Research on soil desalinization through platform fields and by irrigation using sea-ice water

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Abstract

Saline soil damage is a major limiting factor of high-yield agriculture in the coastal soil-salinization region in China. Results indicate that the comprehensive land use pattern of elevated-platform-fields and shallow-pond reduced the saline soil damage effectively. The desalinization efficiency is up to 52% of original salt content by used of building platform-fields in Huanghua city of Hebei province in China. The desalinization efficiency was also notable for using sea-ice water to irrigate during the crop growth stages. For example, irrigating by using low mineral sea-ice water in July had a better desalinization efficiency, with a total desalinization volume up to 2.7 g per one cubic meter sample area, with the relative quantity was 6.2 g as compared to the un-elevated barren-salinized land and 3.8 g as compared to the non-irrigation elevated-platform fields, respectively, which means the desalinization efficiency extent of the elevated-platform fields (compared to un-elevated barren-salinization land) was better than the desalinization efficiency by sea-ice water irrigation (compared to non-irrigated areas). This research impacts the establishment of desalinization systems using elevated-platform fields and shallow pond pattern in coastal barren-salinization land area, but also the safe application of sea-ice water to the agriculture irrigation.

Key Words

Elevated-platform fields, shallow ponds.

Introduction

There are large amounts of saline land in China. Statistics show that China's salinization soil area is 2.7×10^5 km^2, of which 6.67×10^4 km^2, or 7% of the total, is used for agricultural (Wang 2007). Shi Yuan-Chun proposed the integrated management of saline soil to achieve regional resistance to drought and flood and the elimination of soil salinization through regulation and management of regional water movement (Shi *et al* 1986; Marlet 2009). An effective way is to establish a "water net" and "tube-well project" for reducing groundwater levels, so that the arable layer is kept away from the high saline groundwater, and eventually achieving the salt reduction and water sustainable use; but one of its disadvantages is the drainage requires a long-term, sustained process, and the latter part of pipe network maintenance is costly. The precipitation in the coastal area is concentrated in the summer, and it is very easy to form flood conditions, since drainage is slowed. It can cause salt accumulation that can move upward, thus affecting land quality. Its second drawback is that large amounts of fresh water are required for irrigation to achieve soil desalinization, thus this method is not suitable for areas that have shortages of freshwater. In China, we faced a new challenge regarding saline soil reclamation by using limited freshwater resources (Huang 2003).

Saline soil injury is mainly found in the coastal region, whether the land-use patterns are reasonable directly affects the soil salinity change and re-distribution of soil salinity, furthermore affecting the grain yield and land security. Mao-Tuo village in Dongying City, Shandong Province began to carry out soil improvement projects since 1996, due to aggressively using the Yellow River to elute soil salt. Almost all the lands in the village had completed engineering transformations by 2007. The former salty fields now can be planted grapes, melons, fruits and other high-income economic crops, and per hectare income increased to 90,000 yuan. The successful experience of Dongying has great guiding significance(Zhang 2008), showing the distinct advantages of integrated land use management patterns of elevated-platform fields and shallow ponds: 1) the post-maintenance costs are very low, and 2) significantly reduced risk of floods. This guarantees the security of arable layer. After successful research and development of desalination of sea-ice water resources (Shi *et al.* 2002 ; Gu *et al.* 2003), experts Shi Pei-Jun and Gu Wei provided valuable water resources for the soil salty-eluting in coastal region. The comprehensive land use improvement models of elevated-platform fields and the sea-ice water resources utilization make it possible for barren-soil transformation, which is impossible in the past. Xiao Jian-guo (Xiao *et al*. 2003) and other experts' studies have shown that field crops can grow normally or even increase production under the condition of 3g/L the

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sea-ice water irrigation, but the experiments should based on light-saline soil conditions (salt content of 1g/L or so). However, their studies don't give enough considerations to the regional suitability of agricultural irrigation (Wang 2003) and researches on the long-term sustainable safely utilization of sea-ice water resources are also insufficient. The comprehensive land use improvement models of elevated-platform fields and sea-ice water resources utilization will be quite different from the traditional land use patterns. Therefore, the comprehensive desalinization land use models of elevated-platform fields and sea-ice water resources irrigation is of great significance to the coastal heavy-salinity land area.

