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Installation and set up the Smart water-saving irrigation techniques for coffee farm: The case study in Vietnam

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Abstract*— *Vietnam is among the most vulnerable nations to climate change impacts according to a recent International Panel on Climate Change report. The country's diverse geography means it is hit by typhoons, landslides, flooding and droughts, weather events expected to worsen in coming years. An inadequate of reserved water was the reason which made large-scale water reservoirs loaded only 20 - 40% capacity. Meanwhile, the small-scale reservoirs were almost empty and not able to supply water for farming and inhabitants. Consequently, thousands of crops area died on fire and could not be cultivated. Among them, cafe trees exhibited the most serious effects. According to preliminary statistics, up to now, the whole Central Highlands had up to 95,000 ha of crops lacking irrigation water, of which over 7,000 ha has stopped production due to lack of water. This study works on the installation and set up the smart water-saving irrigation techniques for coffee farm in central highland in Vietnam. The success of this research to agriculture not only saves water for crops, contributes to climate change adaptation but also opens a new step in agriculture, agriculture 4.0.
Keywords*— *smart water-saving irrigation, coffee farm, climate change, smart agricultural.

I. INTRODUCTION

Central highlands were determined as a potential agriculture region in Vietnam. Over the past years, climate change has caused several complicatedly dangerous weather phenomena in the area. In the year 2005, the average rainfall of the region is 60% in comparison with the observed values of other years. Moreover, 2015 was recognized as the most drought year in central highlands. Due to the effect of El Nino, Vietnam experienced 17 large-scale heat waves with 0.5 - 1.5 ^{o}C above the mean temperature of previous years, causing many damages for the production and living of people in the whole country. From the early year 2016, drought, water lacking, sanitization occurred widespread in the provinces of South Central, Central Highlands, and Mekong Delta with extremely high intensity in comparison with the year 2015. For instance, the prolonged drought made 123,000 and 319,000 people (the statistics were collected until mid-April) fell into a shortage of living water and foods in Central Highlands, respectively.

An inadequate of reserved water was the reason which made large-scale water reservoirs loaded only 20 - 40% capacity. Meanwhile, the small-scale reservoirs were almost empty and not able to supply water for farming and inhabitants. Consequently, thousands of crops area died on fire and could not be cultivated. Among them, cafe trees exhibited the most serious effects. According to preliminary statistics, up to now, the whole Central Highlands had up to 95,000 ha of crops lacking irrigation water, of which over 7,000 ha has stopped production due to lack of water. Large-scale severe drought affected the productivity and product quality over 100,000 hectares of coffee; Some dead coffee areas could not be recovered. This is a difficult problem that Dak Nong is facing at the present. Thus, overcoming this issue, water crisis, with urgent and effective solutions could lead Dak Nong as well as other provinces to higher productivity of crop and better living for people. The application of technology to agricultural production has been implemented in many countries around the world and brought about significant effects. So far, many studies related to crop water requirements have been carried out for higher grade Coffee arabica, [1-6] however, the study on the installation and set up the smart water-saving irrigation techniques for coffee farm do not have

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much works focus on that. In particular, water issue on coffee plant is a big problem in Vietnam because of climate change effect in Vietnam.

Herein, we have studied the installation and set up the smart water-saving irrigation techniques for coffee farm in central highland in Vietnam that not only access to economical irrigation technologies but have not gone into depth to calculate the necessary irrigation water needs of plants as well as approached automatic and intelligent agriculture. The success of this study is therefore of great significance due to the applying this research to agriculture not only saves water for crops, contributes to climate change adaptation but also opens a new step in agriculture, agriculture 4.0.

II. METHODOLOGY

2.1. Document review method: Understanding the situation of water scarcity in the study area, economical irrigation methods that have been and are being applied in the investigating area and the world, domestic and international investigation into water-saving methods on crops.

2.2. Field method: Field working in the study area to assess the potential of land, water resources; learning about climate characteristics, properties of plants and farming practices of the people.

