# SHALL WE ADJUST DRAINAGE STRATEGIES TO WATER-SAVING PRACTICES- A CASE STUDY

# LES STRATÉGIES DE DRAINAGE DOIVENT ELLES S'AJUSTER AUX PRATIQUES VISANT LES ÉCONOMIES D'EAU - ÉTUDE DE CAS

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## ABSTRACT

Artificial drainage is important for the salinity control of arid and semi-arid irrigated area. In recent years, a nation-wide water saving upgrading program for large irrigated areas was launched in China which has resulted in the role of drainage systems and many environmental changes. This paper studies the environmental change in the Hetao Irrigation District. Records of irrigation, drainage, groundwater and water quality in Wuliangsu Lake fed by drainage returns were collected. The change in soil salinity was also detected. The results show that application of water-saving practices has resulted in the falling down of groundwater table and the decrease in drainage water. On the one hand, it helps to control soil salinity, but one the other hand, more and more salt is continuously accumulated inside the area. The present drainage system and strategies could not sustain salt balance. Moreover, the worsening water quality in Wuliangsu Lake has caused the spreading of reedy area. Therefore it is necessary to adjust the drainage strategies and develop new drainage technique to get the equilibriums among water saving, soil salinity control and local eco-environment.

## RÉSUMÉ

Le drainage artificiel est important pour le contrôle de la salinité dans les zones irriguées aride et semi-aride. Au cours des dernières années, en Chine, un programme de mise à niveau des économies d'eau dans les grands périmètres irrigués à a été lancé à l'échelle nationale, il a questionné le rôle des systèmes de drainage et entrainé de nombreux changements environnementaux. Cet article étudie les modifications de l'environnement dans le district d'irrigation à Hetao. Des données ont été collectées sur l'irrigation, le drainage, les eaux souterraines et la qualité de l'eau du lac Wuliangsu, alimenté par des retours de drainage. Une modification de la salinité des sols a été détectée. Les résultats montrent que l'application de pratiques d'économies en eau a entraîné la chute de la nappe phréatique et une réduction des eaux drainées. D'une part, il aide à contrôler la salinité des sols, mais d'autre part, de plus en plus de sels sont accumulés en permanence à l'intérieur de la zone. Le système de drainage actuel et les stratégies actuelles ne peuvent pas maintenir l'équilibre en sel. En outre, l'aggravation de la qualité des eaux du lac Wuliangsu a endommagé la zone roselière. Par conséquent, il est nécessaire d'ajuster les stratégies de drainage et de développer de nouvelles techniques de drainage pour obtenir les équilibres entre les économies d'eau, le contrôle de la salinité du sol et de l'écologie de l'environnement local.

**Keywords:** drainage; water-saving practices; environmental impact;

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## 1. Introduction

Irrigated agriculture plays an import role in securing food security. It has been an essential component of any strategy to increase food supply. However, irrigation projects and irrigation agriculture practices can impact the environment in a variety of ways. Among these impacts, soil salinization is a worldwide problem that is mostly concerned in arid and semi-arid areas. To combat soil salinization, artificial drainage is thought to be the most important method and has been taken as an indispensable part of one irrigation system. In some areas such as in the west-north of China, dry drainage is also proved to be effective to control soil salinity. In recent years, most irrigated systems in china is experiencing water saving upgrading. The groundwater table is lowering and has resulted in many environmental changes. The purpose of this paper is to examine the responses of environment to the water management change in the Hetao Irrigation District and to explore reasonable water management strategies for achieving food production and environment protection goals in HID and similar irrigation projects.

## 2. Study area and material

### Study area

HID is located in the Inner Mongolia Autonomous Region, Northern China. It covers a total area of 1 100 000 ha including 570 000 ha of agricultural area irrigated by Yellow River and is one of the three national's largest irrigation districts. HID has been irrigated by Yellow river for around 2000 years. But modern irrigation system was built continuously since 1950's. HID suffered from waterlogging and salinity due to the great increase in water use and the lack of artificial drainage. To improve drainage capacity, the artificial drainage system was continuously developed and improved. Consequently the agricultural productivity in HID has obviously improved.

The district has been requested by the central government to reduce the abstraction from Yellow River from averagely 5 billion $m^3$/year to 4 billion $m^3$/year. To match agricultural water requirement, large scale water-saving renovation has been in progress since 1999, which including cropping pattern readjustment, canal lining, deficit irrigation, groundwater utilization and water policy reform.

### Material and method

Long-term (1954-2012) historical data for the quantity and quality of irrigation and drainage water were collected from the HID Administration. And then a multiscale salt balance were performed to calculate the residual salt. Groundwater table depths and corresponding quality data (1966-2013) for more than 200 monitoring wells were also collected compute the percent areas covered by different salinity.

To examine the soil salinity evolution, seven sets of Landsat images were selected to retrieve medium saline soils and heavy saline soils by means of supervised classification.

