INFLUENCE OF ATMOSPHERIC PRECIPITATION ON SOIL LEACHING AND DESALINIZATION IN SEMI-HUMID REGION

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Abstract
The average annual precipitation on the North China Plain is 500–600 mm, 74 % of which occurs during the rainy season (July and August) producing soil leaching and desalinization. The effect of root zone desalinization is commonly seen after rainfall events in excess of 25 mm. The key to enhancing the effect of salt leaching and desalinization lies in setting up drainage facilities and water management. Until 1975, the five tributary systems of Haihe River had their own drainage outlets to drain flood, excessive rainwater and saline groundwater. Together with the water drainage a lot of salt drained into the sea. Large-scale exploitation and utilization of groundwater for irrigation started in the 1970's. Groundwater extraction for irrigation has resulted in a reduction in both the groundwater table and phreatic water evaporation. Rainfall infiltration has increased and the effect of salt leaching and desalinization by rainfall had been enhanced and the quality of the groundwater has improved due to recharge by rainwater and the water diverted from the Yellow River. The secondary salinization in irrigation districts of North China Plain had been controlled, and a large area of saline-alkali land has become productive farmland.

Additional Keywords: salt accumulation, Haihe River, well irrigation, drainage

Characteristics of atmospheric precipitation

The North China Plain located to the north of the Yellow River belongs to seasonal arid semi-humid continental monsoon climate region. The average annual precipitation is 500 – 600 mm, but the precipitation is unreliable. As the influenced by the periodic variation of west wind circulation in middle and high latitudes, the variation of precipitation between years is very unstable. There were often occurred consecutive wet years and dry years or wet year and dry year appeared alternatively.

Under the influence of monsoon climate, the precipitation is concentrated in summer, mainly in July and August. The summer precipitation in Nanpi County accounted for 74 % of the whole year, in spring and autumn were 11 % and 13%, in winter was only 2%. This rainfall pattern creates the following characteristics: drought in spring and waterlogging in summer, then drought in autumn and winter again, drought and waterlogging occur alternatively. In dry spring and autumn, salt accumulates in soil, and in wet summer, desalinization of soil occurs.

According to the analysis of meteorological data, the ratio between annual evaporation and precipitation is 3.1 – 3.9.The maximum evaporation appears in spring and winter, which may be 16 – 38 times the precipitation. This is the climate condition for salt accumulation in soil in the plain area where the groundwater is shallow and highly mineralized.

After the atmospheric precipitation has reached the ground, 8 % of the annual precipitation has transformed into surface runoff, 20.6 % has turned into shallow groundwater, and 71.4 % into soil water of the aeration zone. The evaporation of soil and phreatic water has caused salt accumulation in soil, and soil leaching and desalinization occurred due to rainfall infiltration.

Atmospheric precipitation and regional movement of water and salt

According to the analysis of the amounts of water and salt flowing from the mountain area to the plain area and these from the plain area into the sea in 1966 – 1981 in Beijing, Tainjin and Hebei Province in the Haihe River basin, the precipitation was 580 mm in rainy season in 1977, it was a wet year, the plain area was in a desalinization state. The precipitation in the plain area in this year was more than that in the mountain area, the precipitation in rainy season achieved 900 mm in the eastern part of the plain area. That is the cause why the amounts of water and salt flowing into the sea were so big. The precipitation was 444 and 555 mm in rainy season of 1966 and 1967 respectively, they were a normal year and sub-wet year, that the plain area was situated in salt balance state. The precipitation was 319 mm and 286 mm in rainy season of 1968 and 1972 respectively, they were extraordinary dry years, the plain area in a salt accumulation state (Table 1).

Relationship between precipitation and soil desalinization in rainy season

In semi-humid region, the rainfall is concentrated in rainy season, generally accounting for 74 % of the annual precipitation, it is the season of soil desalinization. The amount of precipitation in rainy season plays a decisive role in soil desalinization. According to the observation at fixed points in 1980 – 1989 in Nanpi Pilot Area, in the five

years (1981, 1984, 1985, 1987 and 1988) the precipitation in July and August were all more than 300 mm (332.4 – 509.4), these years were normal or sub-wet years, the root zone soil was desalted, with a ratio of desalinization of 4 - 16.4%. The other five years (1980, 1982, 1983, 1986 and 1989) were sub-dry or dry years, the precipitation in July and August were about 200 mm (150.6 – 256.4 mm). In 3 years of them salt accumulation occurred with a ratio of salt accumulation of 3.1 – 42 %. The relationship between the precipitation in rainy season and soil desalinization is shown in Figure 1.

