埤塘之旱澇因應策略效益評估—以桃園新坡工作站 9-6 灌區為例

Evaluating water management strategies of ponds for droughts and floods—a case study of Xinpo Station 9-6 irrigation area in Taoyuan

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摘要

桃園地區因台地地形儲水不易，早期先民挖掘許多埤塘蓄水作農業灌溉用途，這些埤塘與石門水庫、桃園大圳及週邊農地串連成完整的農業供水系統。善加利用埤塘可增加農業系統的供水韌性，同時埤塘及農地還可在降雨時提供額外儲水空間，減少洪水損害，減緩氣候變遷對於農業系統之衝擊。本研究的目標為（1）建立桃園新坡工作站之草埤(桃園大圳 9-6 池)灌區 Vensim 系統動力學模型，模擬埤塘水位及農地湛水深變化；(2）制定調適策略：參考以往相關農業政策或研究，確保系統在模擬期間盡可能維持水稻田所需灌溉水量，減少費水情況，同時在降雨期間減少溢流量。

本研究模擬 2023 年水稻二期作(2023.8.1~2023.1.28，共 120 天)，模擬之埤塘水位與實際水位之(圖 1)，趨勢大致相同，但該水文模型準確度尚有可提升空間，未來可考慮使用最佳化方法檢定參數，提升模型準確度與可信度。根據模擬之埤塘水位及水稻田湛水深變化，現況雖沒有缺水情況發生(田間湛水深低於凋萎點)，但該系統仍存在以下問題:

1. 農地湛水深對雨量敏感，降雨時會使實際湛水深大於需求湛水深，現況實際湛水總量為所需湛水總量之 1.31 倍；
2. 埤塘、農地水位過高時產生溢流，模擬期間內，現況埤塘共產生溢流 6,218m³、農地共產生溢流 7,129 m³。

以上情況都造成水資源浪費，須採取更節約的供水方式，本研究統整可能使

用之調適策略(表 1)應用至該灌溉系統。發現在供水方面(圖 2)，所有調適策略皆在滿足水稻湛水深的同時減少灌溉量，而策略 A、B 可將大圳供水量降至現況之 62.6%、77.6%，同時仍然滿足水稻所需湛水，可幫助節省大圳供水量。在排水方面(圖 3)，所有調適策略都成功讓埤塘溢流量降為 0；策略 A 讓農地溢流量降至現況之 88.6%；策略 B、E 讓農地溢流量降為 0，惟策略 B 採用預先排水，還需後續討論預先排水時是否會超出渠道負荷量；策略 D 採用的間歇灌溉使農地溢流量成長 2.3 倍，是由於此系統無法預知降雨，若恰好灌溉當日有降雨發生，可能會造成水位超出田埂高度的情況。未來將考慮各調適策略加成、或套用在未來氣候情境之效果。

關鍵字: 埤塘，農業水資源管理，系統動力模式，水稻田，旱澇

Abstract

The terraced landscape of the Taoyuan region presents significant challenges for water storage, prompting early settlers to excavate numerous ponds to store water for agricultural irrigation. These ponds, in conjunction with the Shimen Reservoir, the Taoyuan main canal, and surrounding agricultural fields, form a truly comprehensive agricultural pond-irrigation system. The effective utilization of these ponds can enhance the resilience of the agricultural water supply system. Additionally, during rainfall events, these ponds and agricultural lands can provide supplementary storage capacity, reducing flood damage and mitigating the impacts of climate change on agricultural systems. The objectives of this study are: (1) To develop the Vensim system dynamics model for the Caopi (Taoyuan Main Canal 9-6 Pond) irrigation area at the Xinpo Workstation in Taoyuan, simulating pond water level and paddy filed water depth; (2) To formulate adaptation strategies by referencing previous agricultural policies and studies, aiming to ensure that the required irrigation water volume for paddy filed is maintained throughout the simulation period, minimizing water wastage and reducing drainage during rainfall events.

This study simulates the second rice cropping season of 2023 (August 1, 2023, to January 28, 2024, 120 days). The simulated pond water level and actual water level (Figure 1) show a generally consistent trend, though there remains room for improvement in the accuracy of the hydrological model. Future studies could consider employing optimization methods for parameter calibration to enhance model accuracy and reliability. Based on the

simulated pond water levels and rice field water depth changes, although no water shortages are observed under current condition (with field water depth not falling below the wilting point), the system still exhibits the following issues:

1. The water depth in the paddy filed is sensitive to rainfall. During rainfall, the actual water depth may exceed the required depth, with the current actual water volume being 1.31 times the required volume.
2. High water levels in ponds and paddy filed lead to drainage. During the simulation period, total drainage from the ponds amounted to 6,218 m^3, while total drainage from the farmland reached 7,129 m^3.