To examine the environment evolution of Wuliangsuhai Lake, five archived Landsat images in Augustwere used to detect free water surface and reedy water Yearly averaged data for TDS, TP, TN, BOD and COD were collected to compare the lake water quality change from the local environmental protection administration.

## 3. Environmental impacts of water management

### Irrigation and drainage practices

The irrigation rate in HID tends to decrease in the past sixty years. Before the completion of San-Sheng-Gong head works and the main irrigation canal in 1961, irrigation in HID District was uncontrolled and the irrigation rate could be as much as 13276 $m^3$/ha. As artificial drainage was not available while water was over-applied, drainage water was not generated from groundwater but from irrigation returns. After 1961, the irrigation rate decreased to 7965 $m^3$/ha and subsurface drainage system began to take effect with a capacity of around 300 $m^3$/ha. In 1975, the main drainage canal and the pumping station were reconstructed, which resulted in the great improvement of drainage capacity. The yearly drainage rate has risen to 1487 $m^3$/ha. Since 1980's, the irrigation rate decreased continuously and declined to a minimum 6959 $m^3$/ha in 2012. Correspondingly, the drainage rate also decreased until the large-scale construction of field drainage system that was built in 1990. It is also found that the TDS of drainage water would increase if less water is drained.

### Impact on the groundwater

The groundwater table in HID is strongly linked to irrigation and drainage practices. Before the operation of main drainage canal and pumping station, the yearly averaged depth was 1.5 m with a variance of 0.8 m. From 1980 to 1995, the yearly averaged depth was 1.68 m with a variance of 1.5 m due to the improvement of drainage capacity. The water

saving practices began in 1995 resulted in a continuous decline in groundwater table, with an average of 2.1 m in recent ten years.

Yearly averaged TDS of groundwater has changed from 2.9 g/l in 1985 to 4.1 g/l in 2012. Moreover the area where TDS is lower than 3 g/l has decreased from 82.3% in 1985 to 52.3% in 2012 while the area where TDS is higher 3 g/l has increased from 17.7% to 47.7% correspondingly. This rise in groundwater salinity is in keeping with the continuously salt accumulation inside the system. To prevent groundwater salinization and soil salinization, it is necessary to lessen salt loads.

### Impact on the salt balance and soil salinity

Despite the improvement of the system and the management, salts brought by irrigation have never been drained out of the district (Fig. 5) and continuously accumulated inside the system. Before 1977, the yearly residual salt was about 1,220,000 tons. With the expanding of irrigated area, this value increased to 2,621,000 tons in 1991. With the operation of World Bank-supported drainage system, the yearly residual salt decreased from 2,621,000 tons in 1991 to 400,000 tons in 1995. However the residual salt tended to increase since 1995 because of water saving practices and less drainage, indicating potential salinization risk.

There is a corresponding relationship between the soil salinity evolution and the development of irrigation and drainage system or practices. The saline area has increased due to uncontrolled irrigation and lack of efficient drainage. Proper irrigation and drainage help to control soil salinity. Recent water-saving help to mitigate soil salinity in despite of salt accumulation.

Dry drainage system is estimated the capacity is lowering as the groundwater table is lowering. It is also found that the groundwater table is isn't the exclusive salinity control factor in recent years. How to maintain salt balance in irrigated areas and prevent form salinization is needed to be investigated.

### Impact on Wuliangsuhai

After initial development, the drainage water from HID became the main water sources of the Wuliangsu Lake. It has become a rare multifunctional wetland. However, Wuliangsuhai Lake has been increasingly eutrophicated as a result of non-point source pollution from the Hetao Irrigation District.

The relationship between water quality and drainage presents that the volume of drainage water is quite important to the lake water quality. After the effective drainage was applied, the TDS of lake water decrease when the volume of drainage water increased. the converse is also true. On the contrary, the increasing of drainage water in recent ten years helps the lake water have a stable TDS. Therefore, to maintain the quality of the lake water needs certain amount of recharge from the drainage water.

## 4. Discussion and conclusions

The on-going water-saving renovation project aims to lessen the inlet Yellow River water from 5.2 billion $m^3$/a to 4.0 billion $m^3$/a averagely. Obviously this will lower the groundwater table and lessen the drainage. It was estimated that the total drainage would decrease to 0.32 billion m3/a and the groundwater table would have a 0.4 m fall, providing the project is completed. The TDS of drainage water and lake water will eventually increase since less groundwater is drained out, as explained above. And the impacts on hydrology and environment could be more immense than that occurred from 1995 to 2003 because the water saving project had been only 10% completed according to HID. Actually the yearly averaged groundwater table depth had a 0.8 m fall from 1995 to 2011. Therefore soil salinity and wetland eco-environment face serious challenge if no efforts is made. It is necessary to perform a comprehensive study to evaluate the impacts of water management change on hydrology and environment and explore solutions to ensure crop productivity with minimum negative eco-environmental damage.

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