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# Modeling smart irrigation system for mixed crop field water demand- a case study in central Taiwan

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## Modeling smart irrigation system for mixed crop field water demand- a case study in central Taiwan

## OUTLINE

- I Introduction
- II Study region
- III Model establishment
- IV Result and discussion
- V Conclusion

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# I. Introduction

**I. CLIMATE CHANGE**

- The climate change will enhance significant difference between drought and waterlogging period.

**II. WATER DEMAD**

- The agricultural water demand in Taiwan is more than 70% of total yearly water usage. In a drought period, other industries often transpose the water resource from agricultural water.

**III. PRECISION IRRIGATION**

- The purpose of the study is to make agricultural water usage in the field more efficiently and upgrade the operation accuracy of irrigation systems would bring about proper irrigation to the crops and ensure the yield in the drought.

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# I. Introduction

**Extreme climate cause flood and drought**

- Typhoon caused serious siltation of the reservoir, reduced water storage capacity, and increased water supply risk.
- Extreme climate lead to drought and thirst reservoir.
- Make water used more efficiency become an important topic.

- Cao-Gong canal was seriously injured by Typhoon Morakot(2009)


- Sun Moon Lake is short of water due to drought(2015)

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# II. Study region

## 1.Location: Tzu-Tsai-Pi(TTP.) Channel irrigation system

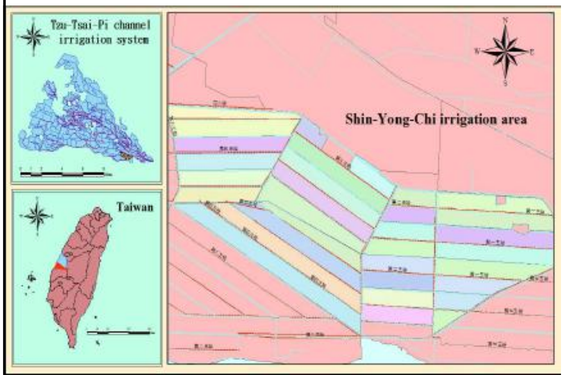


**Fig. 1** Location of Shin-Yong-Chi irrigation area

Shin-Yong-Chi is a main branch of upper TTP. Channel in Sijhou Township .

Lies mainly in Chang-hua, Taiwan and Jhuoshuei River Watershed

Dominated by the Rainy season, typhoon and shows strong seasonality. The mean annual precipitation is 1,750 mm.

TTP. channel water fill with sediments and mud that contain lots of nutrients, which contributes high rice quality here.



# II. Study region

## 2. Canal system and monitoring stations distribution of study region

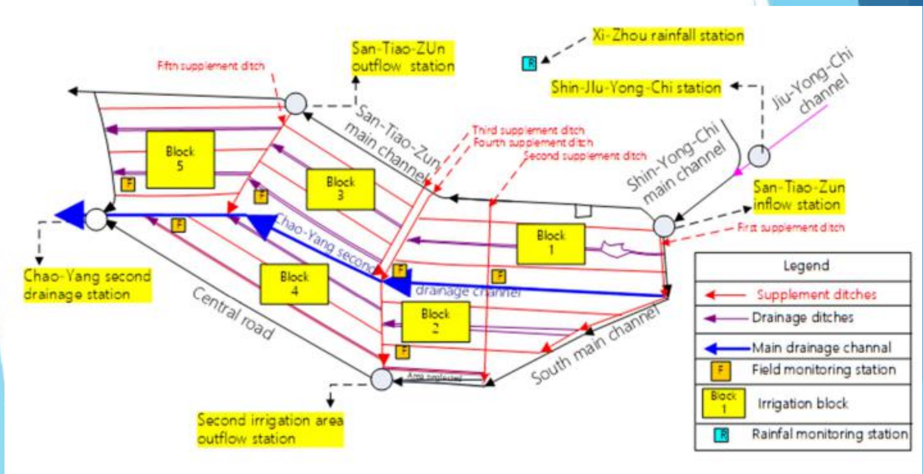


**Fig.2** Layout of blocks, drainage, and irrigation channels

# II. Study region

## 3. Crop period and block area of study region

Table1 Cultivating period and Crop period

| Period / Date / Days / Crop | 1st Crop | | 2nd Crop | |
|---|---|---|---|---|
| | Date | Irrigated days | Date | Irrigated days |
| Seedling | 1 Jan. -31 Jan. | 21 | 1 Jul.- 20 Jul. | 20 |
| Ponding Field | 11 Jan.-31 Jan. | 21 | 1 Jul.- 20 Jul. | 20 |
| Sort out Field | 11 Feb.- 20 Feb. | 10 | 21 Jul.- 10 Aug. | 21 |
| Cultivating Field | 21 Feb.-30 Jun. | 130 | 11 Aug.-30 Nov. | 112 |

