桃園市智慧節水管理系統研發與水資源多元應用計畫

Development of Smart Water-saving Management System and Multiple Application of Water Resources in Taoyuan City

委託單位：經濟部水利署

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摘　要

一、計畫緣起

臺灣降雨豐枯比懸殊、坡短流急，氣候變遷現象使農業水資源短少問題更顯嚴峻，因應缺水危機下，研擬氣候變遷下水資源多元開發及有效利用為重要課題。近年來智慧化水資源利用之推動亦為國際趨勢，農業占整體水資源的大宗約 70~73 %，如何由農業生產過程導入智慧化管理，達成節水且同時兼顧農業生產本質的目標是為本計畫之重點所在。本計畫今年度以桃園市為研究區域，擬整合物聯網(IoT)感測技術、智慧環控管理技術初步建立智慧節水管理系統，並以 2 次現地示範區省水試驗進行驗證，配合作物栽培管理分析平台，建立前瞻智慧節水管理系統，可作為氣候變遷下提升水資源韌性重要調適策略方案。

二、計畫基本資料盤點

計畫資料蒐集包含桃園水源利用、農作資料、智慧農業案例蒐集；桃園市水源利用以地面水為主，以 2017 年水權量為例，用水標的運用依序為家用及公共給水(76 %)；農業用水(22 %)；工業用水(2 %)，桃園市境內可供糧食生產地為 34,885.7 ha，位於桃園及石門水利會灌區內之比例為 63.5 %、灌區外為 36.5 %。桃園市作物以水稻為主(約 63.1 %)，蔬菜類次之(28.6%)，其餘 8.3 %為雜糧、特用作物、水果類及花卉。智慧農業案例已初步完成國

際案例(美國、日本、西班牙、印度)及國內案例之蒐。

三、標的作物篩選暨灌溉管理方法探討

臺灣地區對於作物分類以農委會(2006)編撰之台灣農家要覽分類最為詳盡；本計畫針對短期旱作物、長年作物、稻作之特性說明。短期旱作物以蔬菜而言就有 47 種之多，桃園市 2018 年種植各類蔬菜之面積情形中其他葉菜類 2,596.25 ha，其餘栽培面積前 6 高者分別為不結球白菜、竹筍、莧菜、蕹菜、西瓜、菠菜。長年作物一般係指長年種植果樹類作物，茶(樹)雖為長年作物，但因具有特定用途可作工業原料及具高經濟價值，因此可被歸類為特用作物(又稱工藝或商用作物)栽培。桃園市 2018 年長年作物種植面積前 6 高者分別為桃、柿、香蕉、桶柑、紅龍果、文旦柚。桃園市所種植的稻米品種以台梗 14 號和桃園 3 號最多。

農業灌溉用水標準依作物種類及灌溉方法而有差異，分水田及旱田用水。以北部地區為例，實施續灌及輪灌制度下之水稻灌溉用水量分別為 3,594 mm/yr、2,851 mm/yr。不同灌溉方式會影響期作單位面積用水量，其中輪灌較續灌方式可節水 19.51~29.08 %(一期作)、22.02~31.12 %(二期作)。另不同土壤亦有不同之水田計畫用水深，依臺灣省水利局(1977)所列：黏土(8 mm/day)、坋質壤土(10 mm/day)、壤土(12 mm/day)、砂質壤土(15 mm/day)、砂土(20 mm/day)，可依此迅速計算水田每期作或每年需水量。

本計畫標的作物篩選考量(1).作物需水特性、(2).用水來源、(3).作物代表性、(4).國土規劃適宜性、(5.)是否地方重點發展作物等篩選原則綜合評析，進行本計畫本年度與後續推動之標的作物篩選，本年度標的作物以短期旱作物為主，分別為葉菜類蔬菜的小白菜及萵苣等 2 種；後續 2 年度標的作物篩選建議分別為 2020 年的(1).果菜類蔬菜(胡瓜或蕃茄)、(2).常綠果樹(紅龍果)；2021 年的(1).水稻、(2).根莖類蔬菜(馬鈴薯或芋頭)。

四、智慧節水管理系統之先期規劃

智慧節水管理系統建置主要是建立田區微氣候監測站，構建環境監測系統，感測元件包含(1).溫度、(2).濕度、(3).風速風向計、(4).日輻射計、(5).

