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SOIL RESEARCH REPORT NO. 11

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NANJING, CHINA

1984

Soil Research Report No. 11, 1984
Institute of Soil Science, Academia Sinica
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EFFECT OF PUMPED-WELL DRAINAGE ON THE PREVENTION AND CONTROL OF DROUGHT, WATERLOGGING, SALINIZATION AND ALKALIZATION IN HUANG-HUAI-HAI PLAIN AND ITS UTILIZATION

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Huang-Huai-Hai Plain, being the largest alluvial plain in China and with a flat relief and deep solum, is one of the important agricultural bases of the country. In this region, however, the development of agricultural production is greatly affected by the disaster of drought, waterlogging, salinization and alkalization.

Huang-Huai-Hai Plain belongs to semi-arid and semi-humid region under monsoon climate and has an annual precipitation about 600 to 1000mm, which is distributed unevenly and about 60-70 percent in summer, and an evaporation capacity several times more than the precipitation. Hung-Huai-Hai plain is characterized by flat macro-relief, undulating meso-and micro-relief, alternate distribution of mounds, slope lands and low-lying lands, which usually leads to the redistribution of water and salts, induces a relatively shallow ground water depth and impedes the runoff of surface and grouud water. Such climatic, relief, geomorphological and hydrogeological features always lead to drought in spring and autumn and waterlogging in summer, which aggravates the salinization and waterlogging of the soil, the fact indicates that the drought, waterlogging, salinization and alkalization are closely related and give harmfulness to crops alternately. Owing to ignorance of the natural conditions and the cause of drought, waterlogging, salinization and alkalization of the soil it had been failed to deal reasonably with the relationship between diversion and storage of water, irrgation and drainage, which induced a roundabout course of our work in the past. For solving the problem of drought, such measures as extensive diversion of water from the Huanghe River for gravity irrigation and establishing reserviors in the plain areas were taken. But owing to the drainage measure being neglected, the ground-water table rised up greatly and so caused secondary salinization of soils and more serious waterlogging in large area. Therefore, irrigation had to be stoped in most of the irrigation area. Thereafter, for the control of secondary salinization of soils, the drainage measures were stressed and strengthened, which alleviated the secondary salinization of soils, but the problem

of drought remained unsolved. It can be seen from above that only by properly solving the contradiction between irrigation and secondary salinization of soils, and between irrigation and eliminating waterlogging, that is to say, only by integrated control of drought, waterlogging, salinization and alkalization and adopting various effective measures in accordance with local conditions, can good results be obtained.

In recent years, various forms of integrated water conservancy measures, suitable to local conditions, in which irrigation and drainage well, irrigation canal and drainage ditch are well coordinated in combination with rational farming and forestry measures have been adopted in Huang–Huai–Hai Plain and good results have been got in controlling drought, waterlogging salinization and alkalization. The key for controlling drought, waterlogging, salinization and alkalization lies on the regulation of the water–salt regime in soil and groundwater. In the concrete, it is necessary to conduct irrigation and drainage so as to replenish soil water, leach the excessive salts from soil, drain off excessive water and salts, and control groundwater table and to prevent the waterlogging and salinization. It has been proved by scientific experiments and production practices for many years that such measures as canal irrigation and open ditch drainage by gravity may give good results under certain conditions, but can not meet the need of regulating water–salt regime in most areas, because the canal irrigation by gravity usually divert water with considerable salts from outside into the irrigated area, and the open ditch drainage is often failed to regulate the balance of water and salts due to the collapse of ditch walls and limitation of the outlets of drainage water. Pumped–well irrigation with groundwater may not increase the input of water and salts, and can solve the contradiction between irrigation and drainage. In addition, the pumped–well irrigation and drainage without the problem of collapse of ditches may lead to a greater falling depth of groundwater table, and have better ability to control groundwater table and to drain off excessive water and salts, and they are free from the restriciton of elevation of drainage outlet. Therefore, the pumped–well irrigation and drainage can be used to regulate and control the water–salt regime of soil and groundwater effectively.

The pumped–wells used in regulating the water–salt regime of soil and groundwater are of great importance for the prevetion and control of drought, waterlogging, salinization and alkalization. The use of pumped–wells in irrigation and draining groundwater can not only make use of local groundwater resources for irrigation to combat drought, drain off highly mineralized groundwater, lower groundwater table and prevent secondary salinization of soils, but also increase the water storage capacity of soil, and alleviate the harm of waterlogging. In areas where the groundwater is mineralized, a desalinized groundwater layer may be gradually built up. It can be seen that the proper use of pumped–well may offer a prereguisite for the unified regulation of precipitation, surface and ground water via the regulation and control of ground water.