Methods

Profiles of the experimental area

Huanghua, a coastal city of Hebei province, is located at latitude 38° 09' N~ 38° 39' N longitude 117° 05' E~ 117° 49' E, with a total area of 2.25 km^2. Its soil salt is mainly from sea water, with the deposition of sea saline sludge occurring directly from exposure to the coastal saline waters, its soil surface has a high salt accumulation and soil profile also is very highly saline. Therefore, the experimental area is a heavy-saline wasteland, which has been excluded from many soil improvement programs in the past. The sample elevated-platform fields were built in 2007.

Experimental Designs and Methods

For better reference, we chose three comparable sample area, they are: the Mao Tuo Village of Dongying city, the 11th Sino-Czech farm in Huanghua city, the Sino-Czech celebrity golf court of Huanghua city, based on salt analysis of earth samples in these three sample areas. As to the elevated-platform fields of the 11th Sino-Czech farm in Huanghua city, during the seeding growth period of May 21 and grain-filling stage of July 16, applied 3 g/L and 1.6 g/L sea-ice water to irrigate respectively, two irrigation volume are both 375 m^3/km^2. Soil solution extracted by using 5:1 water:soil ratio, using the DDBJ-350-type conductivity device to measure the conductivity of extracted liquid, finally obtained soil salinity through the standard curve. Through the comparative analysis of soil-salinity volume changes between the elevated-platform fields and waste salt-land, can get their differences soil salt-drainage contribution volume.

Results

Distribution of soil salinity of elevated-platform fields in different regions

Surface soil salinity of waste salt-land in Huanghua and Mao Tuo are both very high, soil salinity shows a decrease trend with the increase of soil layer depth, and the downward trend gradually slowed down; on the contrary, the surface soil salinity of the elevated-platform fields in two regions showed a lower soil salinity, and with the increase in soil depth, its soil salinity increased slightly. A significant phenomenon can be found that, surface soil salinity of waste salt-land (0-20 cm depth) in is 15.2 g/kg, while the corresponding salinity of the elevated-platform fields layer of Mao Tuo is just 1.7 g/kg, which means the desalination efficiency of the elevated-platform fields extends to 89% in Mao Tuo. There is a similar phenomenon in Huanghua sample area: surface soil salinity of waste salt-land (0-20 cm depth) in Huanghua is 5.9 g/kg, while the corresponding salinity of the elevated-platform fields layer of Huang Hua is only 3.1 g/kg, the desalination efficiency of the elevated-platform fields in Huanghua ups to 47%. As to the Sino-Czech celebrity golf court of Huanghua, after two years' mechanical soil-elevated and greening projects, the soil salinity of the plow layer dropped to 2g/kg below which soil-saline injury is almost eliminated.

Distribution soil salinity of the elevated-platform fields under different irrigation treatment

Figure 1 (a) shows that soil salinity of 0 ~ 10cm soil layer of Huanghua increased to 14 g/kg in July 22, 2009. Find the waste salt-land surface experienced a strong salt accumulation process along with the weather change, but the 20 ~ 100cm soil layer is within 4 ~ 6 g/kg mainly controlled by ground water, so the change is relatively stable. Figure 1 (b) shows the salinity change rules of non-irrigation treatment elevated-platform fields, soil salinity showed mainly a gradual increasing trend from 0 cm to 120cm soil layer, while a reducing trend from 120 cm to 240 cm, this is because the salt migrated from the soil surface to deep soil layer; at the same time, the shallow groundwater transported salt upward due to its inner capillary tension, these two processes join together to form the phenomenon of salt accumulation (Shang1985; Li 1988). Associated with Figure 1 (a), can find the non-irrigation treatment elevated-platform fields is not like the waste salt-land, which has a strong surface salt accumulation process. Figure 1 (c) shows that: salinity of 0 ~ 100cm soil layer under 3 g/L sea-ice water irrigation treatment increased slightly from May 21 to June 23, basically being maintained within 4-6 g/kg. After the 1.6 g/L of the sea ice water irrigation treatment in July 16, it shows a significant desalinization process, until July 22, the soil salt-accumulation layer appears in

180cm depth, compared with Figure 1 (b) shows that the accumulation layer of soil salinity has moved down by 60 cm, which shows a notable desalinization efficiency under sea-ice water irrigation treatment.

Desalinization efficiency of elevated-platform fields compared with the waste salt-land
Salt of the surface soil(0-40cm) in waste salt-land increased by 5,721 g/m^3 within two-months of June and July, while the corresponding Salt volume in non-irrigated elevated-platform fields decreased by 923 g/m^3, the relative desalinization is 5,211 g/m^3 as to the waste salt-land; the desalinization of 1.6 g/L sea ice water irrigation treatment in elevated-platform fields is 899 g/m^3, with a relative desalinization of 5,186 g/m^3. Analysis shows the significant desalinization efficiency of the elevated-platform fields.