大氣壓力計、(6).雨量計、(7).土壤水分張力計、(8).自記水位計、(9).自動資料蒐集記錄器；智慧灌溉系統採用以色列 Netafim 滴灌設備作；透過 NMC PRO 灌溉控制器及網路傳輸裝置(4G)進行資料紀錄及傳輸整合。

本計畫並開發一個管理平台供管理者及用戶共同使用，完整架構包括用戶使用介面(前臺)及管理者查詢及管理介面(後臺)。本計畫今年度以完成前臺開發為主。系統功能主要為環境監控、作物生長紀錄、用水分析、耕地地理資訊儲存、用戶耕地管理等。

五、智慧節水試驗規劃

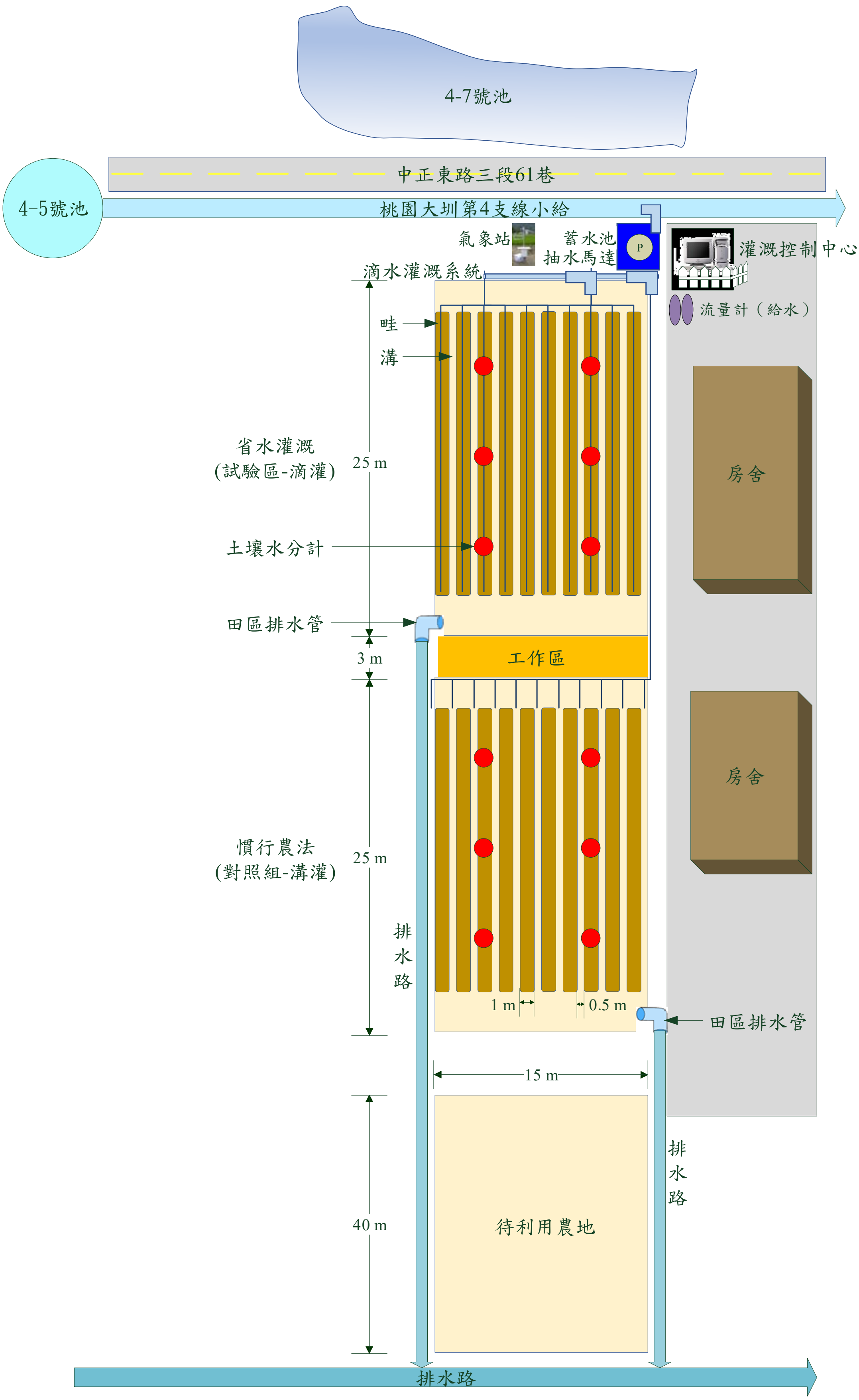
本計畫智慧節水試驗於農工中心位於大園區試驗田區執行(如摘圖-1)，示範場域位屬桃園水利會桃園大圳第 4 支線 4-5 號埤塘灌區，田區坵塊長為 93 m、寬 17 m(面積：0.1581 ha)，田面經 2018 年農委會計畫試驗以雷射整平，田區上游現設有供水蓄水池提供試驗供水所需。