For integrated control of drought, waterlogging, salinization and alkalization,

based on the features of soil and hydrogeologcal conditions of Huang–Huai–Hai Plain, the shallow well should be the main pattern in the application of pumped wells so as to use the shallow groundwater. Generally, the shallow well depth ranges from 20 to 60 m, and the spacing from 200 to 500m. In order to regulate and control ground water effectively, in areas with fresh water in whole solum, filter strainers may be used in the whole well cylinder from bottom to top. In the case of the water in aquifer is too mineralized to be used for irrigation, a length of impermeable well tube should be used. to impede the mineralized groundwater. In areas with hightly mineralized groundwater in shallow horizon but with fresh water in deep horizon, a combination of deep and shallow pumped wells may be adopted. The deep wells are used to pump up fresh ground–water in deep stratum for irrigation and the shallow wells are used to pump up and drain away the highly mineralized groundwater so as to regulate dynamic regime of groundwater. While in areas where the ground water in deep stratum is alkaline, care must be taken to prevent possible alkalization of soils after irrigation. In addition, it is necessary to find out the storage capacity of ground water and then exploit them in a planned way, for once the groundwater is over–exploited, it would hardly be recharged.

Using shallow pumped wells to regulate and control the regime of water–salts is of great importance for bringing drought, waterlogging, salinization and alkalization under control. But only by combining with canal irrigation and ditch drainage, can the goal of regulating the balance of water–salt in whole region be attained. The groundwater in Huang–Huai–Hai plain is mainly recharged by infiltration of rainfall, seepage of stream and irrigation canal. The exploitation and utilization of groundwater on a wide scale usually result in the greater decline of groundwater table and the formation of cone of depression, and the groundwater, therefore, need to be rationally recharged by diverting water from the river. In areas with highly mineralized groundwater, it is also necessary to divert water from the river for irrigation and desalinizing the ground water, all the facts indicate that the shallow well irrigation must be combined with canal irrigation. Although pumped–well drainage can alleviate waterlogging to a certain extent by lowering groundwater table, it can not drain off the surface runoff induced by concentrated rainfall in time. In addition, it is quite expensive to use pumped–well drainage for eliminating waterlogging. So a horizontal drainage system must be established to control waterlogging; however, in areas with pumped wells, the criterion of drainage system may be appropriately lowered. In areas where the groundwater is highly mineralized, the water pumped and drained by pumped–wells must be drained out from the improving area via the horizontal drainage ditch system. Only by unified utilization and close coordination of pumped wells, irrigation canals and drainage ditches combined with various measures of agriculture and forestry (e.g. land leveling, reasonable cultivation, increasing application of organic manures, afforestation, etc.) can the unified regulation of precipitation, surface and ground water be

realized and the goal of regulating and controlling the regime of water-salt in soils and groundwater be attained. And at the same time the soil fertility can be promoted progressively and the drought, waterlogging, salinization and alkalization can be controlled.

In different parts of Huang–Huai–Hai Plain, the conditions of soil improvement are quite different owing to their different relief, geomorphological, soil and hydrogeolgical conditions. Therefore in this region, the types, structures and arrangement of pumped–wells in their application are varied according to the local conditions, different areas have different patterns in the application of wells for irrigation and draingage, the following three areas may be used as the examples.

1. Fresh groundwater area: In the upper and middle parts and the areas where the old river course is buried in alluvial plain, the runoff is unobstructed and the groundwater in both shallow and deep layers is mostly fresh water which may be used for irrigation. Owing to undulating meso–and micro–relief, soil salinization usually occurs in the fringe areas of various depressions and protrusions of the micro–relief. The salts in these soils are characterized by strong accumulation in soil surfaces and low content in subsoils. The drought and salinization of soils can be eliminated as long as the groundwater table is controlled at a certain depth and the irrigation for salt leaching is rationally conducted. In this area, the application of pumped well is the most effective and economical way. The pattern of application of pumped–well is well irrigation in combination with well drainage, that is to say, while groundwater is pumped up for irrigation, it can simultaneously lower the groundwater table. Moreover, it is necessary to build main drainage system in combination with the shallow field ditches for preventing the soil waterlogging. By adopting these measures good results have been achieved in Fengqiu County, Henan Province, where 4800 pumped wells had been built during 1965 and 1974 and the salt–affected soil area in 1974 decreased by four fifths as compared with that in 1964. The observation results in Shengsuiyuan Irrigation Experiment Area of the county showed that the groundwater table had started to fall markedly since the well irrigation and drainage began to operate in 1965, and the year-round level of groundwater was controlled between three and six metres in depth during 1967 and 1969 (see Fig. 1). Salts moved downwards one metre below the soil surface (Table 1).