Analysis of salt-drainage contribution difference between the elevated-platform fields and sea-ice water irrigation
In Figure 2 (g) and (h), notice that: salt-drainage effect of 1.6 g/L sea-ice irrigation treatment can reaches depth of 120cm, while the salt-drainage effect of elevated-platform fields treatment reaches depth of 2 m or so; as to the salt-drainage contribution rate comparison of these two treatments is also interesting: within 0-100cm soil layers, the elevated-platform fields treatment is much notable than the 1.6 g/L sea-salt irrigation treatment, while salt-drainage effect of the latter is more notable when below 100 cm. Comparing (g) and (h) of Figure 2: salt-drainage contribution rate of the elevated-platform fields treatment is better than sea-ice irrigation treatment, the 3 g/L sea-ice irrigation plays a negative role to the salt-drainage from May to June, which strengthening the risk of soil-saline injury, while in the period of July and August, the sea-ice irrigation treatment achieved a better salt-drainage effect.

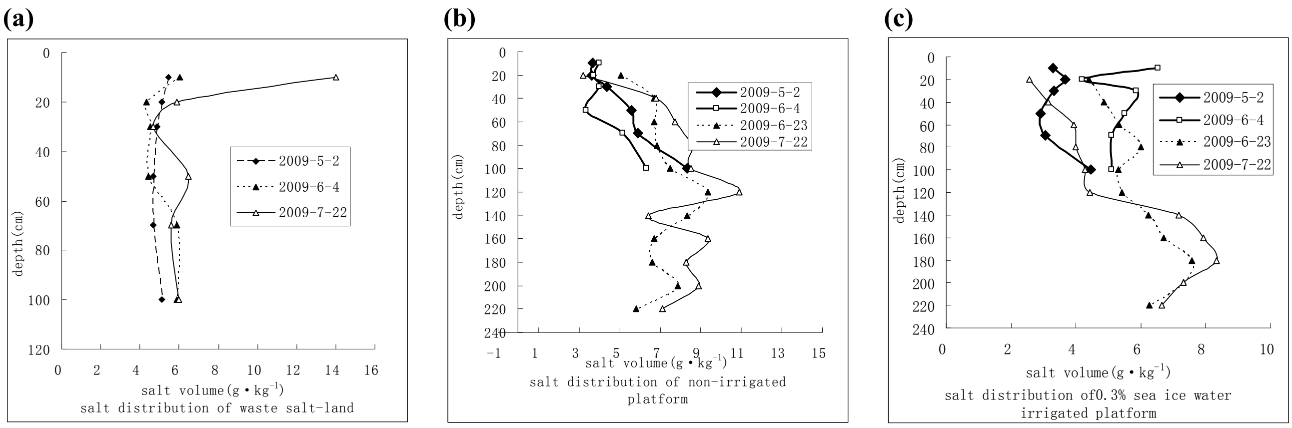

Figure 1. Platform soil layer salt distribute regulation under different irrigation (2009).

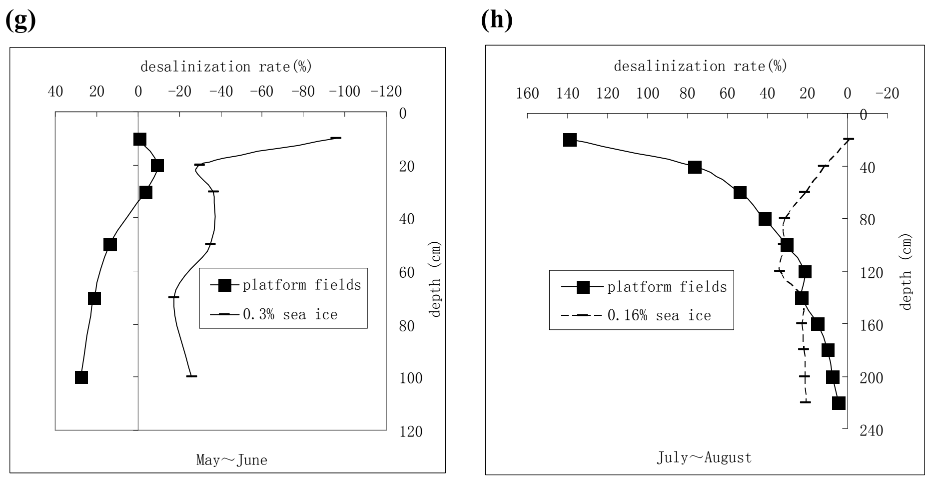

Figure 2. Desalination analysis of platform fields and sea-ice irrigation (2009).