摘圖-1 本計畫示範場域(試驗田區)周邊區位圖

示範場域控制系統施設以完整記錄及擷取所有數據為前提，施設 2 組控制系統，第 1 組為智慧節水滴灌系統、第 2 組為氣象暨土壤水分記錄站，布置示意圖如摘圖-2。因此示範場域(田區)設置 1 套智慧滴水灌溉系統，作為試驗組的主要灌溉設施。田區設置氣象監測設備 1 組，包含紀錄擷取器、

溫度計、溼度計、壓力計、雨量計、日照計(日輻射計)、風速計等設施。為監測兩田區之土壤水分狀況，每一試驗組施設土壤水份計 6 支；流量監測方面，為監測兩試驗田區於試驗期間之分別引灌水量及排出田區水量，各田區設置 1 組入流監測及出流監測；其中入流量監測統一由滴灌系統的 2 組流量計分別觀測試驗組及對照組之供灌水量，因此另需於設置 2 組流量觀測設備，2 組分別施設於 2 田區之出流口處；由於本計畫於田間實施，水量極小，採用 6 吋 PVC 排水管配合自記水位計監測方式獲得排水量。

2 次試驗作物依序為小白菜及萵苣，試驗期間為 7~9 月，示範場域包含試驗組(滴灌區)及對照組(溝灌區)，每一區試驗田長 25 m、寬 15 m(面積 375 m^2)，試驗水源為桃園大圳灌溉原水，各試驗田區設置 10 畦，每畦種植 400 株，每 1 試驗田區 4,000 株，總計第 1 次試驗蔬菜總株數為 8,000 株，第 2 次試驗根據第 1 次試驗進行株距調整，每一畦種植 300 株(共 75 排，每一排種植 4 株)，每一試驗區種植 3,000 株，總株數為 6,000 株。



摘圖-2 示範場域(試驗田區)之感測元件及灌溉設備布置示意圖

六、智慧節水管理系統實施之效益評估

第 1 次智慧節水試驗期間共計試驗 20 日；本計畫依據智慧節水管理系統試驗成果初步顯示採用智慧節水系統(滴灌)較傳統農法(溝灌)節省水量約 57.7 %，如摘表-1 所示；另作物品質評估，針對作物抽樣 800 株進行(1).生長株高、(2).葉片數量、(3).單葉葉寬、(4).單株總葉寬等 4 項參數觀測，利用 Rg(H) (株高生長倍數)、Rg(L) (葉數生長倍數)等指標進行評估，以釐清省水灌溉對於對於生長及產量之影響；試驗成果顯示 Rg(H)及 Rg(L)分別介於 0.86~1.05 及 0.91~1.04，綜合評估顯示本年度試驗中滴灌或溝灌方式對作物生長雖無明顯正面或負面影響，但滴灌節水量遠高於溝灌，灌溉時間也較短，對作物產量亦具微幅正面效益。

摘表-1 第 1 次智慧節水灌溉試驗之灌溉水量節水效益分析

天數	試驗組(滴灌區)			對照組(溝灌區)			節水評估	
	給水量 (m^3)	流量 (cms)	灌溉時間 (min)	給水量 (m^3)	流量 (cms)	灌溉時間 (min)	節水量 (m^3)	節水率 (%)
1	4.39	0.0021	70	5.63	0.0031	30.0	1.24	22.02
2	3.65	0.0010	60	8.43	0.0039	31.4	4.78	56.70
3	1.89	0.0010	30	2.93	0.0016	30.0	1.04	35.49
4	1.90	0.0011	30	7.99	0.0044	30.0	6.09	76.22
5	1.90	0.0010	30	7.82	0.0045	30.0	5.92	75.70
6	1.88	0.0010	30	8.03	0.0045	30.0	6.15	76.59
7			0	6.69	0.0043	26.7	6.69	100.00
8	1.89	0.0010	30	5.87	0.0037	28.7	3.98	67.80
9	2.68	0.0015	60	5.98	0.0033	30.0	3.30	55.18
10	3.81	0.0011	60	4.36	0.0024	30.0	0.55	12.61
11	3.80	0.0011	60	6.79	0.0038	30.0	2.99	44.04
12	3.82	0.0011	60	7.09	0.0038	30.0	3.27	46.12
13	3.81	0.0011	60	8.12	0.0038	30.0	4.31	53.08
14	3.77	0.0010	60	7.00	0.0039	30.0	3.23	46.14
總計	39.19		640	92.73		416.8	53.54	57.74

