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SUMMARY OF DOCTORAL THESIS

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Title: Evaluation of water delivery performance in irrigation systems subjected to reuse of agricultural drainage water and improving the water quality by reuse regulation
(農業排水の再利用を行う灌漑用水路系の配水実効評価と再利用制御による水質改善)

The main problem facing farmers in the Nile Delta is water shortage at the ends of irrigation networks and canals. These problems have worsened as water demands have increased. Egypt's Ministry of Water Resources and Irrigation (MWRI) is currently trying to avoid water deficits by returning agricultural drainage water to the irrigation canals. Kafr El-Sheikh Governorate, they constructed culverts that connected canal ends with the main drain (Bhr Nashrat) to provide supplemental agricultural drainage backflows (SADB) to irrigation canal. However, this return is not controlled, and the flows are based only on differences in the hydraulic head. In Egypt, the reuse of agricultural drainage water is a supplemental to fresh water supply. Government pumping stations (official) and farmers' small diesel pumps (unofficial) lift water up from drainage canals and direct it back into the irrigation canals to reuse for agriculture, thereby increasing the available water resources of Egypt by 12.6%. However, as water passes through the soil and drainage network, it picks up salts, agricultural chemicals, and other pollutants, leading to differences in the quality of drainage and irrigation water. Therefore, mixing the two water types deteriorates the overall quality. The common practice in Egypt is to mix drainage into fresh water up to the point where the salinity of the mixed water is about 1,000 mg L-1. This thesis consisting of three main studies.

Evaluating the effectiveness of SADB to counteract water shortage when the water supply from head regulators (WSHR) is insufficient. Moreover, I analyzed the water delivery performance in terms of adequacy, dependability and equity. I tested two water supply conditions: (1) WSHR only and (2) WSHR plus SADB. During the summer (May–September) of 2008, SADB significantly improved the adequacy to meet farmers' water requirements in some months. Adequacy and dependability, therefore, improved from "fair" to "good". During the following winter (October–April), SADB improved adequacy and equity only in March and April since water availability was generally sufficient under WSHR.

Investigating the efficiency of using backflow to supplement the fresh water irrigation and its effect on water quality in Kafr El-Sheikh Governorate. I employed the indicator of water supply ratio (WSR). I tested two water supply conditions: (1) fresh water supply only and (2) fresh water supply plus backflow. During the summer season (May–September) of 2008, WSR was 0.93, and it improved up to 1.27 by adding the backflow. During the summer season (May–September) of 2008, WSR showed and average value of 0.93, and adding the backflow increased it to 1.27. During the following winter season, WSR was 1.50, and increased up to 1.82 by adding the backflow. Based on the monitoring of salinity of water during the study period at four locations – head, middle, tail, and drain – the salinity significantly increased toward the end of the canals. I calculated the effect of backflow on the salinity and obtained improved salinity values by regulating the backflow. During the summer season, backflow significantly deteriorated water quality, but only part of this backflow was actually required, in June and July, to avoid the shortage, and not to exceed the requirements. During the following winter season (October–April), fresh water availability was generally sufficient; however, backflow still occurred, leading to unnecessary deterioration of the water quality. If backflow is controlled according to the actual requirements, the water quality would be improved. An improvement in water salinity of over 30% was realized in June and July, and by 100% in May, August, September, and all winter months.

Reducing water application costs without sacrificing irrigation performance in Safsaf canal. For comparison, I also studied the Meet Yazeed canal (MYC) (which is run without the new techniques). The cost-reduction measures used in this study included reduction of pump discharge rates and the use of electricity instead of diesel. I found that the location of farms along the irrigation canal had little effect on pump operation hours and amount of applied water; instead, crop patterns were the most important factor in this regard. The water-use index (WUI), which is the ratio of applied water to required water, was higher in the SC than in the MYC and El-Mesk canal (MC). Thus, it can be inferred that decreasing the designed pump discharge increases the amount of applied water to meet crop water requirements as an entire area. Decreasing the pump discharge increased the amount of applied water to meet the crop water requirements. During winter, the WUI values of 1.11–1.16 achieved discharge rates of 70–80 L•sec-1 and were considered the optimal values of WUI. Further studies are required to avoid excess of applied water during summer. In SC command area Irrigation took place between 0300 and 1800 in winter season. In contrast, in the MYC and MC were between 0400 and 1100 during winter. During summer, the number of irrigation events in the SC command area were from 0300 to 1200 hours and from 1400 to 2100 hours, whereas in the MYC and MC command areas, this number were from 0300 to 1000 hours and from 1400 to 1800 hours. The application of new techniques prompted farmers to irrigate their fields at night, thereby reducing water losses, and installation and operational costs; and promoting equitable water distribution along the entire irrigation canal and throughout the command area.

The freshwater supply approach used in the area should be modified to improve the management of water distribution. Farmers' behavior must also be improved, since farmers at the canal's head tend to withdraw more water than they need, leading to shortages at the canal's end. The canal systems were designed to provide the maximum water requirements of the water-consuming summer crops, but this has led to an excess freshwater supply in the winter season. Further measures should be considered to improve the management of water distribution. SADB should be controlled by gates and pumps and used to supply water only when WSHR cannot provide enough water. The mixing ratio of SADB water might therefore be higher at the tail of the branch canals. However, if the water quality is sufficiently good, drainage backflow may have the potential to conserve fresh water flowing from the canal head regulators or to increase the area under cultivation. Equity of water distribution and crop water requirements can be met by reducing the pump discharge rate and appropriate crop pattern. Decreasing the pump discharge rate increases the number of night-time irrigation events, which helps maintain sufficient water levels in the canal without loss of fresh water into the drain canal. Application of new techniques such as electric pumps helps reduction of the operational and total costs. Therefore, the alternative methods studied here are cost effective and can be widely used to improve the infrastructure of the improved irrigation systems.