2.3. Collecting information method: Collecting crop and land data, hydro-meteorological statistics in the study area.

2.4. Data analysis method: Using mathematical models to calculate the amount of irrigation water needed for plants and other analytical tools for data evaluation.

2.5. Technology application method: Applying information technology and wireless network to the remote control of intelligent irrigation model; installing and using solar energy as energy for data transmission for irrigation systems.

3. Results and discussion

The smart-economical irrigation model we have faricated that was conducted for about 96 5-year-old coffee trees which divided into 6 rows of the irrigated plot. A sprinkler irrigation system was installed at an altitude of about 0.5 m with a high injection pressure (180 l/h), a spray radius of about 3 m, ensuring to supply water for 4 opposite coffee stumps. A system of Soil Moisture Sensor was remotely controlled through the plant's wilting point, which assists not only to calculate and determine the right amount of irrigation water at the right time but also precisely and necessary for plants in the drought regions. **(Fig. 1)**

3.1. Establish a smart-saving irrigation model

Smart-economical irrigation model is designed with an irrigation pump system (including reservoir, pump, piping and nozzles), a control device system (central equipment, soil moisture sensor boxes), solar cell systems and soil moisture sensors.

The sensor was plugged into the ground. These sensors are responsible for measuring the current soil moisture. In case the soil moisture is lower than the need for the tree (the optimal humidity range has been set), the sensor system will transmit data to the central processor, where the irrigation command is set. The pump is then turned on (manually or automatically) and trees are irrigated until the sensor registers the desired humidity value.

Besides, a camera is installed on the model to help users monitor the operation of the pump system, irrigation valves via smartphones; and the solar cell system is responsible for providing power for the system's data transmission. **(Fig. 2 and 3)**

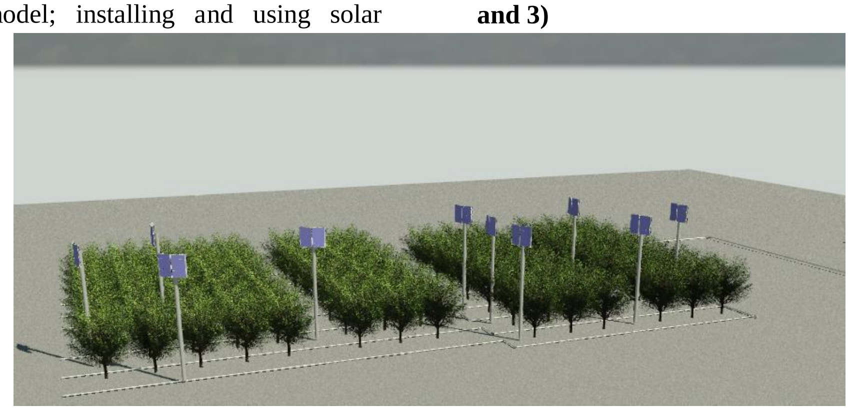

Fig.1: General irrigation model with rain-spray irrigation method in conjunction with soil moisture sensor for coffee plants (horizontally)

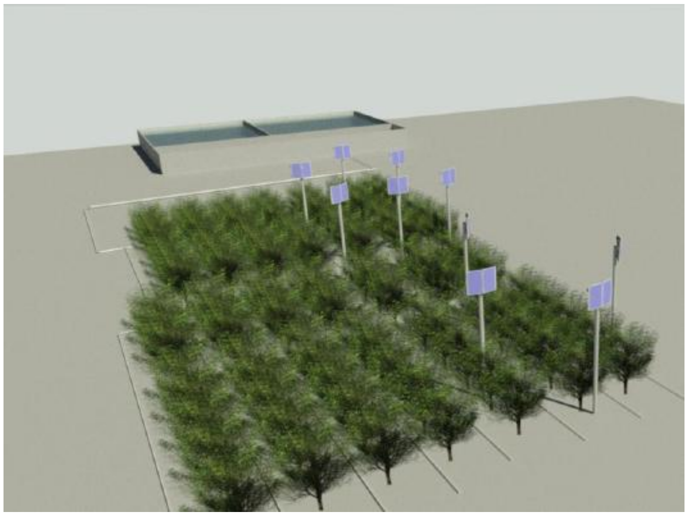

Fig.2. General irrigation model with rain-spray irrigation method in conjunction with soil moisture sensor for coffee plants (vertically)