第 2 次智慧節水試驗共計 30 日；依據智慧節水管理系統試驗成果顯示採用智慧節水系統(滴灌)較傳統農法(溝灌)節省水量約 77.3 %，如摘表-2 所示；另作物品質評估，以作物抽樣 400 株的方式分析顯示使用滴灌之水量僅約溝灌水量 22%的前提下，單株株高約傳統溝灌的 1.24 倍、平均總葉面寬為 1.25 倍、平均單株重量高達 1.91 倍；顯見灌溉方法選用及感測元件之搭配決定灌排時機，有助於大幅減省水源又可確保(提升)原有作物品質及產

量之雙贏目標。

摘表-2 第 2 次智慧節水灌溉試驗之灌溉水量節水效益分析

天數	試驗組(滴灌區)			對照組(溝灌區)			節水評估	
	給水量 (m^3)	流量 (cms)	灌溉時間 (min)	給水量 (m^3)	流量 (cms)	灌溉時間 (min)	節水量 (m^3)	節水率 (%)
1	4.14	0.0012	60				-4.14	
2							0.00	
3	1.97	0.0011	30	15.58	0.0042	62	13.61	87.36
4	1.99	0.0011	30	14.99	0.0042	60	13.00	86.72
5							0.00	
6	1.31	0.0011	20	5.01	0.0042	20	3.70	73.85
7							0.00	
8							0.00	
9	1.97	0.0011	30	7.84	0.0037	35	5.87	74.87
10	1.31	0.0011	20	5.71	0.0048	20	4.40	77.06
11							0.00	
12							0.00	
13							0.00	
14	1.30	0.0011	20	8.56	0.0036	40	7.26	84.81
15	2.30	0.0011	35				-2.30	
16							0.00	
17							0.00	
18							0.00	
19	0.66	0.0011	10	8.53	0.0036	40	7.87	92.26
20							0.00	
21				8.49	0.0034	41	8.49	100.00
22							0.00	
23							0.00	
24							0.00	
25							0.00	
26							0.00	
27	0.90	0.0005	30	5.57	0.0031	30	4.67	83.84
28							0.00	
29	2.03	0.0011	30				-2.03	
30				7.51	0.0032	39	7.51	100.00
總計	19.88		315	87.79		387	67.91	77.36

七、回收水應用於農業灌溉之可行性評估

本計畫考量桃園市境內各水資源回收中心及其周圍灌區位置，針對大溪水資源回收中心及桃園北區水資源回收中心等 2 處水資源回收中心，作為回收水應用於農業灌溉之可行性評估廠區。初步調查成果顯示回收水水質符合景觀澆灌用途、若經稀釋後符合農業用水水質標準後可初步應用於農業灌溉。針對大溪水資源回收中心，初步規劃以月眉圳灌區末流、大溪水

資源回收中心周遭 12ha 土地中約 10.6 ha 農牧用地為示範區域，研擬分散式加壓供水系統及重力式供水系統等供水方案。

桃園北區水資源回收中心回收水現行放流承受水體為南崁溪，考量其緊鄰桃園農田水利會 2-23 號池，且現有生態池原為該池之一部分，故初步規劃於生態池興建一連絡水路至 2-23 號池，並於生態池端設制水門一座，平日將回收水蓄存於生態池內，連絡水路制水門之起閉操作則依桃園農田水利會 2-23 號池灌區需求調配，受益之供灌面積以 2-23 號池灌區計算，受益面積約 143.56 ha。

八、宣導推廣影片製作

本年度針對智慧節水系統，包含感測元件、控制及展示系統等之說明及應用以影片方式記錄，作為計畫成果宣傳用途，利後續節水系統之應用與推廣，宣傳腳本內容規劃包含引言、片頭、各片段落及結語；影片於 2019/07/18 就灌溉系統設備安裝、土壤感測元件與氣象設備佈置等進行拍攝；於 2019/8/16 拍攝田間節水試驗設施、田區整理、菜苗種植；於 2019/9/16 拍攝第 2 期(萵苣)試驗作物收成、訪問水務局局長、簡報發表試驗結果等，最後剪輯完成長度 5 分鐘之宣導推廣影片，另配合水務局之智慧水利及智慧城市政策宣傳，相關成果配合年代電視拍攝，於 2019/11/2 晚上 9 時年代電視台「台灣向前衝」播出。