Table 2 Area of 5 irrigation blocks in study region

| Irrigation Block / Area(Ha) | Paddy | Building | Actual Irrigation Area |
|---|---|---|---|
| Block 1 | 51.02 | 3.98 | 47.04 |
| Block 2 | 37.20 | 0.50 | 36.70 |
| Block 3 | 39.95 | 0.03 | 39.92 |
| Block 4 | 43.76 | 0.77 | 42.99 |
| Block 5 | 42.72 | 0.58 | 42.14 |
| Total | 214.65 | 5.86 | 208.79 |

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# III. Model establishment

## 1.Methodology– Water Balance Method

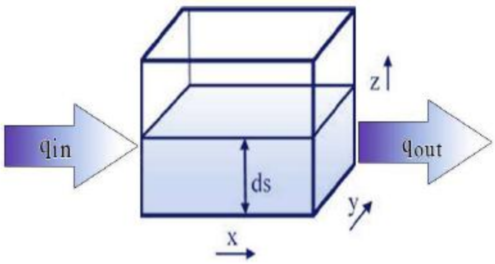


Figure 3. Microcosmic view of three-dimensional porosity medium flow condition.

$$q_{in} - q_{out} = \frac{ds}{dt} \qquad (1)$$

$q_{in}$ is inflow,
$q_{out}$ is outflow,
ds is the change in storage of control volume with in a time t.