Fig.3. Smart watering system remotely controlled by humidity sensor system

In this study, the CROP WAT 4.0 mathematical modeling method was employed to calculate the water demand for coffee plants. Based on information about soil properties, crop characteristics and climate in the study area, we calculated the irrigation water needs for coffee every month. Calculation results are shown in the following **Table 1**.

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Table 1. The irrigation water demand for coffee plants

P	0.26	0.27	0.27	0.28	0.28	0.29	0.29	0.28	0.28	0.27	0.26	0.26
T°C (2016)	23.1	21.9	24.6	26	25.2	24.6	24.2	24.2	24.2	23.9	23.7	22.6
MONTH	1	2	3	4	5	6	7	8	9	10	11	12
ET_o (mm/day)	4.96	5	5.35	5.73	5.63	5.74	5.69	5.49	5.49	5.26	5.04	4.9
Growing phase: business period												
K_c	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
ET_c (mm/day)	4.71	4.75	5.08	5.44	5.35	5.45	5.41	5.22	5.22	5	4.79	4.66
ET_c (mm/month)	141	143	152	163	161	164	162	157	157	150	144	140
P (mm/month)	61	0.3	26	87	284	412	281	224	239	278	79	33
Pe (mm/month)	27	-10	6	45	203	306	201	155	167	199	39	10
I (mm/month)	115	152	147	118	-43	-142	-38	1.2	-10	-49	104	130
I (mm/day)	3.8	5.1	4.9	3.9	-1.4	-4.7	-1.3	0.0	-0.3	-1.6	3.5	4.3
N	1.2	1.1	1.1	1.3	1.5	1.7	1.5	1.4	1.5	1.5	1.3	1.2
I l/stump/month	1042	1385	1335	1073	-387	-1293	-348	11	-93	-441	948	1182
I (l/stump/time)	43	49	51	45	-19	-71	-17	1	-5	-22	40	46

Where:

ET_0: Reference evaporation level

ET_c: Evaporation level of coffee trees

P: Actual rainfall

P_e: Effective rainfall

I: Irrigation water demand

3.2. Design of smart and saving irrigation system with soil moisture sensor operates by solar energy and using wireless sensors to remote controller

❖ **Installation of pumping and irrigation systems**

The irrigation pump system includes pumps, water lines, nozzles, flow valves, and water reservoirs. The model needs to calculate the water pipeline to optimize the efficiency of the irrigation system. [5-7]The design of pumping and irrigation systems are shown in Fig. 4 and 5.

❖ **Installation of central equipments**

Central devices are important for smart-economical irrigation. Central equipments are responsible for processing information, ordering irrigation and turning irrigation systems on and off. **(Fig. 6)**

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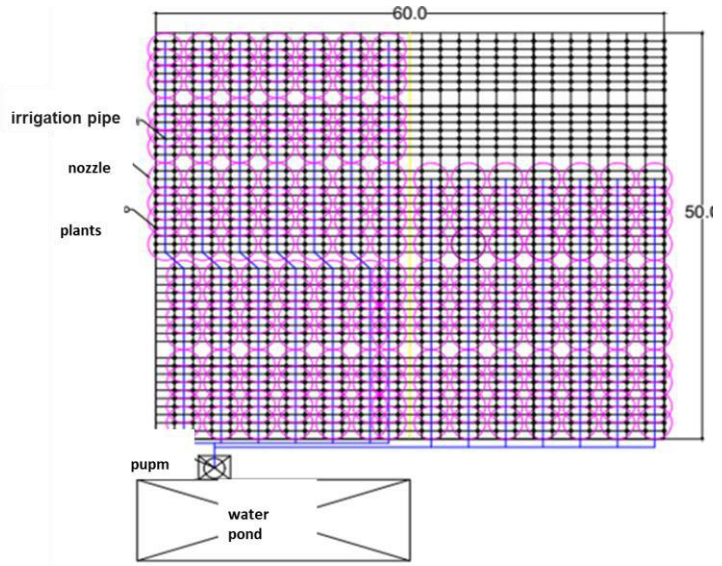