Abstract

1. Project origin

The obvious difference of dry and rainy seasons, steep river bed slope and climate change cause the decrease of the agricultural water resources in Taiwan. Under the crisis of water shortage, it is an important issue to research the diversified development and efficient use of water resources under climate change. In recent years, the promotion of intelligent water use has also become an international trend. Because agriculture accounts for about 70-73% of the total water resources, how to use intelligent management in the agricultural production process to achieve water saving and take into account the essence of agricultural production is the focus of this project. Taoyuan City is the target area in this year. Internet of Things (IoT), sensing technology and intelligent environmental management are combined to establish a smart water-saving management system, moreover, 2 on site demonstration experiments are carried out to verify the effects of water-saving and establish a forward-looking smart water-saving manage system that can be used as an adjustment strategy for improving water resilience under climate change.

2. Collection and arrangement of project data

Data collection includes water use in Taoyuan, farming data, and smart agriculture cases. The water resources are mainly based on surface water in Taoyuan City. Taking the water rights in 2017 as an example, the purposes of water supply are domestic and public water use (76%), agricultural water use (22%); industrial water use (2%) sequentially. The available food production area is 34,885.7 ha in Taoyuan City, furthermore, 63.5% are the irrigation area of Taoyuan Irrigation Association (TIA) and Shihmen Irrigation Association, 36.5 % are not. The crops in Taoyuan City are mainly rice (63.1%), followed by vegetables (28.6%), and the remaining are grains, special crops, fruits and

flowers (8.3%). The international (USA, Japan, Spain, India) and domestic smart agriculture cases have been collected preliminarily.

3. Selection of the target crops and Discussion on Irrigation Management Methods

For the classification of crops in Taiwan, the most detailed classification of Taiwanese farmhouses compiled by the Council of Agriculture(COA) (2006). This project aims at explaining the characteristics of short-term dry crops, long-term crops, and rice. There are 47 types of vegetables in short-term dry crops.

Among the area of vegetables planted in Taoyuan City in 2018, other leafy vegetables were 2,596.25 ha, and the top 6 highest planting areas were Brassica rapa chinensis, bamboo shoots, Amaranthus, Ipomoea aquatica, watermelon, and Spinacia oleracea. Perennial crops are long-term fruit tree crops. Although tea trees are long-term crops, they can be classified as special-purpose cultivation (also known as craft or commercial crops) because they have specific uses as industrial raw materials and high economic value. The top 6 highest planting areas of Taoyuan in 2018 are peach, persimmon, banana, barrel mandarin, red dragon fruit, and Wendan pomelo. The most cultivated rice varieties in Taoyuan are Taigan 14 and Taoyuan 3.

The agricultural irrigation water standard varies according to the type of crop and irrigation method, and it is divided into paddy field and dry field water. In the northern region, the water consumption for rice irrigation under the continuous irrigation and rotation irrigation systems was 3,594 mm/yr and 2,851 mm/yr, respectively. Different irrigation methods will affect the water consumption per unit area of cropping. Among them, rotational Irrigation can save water by 19.51 ~ 29.08% (first crop) and 22.02 ~ 31.12% (second crop) compared with continued irrigation. Different soils have different paddy field plans. According to Taiwan Water Resources Bureau (1977): clay (8 mm/day), loamy loam (10 mm/day), loam (12 mm/day), sandy loam (15 mm/day), sand (20 mm/day), which can be used to calculate the water demand for each cropping season or annual.

In consideration of (1). Crop water requirements, (2). Water resources, (3). Representative of crop (4). Land suitability, (5). Regional development cultivation, Brassica rapa chinensis and Lactuce sative are chosen as the target leaf crops. The target crops are suggested to grow (1). Fruit crops：Cucumis sativus L or Lycopersicon esculentum Mill. (2). Evergreen fruit tree：Hylocereus spp in 2020 and (1). Oryza sativa, (2). Root crops：Solanum tuberosum L. or Colocasia esculenta in 2021 in the next 2 years.

4. Smart water-saving management system construction

Microclimate and environment monitoring station systems are constructed, including (1). thermometer, (2). Hygrometer, (3). Wind speed anemometer, (5). Barometer (6). Rain gauge, (7). Soil water tension meter, (8). Self-recording water level meter, (9). Automatic data collection system. Netafim, a company from Israeli, whose drip irrigation systems are chosen to use. By the means of NMC PRO irrigation control device and network transmission device (4G), the all experiments data is collected.