Discussion

Salinity of the waste salt-land in Huanghua and Mao Tuo both show a decreasing trend with the increase of soil layer depth, and the downward trend gradually decreased; on the contrary, salinity of the elevated-platform fields in two regions show a increasing trend with the increase of soil layer depth. This conclusion shows the desalinization efficiency of the elevated-platform fields is remarkable especially to the surface arable soil layer which effectively decreases the saline injury risk to vegetation.

Soil salinity of non-irrigation treatment shows little changes with depth increase, in which the total salt of 0-60 cm soil layer decreased slightly, salt of below 60 cm shows a slight increase, among one unit area of 0-220 cm depth soil, its total body salt increased 748 g/m^3. It indicates that the 2 m elevated-platform fields can effectively prevent or mitigate the salt increase phenomenon, if coupled with effective irrigation; it can distinctly achieve the goal of decrease salinity or salt-drainage. While on the contrary, the usage of 3 g/L sea-ice water for irrigation in heavy-saline area may cause salt accumulation and even the destruction of soil texture. Although many studies have shown that irrigation using 3g/L sea-ice water may play a role of increasing production, but due to the salt-transport laws of soil itself, irrigation during May or June using 3 g/L sea-ice water can cause a higher risk of salt accumulation injury.

The 2 meter elevated-platform fields shows a notable desalination efficiency in heavy-saline soil area, salt-drainage contribution rate of the elevated-platform fields ups to 138.9% during July and August, using 1.6 g/L sea-ice water for irrigation can help to promote the salt-drainage effect. So in heavy-saline soil area, salt-drainage contribution rate of the elevated-platform fields is far greater than the sea-ice water irrigation treatment. In other words, relying on the desalination efficiency of elevated-platform fields and combining with the local seasonal precipitation patterns, can rational allocate different concentrations of sea-ice water to agriculture irrigation in different periods: in the spring, the primarily purpose of using sea-ice water for irrigation is to promote the growth of the seedling, while during the summer, the purpose of using sea-ice water for irrigation is mainly for salt-drainage. Considering these differences at different periods, we need to make sure that the saline-soil improvement by salt-drainage methods in coastal barren-saline region is sustainable and will lead to good land use.

References

Gu W, Gu S, Shi P, Liu Y, Cui W (2003) The temporal change characteristics of sea ice thickness and regeneration period of sea ice in Liao-Dong Gulf. *Resources Science* **25**,24-32.

Huang R (1985) 'Water Resources and Soil Improvement of China Saline-Alkali Wasteland' (China Agricultural University Press).

Li T, Zheng Y, Wang Y (1983) 'Soil Geography, Version 2' (Higher Education Press).

Li Y (1988) Discussion on critical depth of groundwater and its determinative method. *Journal of Xi'an College of Geology* **10,** 100-105.

Marlet S, Bouksila F, Bahri A (2009) Water and salt balance at irrigation scheme scale a comprehensive approach for salinity assessment in a Saharan oasis. *Agricultural Water Management* **961**, 311–1322

Shang D (1985) Calculating of groundwater critical depth in North of NingXia Area. *Ground Water* **4**, 10-12.

Shi P, Ha S, Yuan Y, Zhou J, Xie F (2002) The desalinization of Bohai Sea Ice and its use value as fresh water resource. *Journal of Natural Resources* **17**, 353-359.

Shi Y, Li, Y (1986) Progress in the study of water and salinity transport in soils. Arid Zone Research **4**, 38-44.

Wang J (2007) 'China Geography Tutorial'. (Higher Education Press).

Wang J, Su Y, Liu M (2003)The exploitation and utilization of the ice in Bohai sea used as freshwater resources and region sustainable development. *Journal of Beijing Normal University (Social Science)* **87**, 85-72.

Xiao J, Xie L, Wang J, Feng G, Shi S (2003) Effects of the Bohai Sea ice melt-water on wheat growth and soil salt accumulation. *Resources Science* **25**, 37-43.

Zhang X (2008) Exploration on agriculture-fishery development mode in saline-alkali soil of Yellow River Delta. *Journal of Hebei Agricultural Sciences* **12,** 116- 117.