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# III. Model establishment

## 2. Paddy Field Water Balance Equation

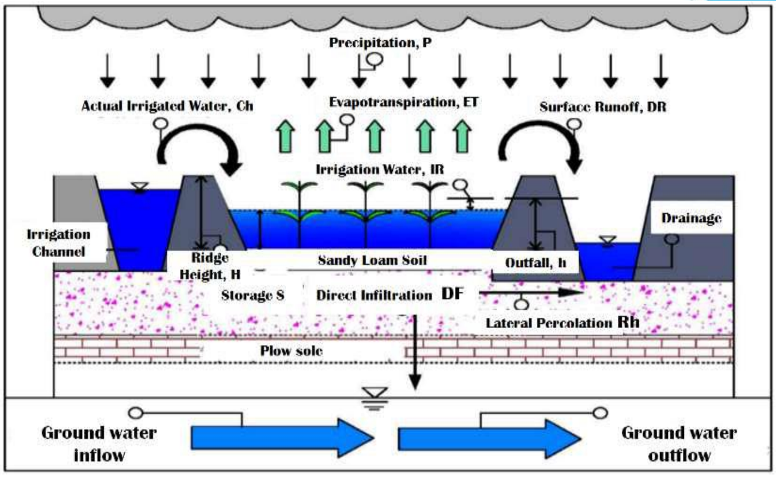


Figure 4. Schema of Field Water Balance

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# III. Model establishment

## 2. Paddy Field Water Balance Equation

$$S_i = S_{i-1} + P_i + Ch_i + Gw_i - ET_i - DR_i - DF_i - Rh_i \qquad (2)$$

$S$ :Field storage depth

$P$:(Rainfall

$Ch$:Applied channel irrigation water

$GW$:Pumped Groundwater

$IR$:Required irrigation water

$Ri$:Channel flow

$ET$:Evapotranspiration

$DR$:Surface runoff/overflow from field

$DF$:Vertical percolation

$Rh$:Lateral seepage inflow

i:Time

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# III. Model establishment

## 3. Upland Water Balance Equation

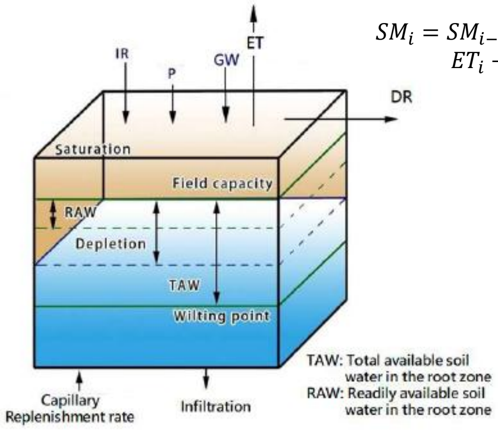


Figure 5. Upland soil water balance

$$SM_i = SM_{i-1} + P_i + IR_i + GW_i + CR_i - ET_i - DR_i - DP_i \quad (3)$$

$SM$ : Soil water content

$P$ : Rainfall

$IR$ : Irrigation water requirement

$GW$ : Pumped ground water

$CR$ : Groundwater capillary replenishment rate

$ET$ : Crop evapotranspiration

$DR$ : Field over flow

$DP$ : Infiltration (Vertical and lateral)

$i$ : Time



# III. Model establishment

## 4. System Construction

The study establish mixed crop water demand model with system dynamic model, rainfall, evapotranspiration, infiltration, irrigated water, ground water and drainage are considered in the model. The flow direction and drainage mechanism are simulated according to field as Figure 6 and 7.

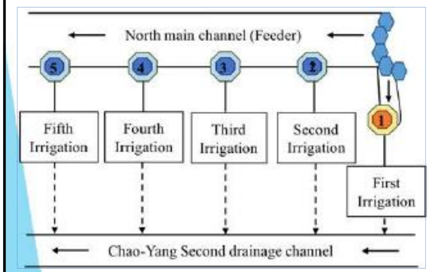


Figure 6. Flow direction of study region

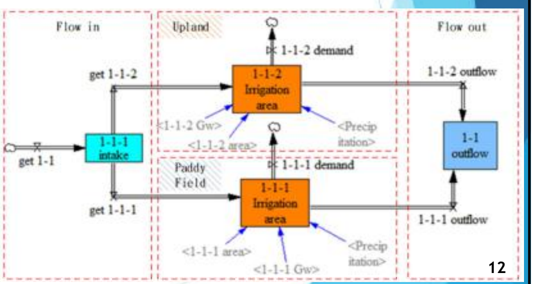


Figure 7. scheme of mixed crop water demand model

# III. Model establishment

## 4. System Construction

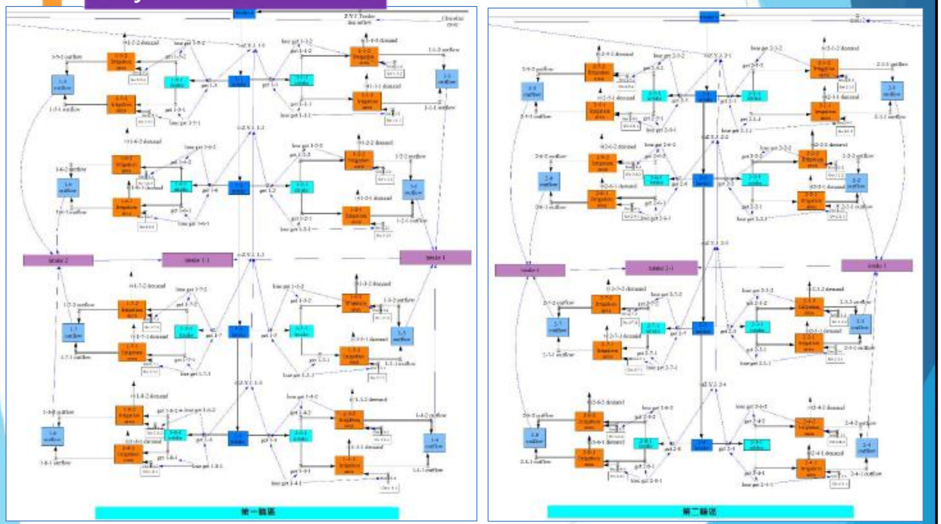

Figure 8. Model structure of block( sample of block 1 and 2)