A data management platform is developed for managers and clients to use. The complete frames of the platform include the client-side interface and the back-side server to manage. The client-side interface would be developed in this year, which contains environment monitoring, crops grow records, irrigation water analysis, cultivated land geography, and cropland management.

5. The planning of smart water-saving experiment

The smart water-saving experiment was performed in the test field of Agricultural Engineering Research Center (AERC) in Dayuan District (see Figure-1). The experiment field belongs to No. 4-5 pond of 4th branch of

Taoyuan Irrigation Main Channel. The field is 93 m long and 17 m wide (area: 0.1581 ha). The field surface was leveled by laser with the 2018 COA plan test. A pond in the upstream of the field provides the water required for the test.

The experiment field control system is based on the premise of complete recording and acquisition of all data. Two sets of control systems are provided. The first group is a smart festival drip irrigation system and the second group is a meteorological and soil moisture recording station. The layout diagram is as shown in Figure-2. Therefore, a smart drip irrigation system was set up in the experiment field as the main irrigation facility. A set of meteorological monitoring equipment is set up in the field, including facilities such as record extractors, thermometers, hygrometers, pressure gauges, rain gauges, sunlight meters (radiometers), and anemometers. In order to monitor the soil moisture status in the two fields, 6 soil moisture meters were provided for each experimental group. In order to monitor the amount of water diversion and drainage in the two test fields during the test period, one set of inflow monitoring and outflow monitoring is set up in each field. Inflow monitoring is uniformly monitored by the two sets of flowmeters of the drip irrigation system for the irrigation and water supply of the test group and the control group. Therefore, two sets of flow observation equipment need to be set up, and the two groups are installed at the outflow of the 2 fields. In the experiment field, the amount of water is very small. The 6-inch PVC drainage pipe and the self-recording water level monitoring method are used to obtain the water discharge.

Brassica rapa chinensis and Lactuce sative are chosen respectively as the target leaf crops in the experiment which is carried out Dayuan District from July to September. The demonstrate area contains test group (drip irrigation) and comparison group (furrow irrigation). The length and the width of each group are about 25 m and 15 m (area 375m^2). There are 10 furrows in each group, 400 plants were grown in 1 furrow, this means there were 4,000 in 1 group, 8,000 plants were grown in the first experiment. In the second experiment, the plant spacing was adjusted according to the first experiment. There are 10 furrows in each group, 300 plants were grown in 1 furrow, this means there were 3,000 in 1 group, 6,000 plants were grown in the second experiment.

6. The experiment procedure and the crops quality evaluation of the smart water-saving management systems

The period of the first smart water-saving experiment is from July 25th (transplant seedings) to August 13th (crop harvest), counted 20 days totally. The results show that test group (drip irrigation) is about 58 % water-saving comparative to comparison group (furrow irrigation). Speaking to the crop's quality evaluation, 400 plants were chosen randomly in each group to compare to the other one, 4 basic factors: (1). The height of plant, (2). The numbers of leaf, (3). The width of the largest leaf, (4). The width of the total plant was observed and the index of Rg(H) (plant height growth factor) and Rg(L)(leaf number growth factor) were calculated. The results show that Rg(H) and Rg(L) are 0.86~1.05 and 0.91~1.04 respectively, in other words, there is no significant difference between test group (drip irrigation) and comparison group (furrow irrigation). However, the amount of water saved by drip irrigation is much higher than that of furrow irrigation, and the irrigation time is shorter, which has a slight positive effect on crop yield.

The second wisdom water-saving test totaled 30 days; according to the results of the smart water-saving management system test, the use of smart water-saving system (drip irrigation) saved about 77.3 % of water compared with traditional agricultural methods (ditch irrigation) (see Table-2); another crop quality assessment, analysis of 400 strains of crops It shows that the amount of water used for drip irrigation is only about 22% of the amount of furrow irrigation. The plant height per plant is about 1.24 times that of traditional furrow irrigation, the average total leaf width is 1.25 times, and the average weight per plant is 1.91 times. The selection and sense of irrigation methods are obvious. The combination of measuring components determines the timing of irrigation and drainage, which helps to significantly reduce water sources and ensure (improve) the win-win target of original crop quality and yield.

7. The assessment of agricultural irrigation supplied by recycled water

Considering the locations of the water resource recovery centers in Taoyuan City and the surrounding irrigation areas, the Daxi Water Resource Recovery Center and the Taoyuan North Water Resource Recovery Center were selected as the feasibility assessment plants for the use of recovered water for agricultural irrigation. The preliminary survey results show that the quality of the recycled water meets landscape uses, and if diluted to meet agricultural water quality standards, it can be used for agricultural irrigation. For the Daxi Water Resources Recycling Center, a preliminary plan is to take about 10.6 ha of agricultural and pastoral land (the end of Yuemeizhen Irrigation District) as a demonstration area. Two schemes of decentralized pressurized water supply system and gravity water supply system were planned.