In these areas, the depth and spacing of pumped wells depend mainly on the buried depth and yeild of the aquifer. In areas with a shallow depth and a large yield of aquifer, the depth of wells is generally about 30m. The effective radius of a pumped–well in which the ground water level can be lowered obviously may be 200 to 300m, the spacing of the wells 400–600m. In areas where the soil has a poor water permeability. a deep depth and a small yield of aquifer, the depth of wells should be 40 to 60m, and the smaller spacing of 200 to 400m should be adopted. The wells adopted are mainly cylindrical wells or vacuum–tube wells constructed by gravel cement filter strainers with an internal diameter of 30 to 50cm and a wall thick of 5–10cm.

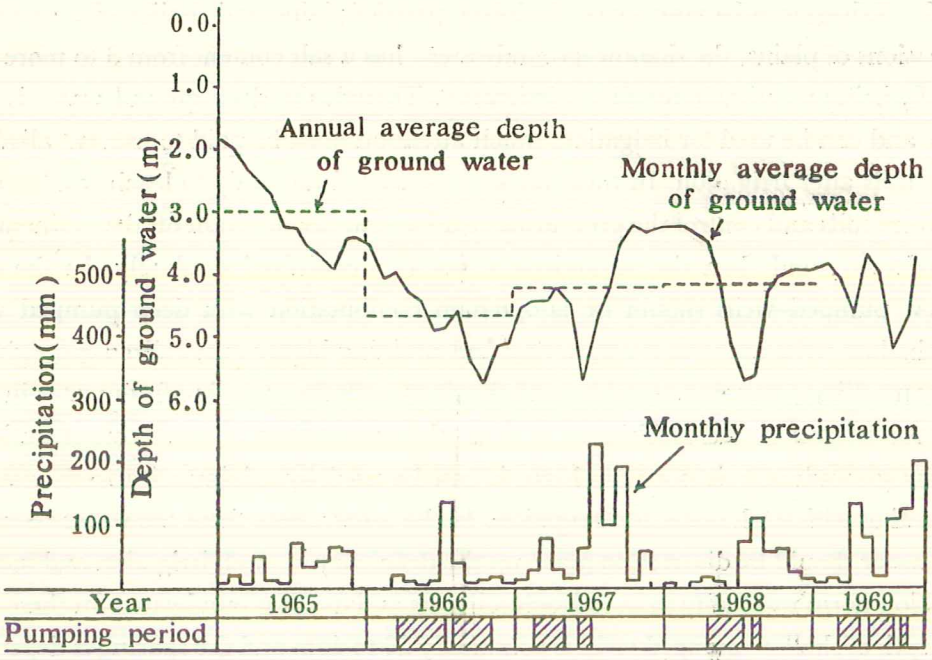

Fig. 1 *Precipitation, pumping period and variation of groundwater table of the experimental area (Data from the Institute of Soil Science, Academia, Sinica, "Turang", No. 4, P192, 1975)*

Table 1 *Variation of salt content of soils in Shengsuiyuan bragade after application of well irrigation and drainage*

Soil dapth (cm)	Date			Desalinization rate,%
	June 1965	June 1970	May 1973	1965—1973
0—5	1.17	0.10	0.04	96.6
5—20	0.27	0.09	0.05	81.5
20—40	0.24	0.07	0.07	70.8
40—70	0.24	0.09	0.09	62.5
70—100	0.20	0.13	0.13	35.0
100—130	0.13	0.27	0.11	15.4
130—160	0.12	0.23	0.10	16.7
160—200	0.12	0.18	0.12	0
200—250	0.12	—	0.14	-16.7
250—300	0.11	—	0.19	—72.7
Depth of desalinization, m	—	1.0	2.0	—

(Data from the Institute of Soil Science, Academia Sinica, "Turang", No. 4, P192, 1975)

