.21±0.02
p-value	$p=0.028<0.05$	$p=0.181>0.05$	$p=0.00001<0.01$	$p=0.0009<0.01$

&Mean± standard deviation, from 2.5-cm to 50-cm depth, $N=7$

4. Conclusions

The results obtained from the study concluded that the soil water content and $EC_{1:5}$ values were higher in the concave soil surface (C- site) and the trend of salt accumulation has occurred in soil surface during observations. The average evaporation was 41.4% to 94.1% higher for C- site than for C site and C+ site during observations. The fluctuation of soil temperature was more dynamic in soil surface than in deeper layers. The average thermal conductivity was 0.29 W/m℃ larger in the C- site than the C site, 0.02 W/m℃ lower in the C+ site than in the C site. The analysis of variance showed that the effect of undulation soil surface was significant ($p<0.05$) difference in soil temperature and evaporation due to the effect of undulation surface on the distribution of soil water content at profiles.

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