The Taoyuan North District Water Resources Recovery Center recovers the water from Nanxun Creek, which is adjacent to No. 2-23 pond of TIA, and the existing ecological pool was originally a part of the No. 2-23 pond. A preliminary plan is to build a liaison waterway in the ecological pool to the 2-23 pond, and set up a water gate at the end of the ecological pool to store the recovered water in the ecological pool on weekdays. The opening and closing operation of the waterway system water gate is adjusted according to the needs of No. 2-23 pond irrigation area. The benefited irrigation area is about 143.56 ha in No. 2-23 pond irrigation area.

8. The production of promotional video

This year, the description and application of smart water-saving systems, including sensing elements, control and display systems, were recorded in the form of videos for the purpose of publicizing the results of the plan, which will facilitate the application and promotion of subsequent water-saving systems. The content plan of the promotion script includes an introduction, an intro, a fragment and a conclusion. The video shoots the installation of irrigation system equipment, soil sensing elements and meteorological equipment on July 18; and shoots the facilities of water-saving test, field consolidation, and vegetable seedling planting on August 16. The working team photographed the 2nd (lettuce) experimental crop harvest, interviewed the director of the Water Authority, and published the results. Finally, the above content was edited to complete a 5-minute promotional video. In conjunction with the promotion of smart water conservancy and smart city policies, the relevant results were filmed with the ERA Communications. The show aired on 9/11/2019 at 9 pm on TV “Taiwan Charges Forward”.