Fig.4. Nozzles for watering coffee plants

Fig.5. Pumping system for coffee plants

Fig.6. The center control box

❖ **Installing soil moisture sensors**

The moisture sensor is placed at a depth of about 80% of the roots. For coffee, roots are distributed mainly at a depth of 20 - 30 cm above the ground. However, the root system absorbs water most effectively at a depth of about 0 - 20 cm. [8-9]Therefore, the sensors are studied and installed at this depth. The sensor probe has a design length of about 15 cm, so during the installation, we must dig for more 5 cm deeper from the ground for the good position of the sensor, to ensure the entire probe is placed within the appropriate range (0-20 cm). **(Fig. 7 and 8)**

Fig.7. Installing a soil moisture sensor

❖ **Installation of solar cell systems**

The position of installing the solar power system is also used to determine the tilt angle of the solar cell so that when the system is fixed, it can receive the maximum total radiation intensity. In addition, tilting the solar panels has another meaning of self-cleaning. When it rains, due to the inclined surface of the battery, rainwater will clean the dirt on the cell, increasing the ability to absorb radiation of the battery.

❖ **Installation of the camera**

The camera has a role to help users monitor the smart-economical irrigation system. Therefore, the camera should be installed in a position that covers a large area of the study zone. Depending on the topographic, we can choose to arrange a dedicated camera support or make use of the tall tree trunks available to mount the camera in the area to be monitored.

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Fig.8. Installing soil moisture sensor system

Fig.9. Installing a Pole Mounted Solar Panel

3.3. Performance evaluation of smart-economical irrigation systems

10 sensors were assessed on a sample of a coffee tree (1-year-old) with a height of 0.7 m, a root length of 0.35 m, a root depth of 0.5 m. The model was carried out on a 1000 m^2 land area with 10 sensors installed at different locations. Soil moisture measurements were conducted at different times on February 4, 2019 (ensuring a change in soil moisture) and characterized soil moisture with a handheld device to verify the accuracy of the sensor system. After conducting experiments on mounting sensors on a testing area of 1000 m^2, the sensor has operated stably. The sensor informs the controller when it is time to increase the humidity of the plant. The trial system for coffee trees initially gave positive results. Accurate and high repeatability of screen results, continuous monitoring of soil moisture values, bring into play the advantages of the system due to the system's automatic shut-off mechanism when the required threshold for each type of tree is reached.

Fig.11. Spectrum Technologies standard sensor. Inc. of America

We can save significant amounts of water and still provide the optimal amount of water for plants. The effect is higher than the current popular irrigation methods (traditional irrigation). After evaluating the accuracy and stability of the

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sensor system, we found that the sensors maintain a stable error of 2.5% compared to standard sensor Spectrum Technologies. Inc. of America. Therefore, it is possible to evaluate the smart irrigation system - economical with accuracy and high stability.

III. CONCLUSIONS

The installation and set up the smart water-saving irrigation techniques for coffee farm in central highland in Vietnam have been studied in this work. The smart-economical irrigation model we have faricated that was conducted for 5-year-old coffee trees as well as the evaluation method the installed system. It can be seen that the process is simple and facile to install and set up. The success of the smart-economical irrigation model brings many economic benefits, with high applicability that was positive results; contribute to soil and water conservation, increase opportunities for sharing water and land resources in the community.

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