# III. Model establishment

## 5.Field monitor stations

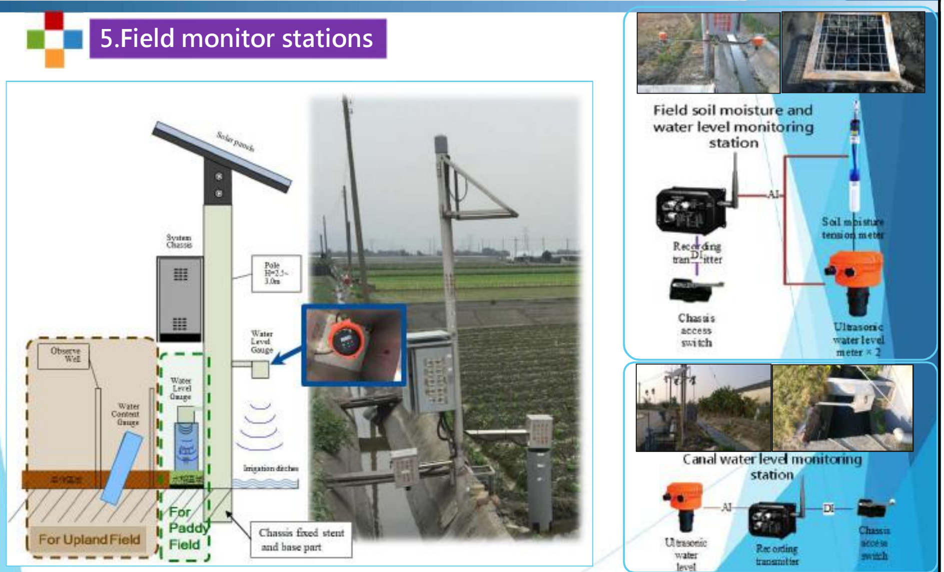


Figure 9 Field monitoring station arrangement and system structure

# III. Model establishment

## 6.Data transmission, computing process

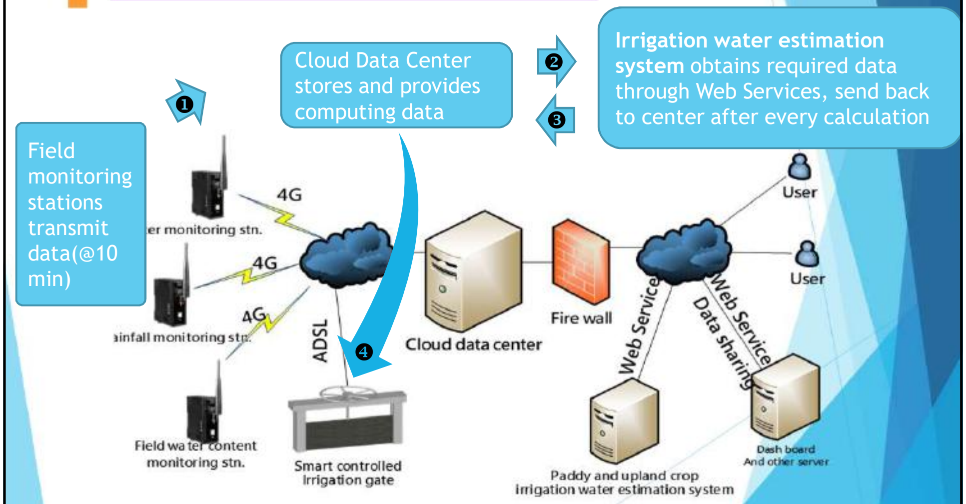


Figure 10 Architecture of monitoring data transmission cloud computing



# III. Model establishment

## 7.Model validation

(1)Root Mean Square Error, (RMSE)

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{N}(O_i - P_i)^2}{N}}$$

=14,228.56 CMD

CMD: Cubic Meters per Day

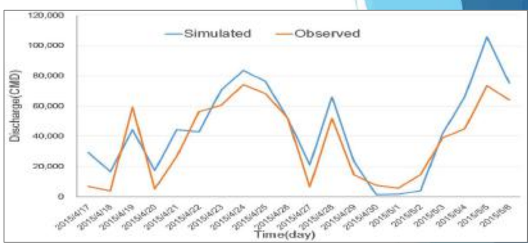


Figure 11 Simulation and observed out flow comparison

(2)Correlation of Determination, $R^2$)

$$R^2 = \left\{\frac{\sum_{i=1}^{N}(O_i - \bar{O})(P_i - \bar{P})}{\sqrt{\sum_{i=1}^{N}(O_i - \bar{O})^2 * \sum_{i=1}^{N}(P - \bar{P})^2}}\right\}^2$$