Figure-1 Location maps around the experiment field of the project

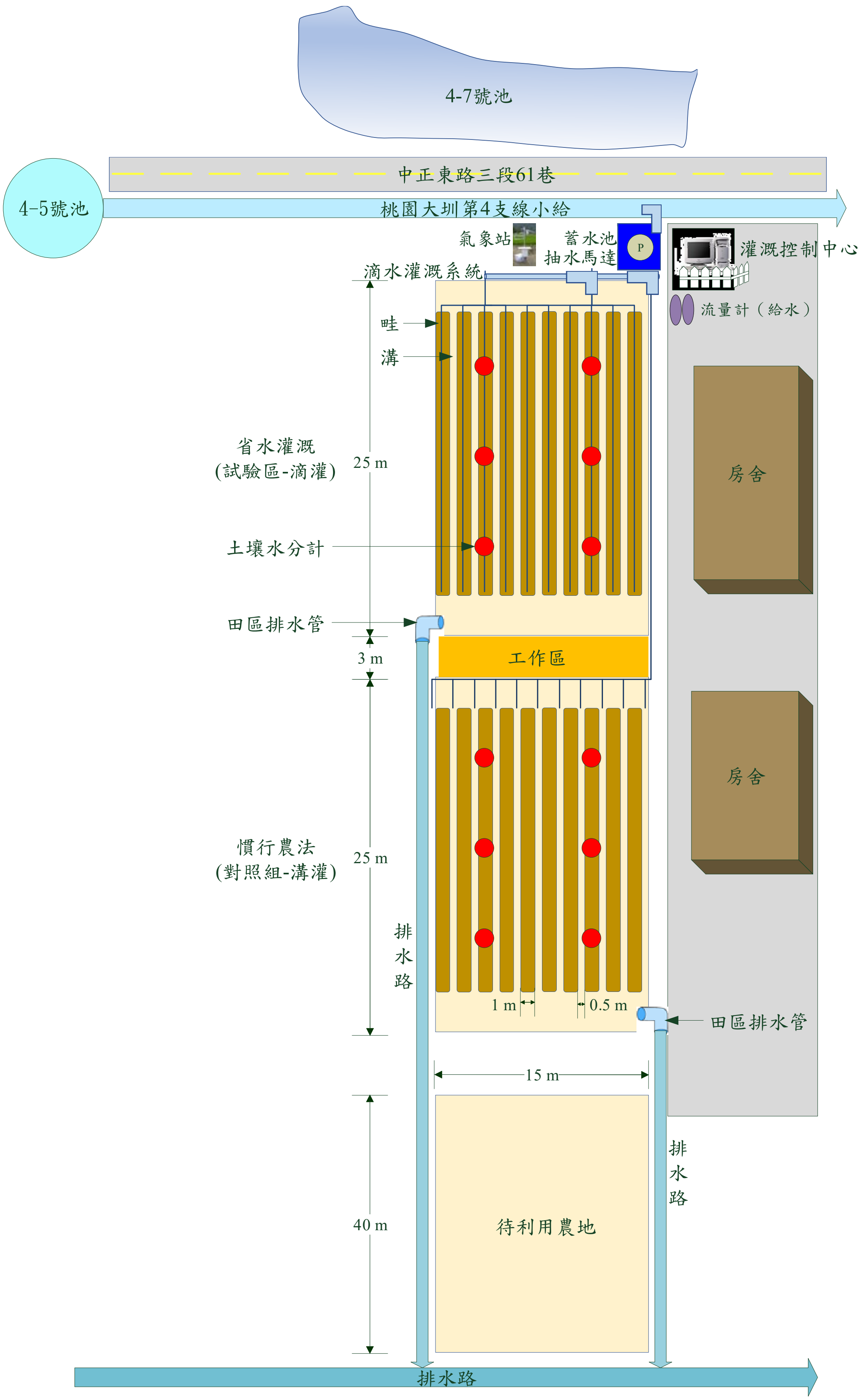


Figure-2 Schematic layout of sensing elements and irrigation equipment

Table-1 Analysis of the water saving benefit of the first intelligent water-saving irrigation experiment

Day	Test group (drip irrigation)			Comparison group (furrow irrigation)			Water saving assessment	
	Water supply (m^3)	Flow (cms)	Irrigation time (min)	Water supply (m^3)	Flow (cms)	Irrigation time (min)	Water saving (m^3)	Water saving rate (%)
1	4.39	0.0021	70	5.63	0.0031	30.0	1.24	22.02
2	3.65	0.0010	60	8.43	0.0039	31.4	4.78	56.70
3	1.89	0.0010	30	2.93	0.0016	30.0	1.04	35.49
4	1.90	0.0011	30	7.99	0.0044	30.0	6.09	76.22
5	1.90	0.0010	30	7.82	0.0045	30.0	5.92	75.70
6	1.88	0.0010	30	8.03	0.0045	30.0	6.15	76.59
7			0	6.69	0.0043	26.7	6.69	100.00
8	1.89	0.0010	30	5.87	0.0037	28.7	3.98	67.80
9	2.68	0.0015	60	5.98	0.0033	30.0	3.30	55.18
10	3.81	0.0011	60	4.36	0.0024	30.0	0.55	12.61
11	3.80	0.0011	60	6.79	0.0038	30.0	2.99	44.04
12	3.82	0.0011	60	7.09	0.0038	30.0	3.27	46.12
13	3.81	0.0011	60	8.12	0.0038	30.0	4.31	53.08
14	3.77	0.0010	60	7.00	0.0039	30.0	3.23	46.14
Total	39.19		640	92.73		416.8	53.54	57.74

Table-2 Analysis of the water saving benefit of the second intelligent water-saving irrigation experiment

Day	Test group (drip irrigation)			Comparison group (furrow irrigation)			Water saving assessment	
	Water supply (m^3)	Flow (cms)	Irrigation time (min)	Water supply (m^3)	Flow (cms)	Irrigation time (min)	Water saving (m^3)	Water saving rate (%)
1	4.14	0.0012	60				-4.14	
2							0.00	
3	1.97	0.0011	30	15.58	0.0042	62	13.61	87.36
4	1.99	0.0011	30	14.99	0.0042	60	13.00	86.72
5							0.00	
6	1.31	0.0011	20	5.01	0.0042	20	3.70	73.85
7							0.00	
8							0.00	
9	1.97	0.0011	30	7.84	0.0037	35	5.87	74.87
10	1.31	0.0011	20	5.71	0.0048	20	4.40	77.06
11							0.00	
12							0.00	
13							0.00	
14	1.30	0.0011	20	8.56	0.0036	40	7.26	84.81
15	2.30	0.0011	35				-2.30	
16							0.00	
17							0.00	
18							0.00	
19	0.66	0.0011	10	8.53	0.0036	40	7.87	92.26
20							0.00	
21				8.49	0.0034	41	8.49	100.00
22							0.00	
23							0.00	
24							0.00	
25							0.00	
26							0.00	
27	0.90	0.0005	30	5.57	0.0031	30	4.67	83.84
28							0.00	
29	2.03	0.0011	30				-2.03	
30				7.51	0.0032	39	7.51	100.00
Total	19.88		315	87.79		387	67.91	77.36