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SUMMARY OF DOCTORAL THESIS

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Title:

Integrated Operation and Management of Irrigation Systems for Sustainable Agriculture Under Arid Environment

(乾燥環境下における持続可能な農業展開のための灌漑システムの総合的管理)

Climate changes will significantly impact agriculture by increasing water demand and reducing water availability in areas where irrigation is most needed, especially in arid regions. The agricultural water management in the Nile Delta will be impacted by climate change increasing prone to flood and storm damage or experience salinity intrusion through surface and groundwater. A factor affecting the Delta water budget is also the uncertainty of precipitation and flows in the Nile river catchment that has been predicted to slightly decrease by 5% in the future decades over sub-catchments of the Blue Nile. The Blue Nile contributes about 60% of its total mean annual flow to Aswan High Dam in Egypt (84×10^9 m^3). Therefore, efficient operation and management of an irrigation system plays an important role in the sustainability of irrigated agriculture because the climate changes will have impacts on decisions of water management and use. Due to its limited water resources, Egypt faces great challenges to enforce policies to improve the performance of the existing delivery system by implement more effective irrigation technologies. Improvements consist of a demand delivery system using mechanical gate structures and controllers to automatically divert water from one portion of a network to another in the desired amount and sequence.

This study was carried out to evaluate and understand the farmers' irrigation practices in their farms before and after modification of the existing irrigation system. In addition, I also evaluated the irrigation network system under government management before and after these improvements in the existing irrigation networks. El-Wasat command area is selected as study area, where paddy rice, one of the most common crop in the Nile Delta, Egypt. Rice contributes 40% of total crop production. This area is located on the northern edge of the Nile Delta, and it is fed from the tail reaches of the main canal. Due to its location, El-Wasat command area receives less amount of water and suffers from shortage of water supply. Moreover, farmers tend to plant more fields with paddy rice than the limit government set (at 50%) and this causes increase of water demand. Therefore, an unbalance of water supply and demand is exacerbated.

A set of performance indicators proposed by Molden and Gates (1990) have been employed for the evaluation of the study. The indicators to evaluate irrigation delivery performance require different data items such as water level, routine discharges, and cropping pattern for branch canals, pump operations for tertiary canals and irrigation events of selected farmers. Data were analyzed, and the values of different indicators are calculated. The results indicate that the water-use application at the improved system is improved. This is due the successful management and operation of the water-supply system by the water users association. Water users' association has a positive effect on managing of the improved tertiary canal. For unimproved system, the results indicate that irrigation delivery by traditional rotation systems is unsuitable at the irrigation districts that are located at the end of large irrigation networks in the Nile Delta, while the demand delivery concept is successful in improving water delivery performance over that of the traditional rotation delivery concept used previously. The new system provided fair shares of water among irrigation districts and allows the irrigation districts

to deliver water from main canal whenever they need water. In addition, the automation improves efficiency, responsiveness, and flexibility of canal system. There still remain main problems of water delivery in the irrigation networks and that is a water shortage in the main canal due to its location at the tail of the feeder canal system in the Nile Delta, and other reasons include rice-farmers' nonobservance of summer crop production plan designed by government. It causes the greater demand of some fields than supply.

This study tries to improve the efficient operation and management of irrigation system because most of the river water is consumed by agricultural sector. Therefore, this study deals with a hydrodynamic model to assess the hydraulic behavior of the irrigation network and to investigate the optimal supply flow discharge. Hydrologic Engineering Centre River Analysis System (HEC-RAS) is employed in this study. HEC-RAS is developed by US Army Corps of Engineers in order to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. This model was applied to El-Wasat command area. This study showed three main cases present more practical operation at lifting points operation taken by three proposal scenarios. Scenarios suggest different ways of delivery scheduling among improved lifting points with proposal and the physical structures' situation of system. The proposed 3 scenarios in this study are "uncontrolled continuous flow", "demand schedule" and "flexible arranged schedule". Practical cases of operation are presented in different ways for pumped water unit at lifting points that are "one time", "lag time" and "migrate time". Demand scheduling and/or the flexible arranged scheduling scenarios succeeded to complete full turns through different sections by different method of lifting point operation. Especially, the flexible arranged scheduling is better choice to improve water distribution among lifting points in terms of stable water delivery. But, these scenarios do not achieve water saving through improved irrigation system because of farmers' behavior and geometry of irrigation system. The main reason is the nonobservance of crop production planning among different locations served by the main canal, especially for rice cultivation in summer. Most of lifting points have area over 70% of paddy field and located in head and middle locations of branch canal and this causes increase of water demand. For the geometry problems, the presence of large losses of water as a result of reduction of cross sections rather than bridges causing problems in the operation of gates automatics.

The study illustrated that the way to improve equitable water allocation should be reducing water losses downstream the lifting points as reduce the cultivation of rice crop according to the prescribed percentage of government, re-planning the crop production among the farmers and punish the offending. Water user's association has positive effect on saving irrigation time and equity water distribution among farmers through tertiary canal level. Therefore, it is essential to expand the responsibility of water user's association from tertiary canal to branch canal due to their success the goals of this association through operation of tertiary canal. The delivered water at downstream the head regulator should be distributed among lifting points through the flexible internal rotation. The evaluation results showed that the continuous flow was applied in the previous explained manner in any branch canals. The water was not distributed based on the volumetric basis among branch canals and there was no any water distribution inside any branch canal. So, improve the performance of the most of the branch canals should be modified the cross section as design cross sections and change to canal lining system. The study shows that HEC-RAS model can be used successfully for a large and complex irrigation system for evaluation and monitoring of its performance in the absence of observed flow data and improvement of irrigation management plans.