=0.8267

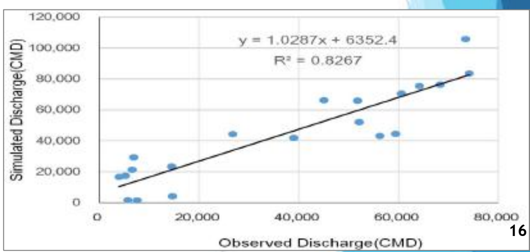




Figure 12 Simulation and observed out flow correlation comparison

# IV. Result and discussion

## 1.Smart gate efficiency

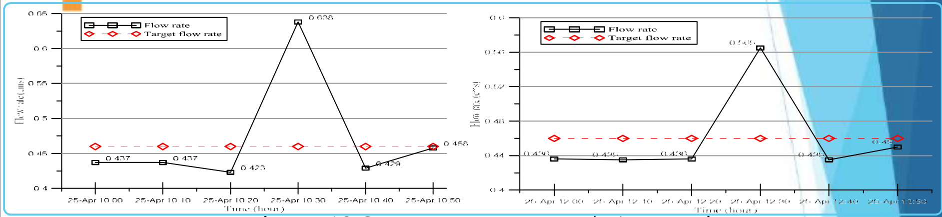


Figure 13 Smart gate auto regulation result

Table3 Smart gate auto regulation error rate and volume change

| Time | Error rate(%) | Water volume change during regulation(m³) |
| --- | --- | --- |
| 25 Apr. 10:00~11:00 | 2.25% | 6.20 |
| 25 Apr. 12:00~13:00 | -0.11% | -0.30 |
| 3 May. 08:00~09:00 | -2.73% | -8.20 |
| 3 May. 10:00~11:00 | 7.27% | 24.00 |
| 3 May. 16:00~17:00 | -3.60% | -15.10 |
| 3 May. 22:00~23:00 | 15.48% | 41.80 |
| 4 May. 00:00~01:00 | -1.87% | -5.60 |
| Average | 2.39% | 6.11 |

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# IV. Result and discussion

## 2. Scenario

1.In the scenario of 30% reduction from irrigation plan, the rotation 1 to 5 obtained the mostly required water, and the field storage curve still keep away from its Field Capacity as shown in Figure 14.

2.For the scenario of 50% water discount, the 5th rotation release more surplus water but that’s because of the rainfall., before the rain comes, the rice plant may be already cannot survive as shown in Figure 15. .

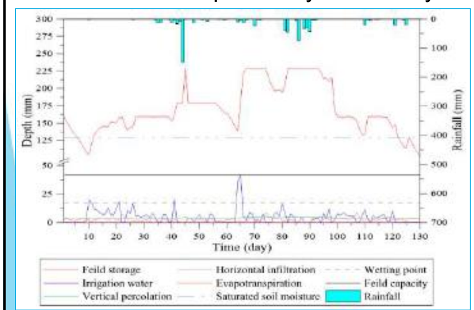


Figure 14. Scenario 1: 30% discount of planned irrigation water

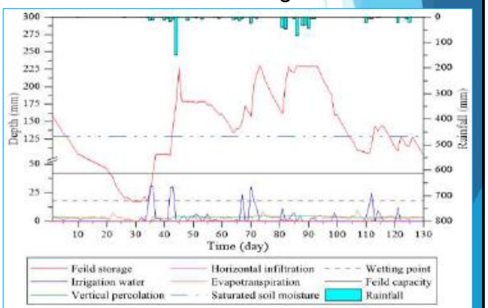


Figure 15. Scenario 2: 50% discount of planned irrigation water

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## V. Conclusion

1. The study applies the water balance model to simulate experiment region water demand and consumption to analyze the limitation of water conservation.

2. Results from the scenario of 50% reduction of irrigation water indicate that the soil water content reached wilting point. It could be applied as a solution of water shortage, but it's suggested to implement adjustment of water gate more frequently for ensuring of the downstream rotation areas to obtain allocated water.

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## V. Conclusion

3. According to the smart gate regulation processes conducted in this study, the average error with the target flow rate is about 2.39%, and the average release amount is only 6.11 tons during the adjustment process. It shows that the smart gate control system has a good effect in the application of intelligent irrigation solution.

4. The precise irrigation system effectively improved the accuracy and the performance of field irrigation management in the mixed cropping area in the study region.

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thank
you !