These conditions result in water resource wastage, necessitating the adoption of more efficient water supply methods. This study integrates possible adaptation strategies (Table 1) into the irrigation system. In terms of water supply (Figure 2), all adaptation strategies reduced irrigation volume while meeting the required water depth for paddy filed. Strategies A and B reduced the water supply from the Main Canal to 62.6% and 77.6% of the current levels, respectively, while still satisfying the water depth requirements, thereby helping to conserve water from the Main Canal. In terms of drainage (Figure 3), all adaptation strategies successfully reduced pond drainage to zero. Strategy A reduced paddy filed drainage to 88.6% of the current level, while Strategies B and E reduced farmland drainage to zero. However, Strategy B, which involves pre-drainage, requires further discussion to determine whether pre-drainage might exceed canal capacity. Strategy D, which utilizes intermittent irrigation, increased farmland drainage by 2.3 times due to the system's inability to predict rainfall. If irrigation coincides with a rainy day, water levels might exceed the field bund height. Future studies will consider the cumulative effects of various adaptation strategies or their application under future climate scenarios.

Keywords: Ponds，Agricultural Water Resource Management，System Dynamics Model，Rice Paddy，Droughts and Floods

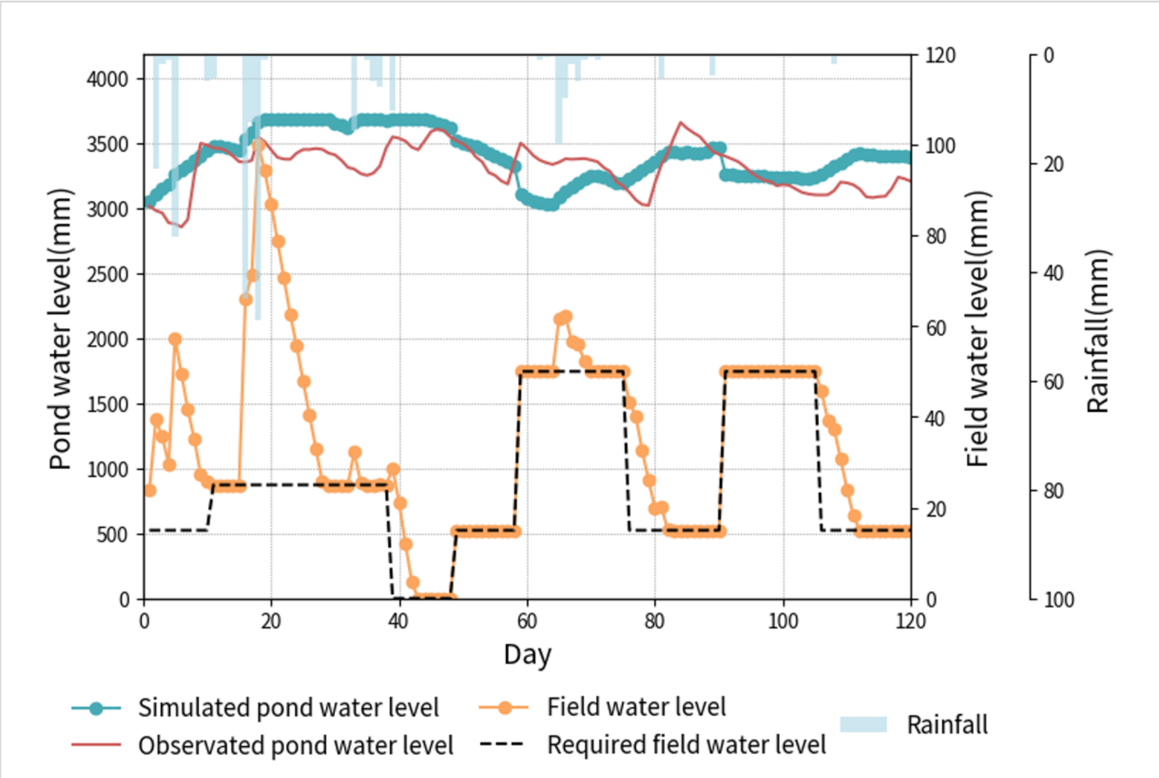

圖 1、研究期間(2023.8.1~2023.1.28，共 120 天)之降雨量、埤塘實際水位、埤塘模擬水位、水稻田模擬湛水深變化圖

策略	描述
A	埤塘 2 階段供水
B	採用氣象預報(完美降雨預報)， 降雨前預先排水
C	間歇灌溉
D	埤塘浚深工程
E	加高田埂高度 25cm

表 1、本研究考慮之調適策略

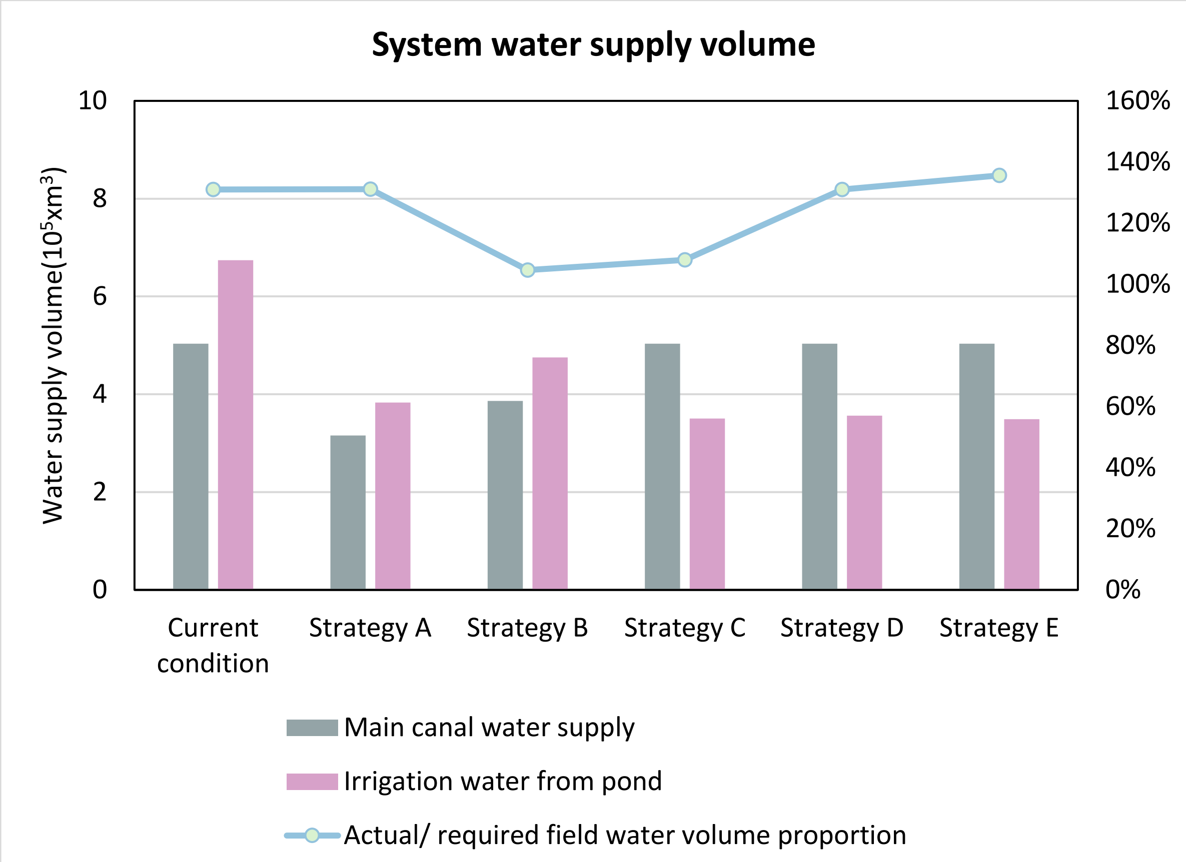

圖 2、研究期間灌溉系統供水總量

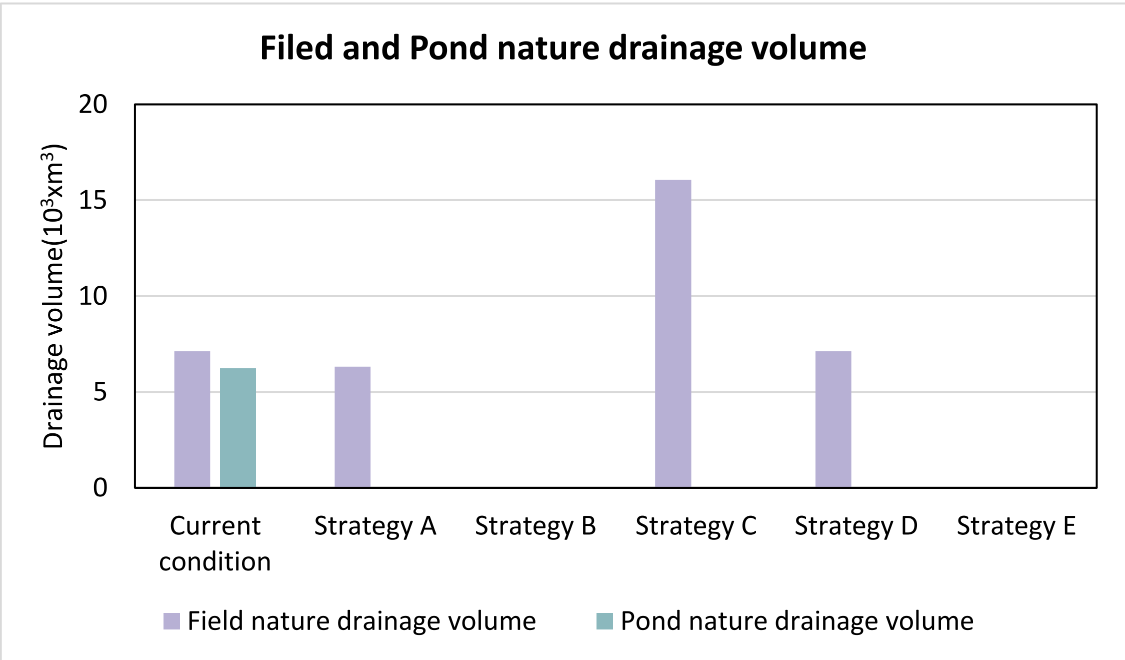

圖 3、研究期間農地與埤塘排水總量