2. **Salt-groundwater area.** In lower partslof plains and shallow-flat or trough depressions of plains, the shallow–groundwater has a salt content from 3 to more than 10 g/L, being unsuitable for direct irrigation. Though the deep ground water is fresh water and can be used for irrigation, much attention must be paid to prevent alkalization of soils after irrigation. In these areas, it is needed not only to leach and remove salts from soils and control the groundwater table, but also to drain off the mineralized groundwater, and then the groundwater can be desalinized gradually. In the areas shallow pumped–wells should be adopted in combination with deep pumped wells. The shallow wells are used for pumping and draining highly mineralized groundwater and controlling groundwater table, and the deep wells for pumping fresh water in deep layer for irrigation and leaching salts from the soils. When the salt concentration of shallow groundwater is not very high, it can be used by mixing with fresh water or alternating with fresh water for irrigation. In the areas where there are water resources, river water should be diverted to make up the deficiency of well irrigation and increase irrigation norm rationally so as to leach soil salts and desalt groundwater. In these area, the depth of shallow pumped wells is commonly 20 to 40m and the spacing is dependent upon the water permeability of soil. The depth and spacing of deep pumped wells depend mainly on the buried depth and yield of aquifer and the requirement of irrigation water. An experiment conducted by Beijing Agricultural University in the Quzhou County, Hebei Province showed that the shallow pumped wells with a depth of 20 to 40m and a spacing of 250 to 300m, and the deep pumped wells with a depth of 250–300 m and a spacing of 700m could basically meet the needs of soil improvment. In the area reclaimed by building pumped wells from 1974 to 1977, more than 350 hectares of salt–affected soils have been improved to a different extent and the groundwater have a tendency of progressive desalinization. A good result of increasing crop yields has been got by using mixture of highly mineralized water and fresh water with a salt content of less than 4 g/L for irrigation to combat drought.

3. **Coastal salt-affected soil area.** In these areas, with a low and flat relief and highly mineralized groundwater, the fresh water is buried quite deeply (generally 400m below) and mostly in a slightly alkaline reaction and unsuited to be exploited for irrigation. Owing to high salt content and severe waterlogging of the soils in these area, it is necessary to divert river water for irrigation, leaching the salts, desalting the groundwater, and eliminating the waterlogging. Therefore, it is needed to build the irrigation system for diverting water and irrigation and to use the open ditch drainage system for draining water and salts. In the areas with serious collapse of drainage ditches, pumped well combined with open ditch drainage, or pumped well combined with underground pipe drainage and main open ditch drainage should be adopted, the pumped well is mainly used for pumping and draining highly mineralized groundwater, and promoting the establishment of fresh groundwater layer along with the infiltration of irrigation and

rainfall water.

According to the differences of soils and hydrogeological conditions, there are two types of soils with different physical properties and structures of solum in coastal regions. The first is that the soils have good water permeability, no impermeable compact interbedded layers of clay within the upper solum of 30 metres and a good hydrodynamic connection between upper and lower water buring layers. Under these circumstances, well pumping may play an important role in draining water and salts from upper solum and lowering the groundwater table in a wider range. The effect of pumped–wells on soil improvement is significant. For example, in Xincun Brigade Experimental Area of Caopie Commune at Dongtai County in the coastal region of Jiangsu Province, on the soils with the permeability coefficients of 1.58 to 1.89 m/day, a good effect on soil improvement has been got by using pumped wells with a depth of 20 to 30m and a spacing of 400 to 500m. The second is that the soils have a poor permeability, a thicker impermeable interbedded layer of clay within the solum of 10 to 20m in depth and little hydrodynamic connection between the upper and lower solum. Under these conditions, little effectiveness of the tube wells with filter made of gravel cement has been found due to their smaller yield of water in common and the water pumped up mainly from lower layer soil, which is almost ineffective on the drainage and desalinization of the upper soil horizon and the lowering of groundwater. For example, in Dayuzhang Experiment area of Shangdong Province, the soil permeability coefficient is 0.7 m/day, and there is a impermeable compact interbeded layer of clay with a thick of 2 to 7m at a depth of 10 to 20m. Experiment results have shown that when gravel cement strainers with an internal diameter of 40cm and a well depth of 30m was used, the water yield of single well was only 5 to 10m^3/hour, the radius influenced by lowering groundwater table was only 30 to 60m, and so it has very little effect on soil reclamation. Similar case also can be found in some inland alluvial plains.

Pumped–wells, mainly used to pump and drain off highly mineralized groundwater, generally require high costs of installation and operation. Therefore, the suitability and economic benefit of pumped wells should be identifid before they are built on the basis of detailed investigation of the hydrogeological condition of the improving areas. In areas where the soil are poor in water permeability and there are impermeable compact interbedded layers in the solum, if the collapse of open ditches occurs seriously, installation of the system of pipe drainage should be considered, if the drainage water can not be drained off by gravity, mechanical drainage should be used. In a word, the measures of soil hydromelioration must be selected and used properly in accordance with the local conditions.

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Information Service
Institute of Soil Science
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