Relationship between a rainfall and soil desalinization

For the occurrence of the effect of soil leaching by rainfall infiltration requires corresponding precipitation, which can dissolve the salt in soil to enable the salt move to subsoil or drainage ditches. Therefore, the soil leaching by rainwater is not only related to the precipitation in rainy season, but also influenced by the amount of a rainfall. The precipitation in July and August in 1986 was only 212.4 mm, it was a sub-dry year, but after the rainy season the soil desalinization occurred with a ratio of desalinization of 27.5 – 35.3 %. The cause was that a rainfall exceeding 35 mm occurred for four

Table 1. Input of water and salt from mountain area into plain area and output from plain area into the sea in Beijing, Tainjin, Hebei Province of Haihe River Basin 1966 – 1981

years	1977	1969	1976	1966	1968	1972
water year	wet	sub-wet	sub-wet	normal	ex. dry	ex. dry
annual precipitation mm	691	622	599	470	426	382
precipitation in July-Sept.(mm)	580	560	555	444	319	286
P %	20	23	30	46	90	93
water billion m^3						
Flow out from mountain area	14.8	10.4	12.3	9.2	10.2	7.7
From plain area to sea	17.0	7.3	5.6	5.3	1.0	0.6
(+), (--)	-2.2	+3.1	+6.7	+3.9	+9.2	+7.1
salt 10000 t						
Flow out from mountain area	438	411	387	315	417	302
From plain area to sea	1205	406	392	224	112	62
(+), (--)	-767	+5	-5	+91	+305	+240

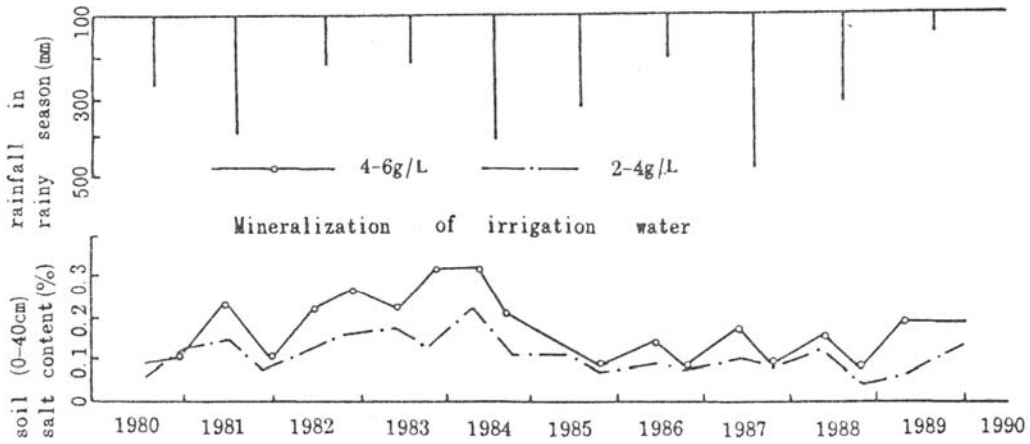

Figure 1. Relationship between precipitation in rainy season and soil desalinization

times (10th July, 20th July, 24th July and 10th August), and the intervals of a rainfall were rather even, so that the soil leaching and desalinization obvious. The amount of a rainfall reflects the intensity of rainfall, the influenced degree and depth of desalinization. In general, soil desalinization may occur while a rainfall was more than 25 mm. The more amount the rainfall at a time, the higher the ratio of desalinization, the deeper the depth of desalinization. The amount of a rainfall were 25 mm, 76 mm and 149 mm, the ratios of desalinization of 0 – 20 cm soil were 34 %, 59 % and 74 % respectively. For the former two times their acted depth was 40 cm, for the last time (149 mm) it reached 1 m. The relationship between a rainfall and soil desalinization ratio is shown in Figure 2.

Setting up drainage facilities and strengthening water management to enhance soil leaching and desalinization by rainwater

At the end of 1950's, China developed irrigation on a large scale to eliminate threaten to agricultural production by drought. Owing to no available drainage facilities the groundwater table had risen, and serious secondary salinization of large area had been caused. The area of saline-alkali land had increased to 4.13 million hm^2 in 1961 from 2.23 million hm^2 in 1958 in the Huang-Huai-Hai Plain. Since 1964, main drainage rivers had been excavated and dredged in Haihe River Plain year by year to centralized resolve the outlets for flood, excessive rainwater and saline groundwater in the plain area. Up to 1975, the five river systems of the Haihe River all have had their new outlets to the sea. The flood and excessive rainwater discharge capacity had increased by sixfold and fourford as compared with that in 1964, and the drainage systems to drain off flood and excessive rainwater in North China Plain completed. A great amount of salt had been drained off together with the water drainage. In rainy season of six wet years (1974,1975,1976,1977,1984, 1987) in Nanpi Pilot Area water and salt had been drained into the sea through the Dalongdian General Main Drainage Ditch. The total amount of salt drained off per unit area was 1395.3 t / km^2. The equation of relationship between Y (salt drained / km^2) and X (rainfall mm) was as follows: $Y=64.9317-0.5233X-0.0017X^2$ (Figure 3). In 1980, not only the secondary salinization of soil in irrigation districts had been controlled, but also the original saline-alkali land of large area had been reclaimed. One half of the saline-alkali land that is 2.07 million hm^2 had turned into nice farmland as compared with 1961 in the Huang-Huai-Hai Plain.

For the purpose of drought combat and irrigation, groundwater had been exploited and utilized on a large scale since 1970's. The shallow brackish and semi – saline groundwater had been also utilized for well irrigation, which had caused the increase of the crops yield was 1 – 2 times than that of non-irrigated crops. Under the condition of drainage, the salt

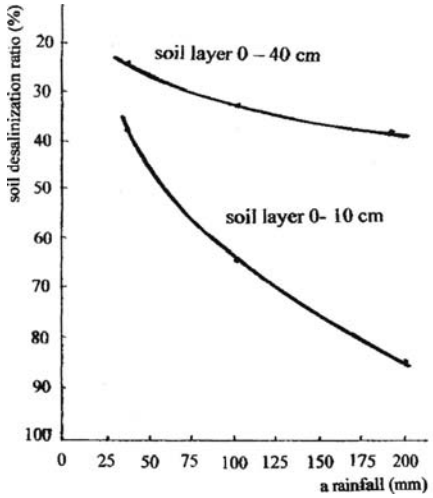

Figure 2. Relationship between a rainfall and soil desalinization ratio

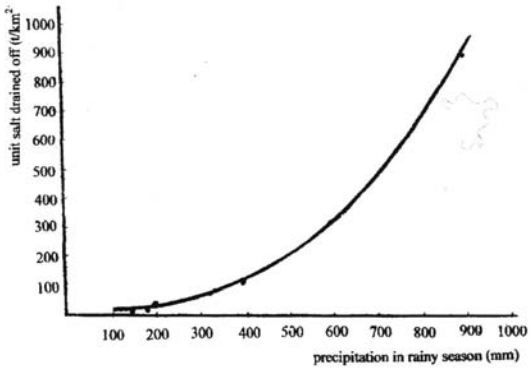

Figure 3. Relationship between rainfall and salt drained off per unit area

in soil increased due to irrigation with saline water can be drained off during rainy season. The exploitation of shallow groundwater including brackish and semi-saline water has played the role of well drainage in the process of well irrigation. The groundwater table dropped, the underground capacity increased, the evaporation of phreatic water reduced, the rainfall infiltration increased, the waterlogging disasters has been prevented, the effect of soil leaching and desalinization has been strengthened and the rainwater has transformed into groundwater resources. In the region with the condition to use the water diverted from the Yellow River for recharging the water resources, the saline groundwater has freshened to some extent gradually. As a result, the comprehensive control of drought, waterlogging, salinity and saline groundwater has realized and good circulation of eco-environment appeared. At the end of last century, the saline-alkali land had reduced one third of that in 1980, only remained 1.33 million hm^2 in Huang-Huai-Hai Plain.

Conclusion

In North China Plain, the precipitation is concentrated in summer, that is a season for soil leaching and desalinization. To bring the effect of soil leaching and desalinization by rainwater into full play, the key lies in setting up drainage facilities and strengthening water management. At the end of 1950's, water diverted from river was used for irrigation on a large scale, but due to no available drainage facilities, groundwater table had risen, the area of saline-alkali land had increased by 50 % in the Huang-Huai-Hai Plain. In 1960's, Control of Haihe River was realized, new outlets to the sea of the five river systems were opened, the drainage systems of water and salt by deep

ditches were set up. In the process of drainage of flood and excessive rainwater, a lot of salt was drained away. Since 1970's, groundwater including brackish water and semi-saline water has been exploited and utilized on a large scale, well irrigation and drainage were combined with canal irrigation, water diverted from the Yellow River was used for storage and recharge groundwater to supply water source, promoting the balance between exploitation and supplement of water resources, and realized the comprehensive control of drought, waterlogging, salinity and saline groundwater. As a result, a large area of saline-alkali land has become nice farmland, the groundwater has freshened to some extent and good circulation of eco-environment has appeared.

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The main drainage rivers had been dredged additional outlets to the sea, to drain off flood, excessive rainwater and saline groundwater. The area of saline-alkali land reduced to 2.09 million hm^2 in 1980 from 4.13 million hm^2 in 1961 in Huang-Huai-Hai Plain. The picture is South Great Drainage River, which outlet is direct to the sea and its inverted siphon culvert through the South Grand Canal. (1972)