Design and Fabrication the Smart Irrigation Technology Using Soil Moisture Sensor System for Vine in Ninh Thuan, Vietnam

V T T Ho¹, A N T Hoang², T D Thu¹ and N D Thi¹*

¹Hochiminh City University of Natural Resources and Environment (HCMUMRE), Vietnam
²Standing officer of National Scientific Program on Natural Resources Environment and Climate Change, Ministry of Natural Resources and Environment

*Corresponding author: dtnga@hcmunre.edu.vn

Abstract. Vietnam's agricultural production depends heavily on natural conditions such as land, weather and irrigation water. Due to the impacts of climate change, the Central Highlands and the South-Central Coast region, Vietnam often suffer from prolonged drought conditions, wilting many crops such as coffee, apple grapes, pepper causing damage big socio-economy, affecting people's lives. According to the survey results of the Central Highlands Agriculture and Forestry Science Institute (WASI), over 73% of farmers irrigate water for crops, wasting water resources and increasing production costs. Therefore, the research for advanced irrigation technology, can determine the appropriate amount of irrigation water, at the right time for each type of crop, thereby saving the maximum amount of irrigation water but still ensuring productivity and capacity increase. In this study, we will develop methods, models and designs smart, economical irrigation systems using humidity sensors to regulate the amount of irrigation water sufficiently and at the right time by solar energy. We have designed a soil moisture sensor system using wireless sensor networks technology for remote control for watering enough and at the right time to supply crops. The Soil Moisture Sensor (Soil Moisture Sensor with accuracy: 0 ~ 50% (m³/m³) within ± 4% of working voltage: DC 3 - 5V. Average current <10 mA) with forecast time is about 1 ~ 60 minutes/time and operation time with solar power > 16 hours. Moreover, we have built a process of smart watering technology based on the Soil Moisture Sensor system and remote control for vine in Ninh Thuan province, Vietnam for the Vine farm 1000 m². The system has been tested in reality in vine research area in Ninh Thuan province, Vietnam for the Vine farm with 1000 m². The system includes automatic sensors connected to the central controller and the pump is simplified by buttons on the electrical cabinet or on the phone application, making it convenient for the farmer to operate and apply.

1. Introduction
The lack of fresh water is a rising concern, particularly in the Mediterranean countries or southern Asian countries such as India, Vietnam, Thai Lan. Among the countries in Asian, Vietnam is the most vulnerable to drought. A connection has been established between climate policies and water management. Water management can be affected strongly by different variables such as the water demand from the different sectors or the consequences of some degrees of warming on hydrological resources. Climate change and its effects are a recurrent topic in research papers regarding water
resources and agriculture. The possible consequences of global warming have led to the consideration of creating water adaptation measures to ensure the availability of water for food production and people and to maintain ecosystems [1-2].

Vietnam is a developing country, Vietnam’s agricultural production also depends heavily on natural conditions such as conditions of land, weather, water sources for irrigation ... When temperature increases, rainfall the change, the anomalies of weather factors increase, will greatly affect agricultural production, especially in farming activities. In addition, climate abnormalities lead to increased epidemics, pests, reduced crop yields, and many other risks in the agricultural sector. In recent years, in many localities, crops have been completely lost due to natural disasters (floods and droughts). In the Central Highlands and South-Central Coast Region, Vietnam a prolonged drought is occurring and has wilted a number of crops such as coffee, apple grapes, and pepper, and serious water shortage. Studies of water-saving irrigation such as drip irrigation, local rain spraying, and underground irrigation have been applied in Vietnam recently.

Especially in the current severe drought, it is very necessary to have an irrigation technology capable of more efficient water saving that can reach 40 - 50% of water savings, however methods current economical irrigation can save the amount of irrigation water, but it is not yet possible to determine the appropriate amount of irrigation water, at the right time for each crop, thereby saving the maximum amount of irrigation water while ensuring energy, plant growth rate. The research and application of information technologies in agricultural production, especially automatic watering technology, has brought about many great benefits and has been applied in developed countries. Most developed countries in the world apply information technology in agricultural production such as Israel, Japan, USA, Netherlands, Australia. Application of information technology in irrigation water management for crops. is currently the best method to determine the exact amount of irrigation water and crop factors. [1-5]. Other authors have performed studies with a focus on irrigation systems, water management or precision agriculture systems. However, the other available surveys on smart irrigation systems analyzed quite a few papers [6-11] and therefore do not focus on the design and fabrication regarding irrigation systems.

This work aims at designing and manufacturing soil moisture sensors, using remote control wireless sensor networks for providing plants enough water at the right times. Sensors are placed under the ground in accordance with the depth of the main root layer of plants at each stage of development. This can aid in ensuring fast and accurate sensitivity of minimum water requirements for best growth and development of trees, thus ensuring both criteria: saving water and creating optimal conditions related to amounts of water for the best growth of plants. The success of this work not only solves the current serious water shortage problem, but also contributes greatly to energy saving and fertilizer loss due to overprocessing, washing process when irrigating, minimizing the eutrophication of the receiving source, contributing to environmental protection towards green growth and sustainable development of water resources.

2. Material and Methods

2.1. Methods of calculation the irrigation demand for crops
This work uses a mathematical model (CropWat - calculating the irrigation demand for crops) to calculate the irrigation water demand for crops in the study area based on Data on weather conditions and crop characteristics, soil properties, farming-related data. CropWat 8.0 is software that calculates water and irrigation needs of crops based on soil, climate and crop documents. The program also allows to develop irrigation plans under different management conditions and to calculate water supply for different seasons. CropWat 8.0 is also used to evaluate farmers’ irrigation practices.
2.2. Designing smart watering system - saving: Designing smart watering system - saving by soil moisture sensor (Soil Moisture Sensor) operated by solar energy remotely controlled by wireless sensor.

The humidity sensor is designed based on the level of humidity suitable for plants. Specifically, in the day study, the humidity sensor was designed at 3 predicted humidity levels for crops: (1) appropriate humidity, no need to irrigate; (2) humidity warning, close to the irrigation threshold; (3) moisture danger level, need to water. The basis of designing the predicted humidity of the humidity sensor is based on the soil properties and the biological properties of the plants. The sensor system includes many sensor buttons placed on fields, gardens at specified positions. The sensor button consists of 2 parts: (i) the above ground components (solar panel, RF receiver / transmitter module, processing board) and (ii) the soil moisture sensor circuit is installed below ground with appropriate depth.

2.3. Methods of test operation of the sensors: The soil moisture sensors are solar-powered and placed underground at a depth that about 80% of the roots are distributed. Information about soil moisture will be wirelessly transmitted by sensors to the central controller for storage and processing. Based on the collected data, the central controller will output the control signal on/off the watering pump when the soil moisture reaches the pump level and stops the pump through the operator. Users can use computers or smartphones connected to the internet (or via phone messaging) to monitor the crop status and control the system instantly through the CCTV system. operation of the system. In which, the method of watering the vine is the method of watering the vine.

3. Results and discussion

3.1. Establish the method and smart irrigation model.
CROPWAT program is the model calculated the water balance (water demand and water should be provided) for crops based on the interactions between the weather conditions (such as temperature, rainfall, evaporation), the natural conditions of the soil and plant's characteristics. From the range of average figures since 2010 - 2016 include: temperature, rainfall, wind speed, humidity, evaporation is collected in the Center of Monitoring Meteorological in Ninh Thuan province; data of crop properties as root depth, plant height, the developmental stage of the plant is collected directly in the research area and reference factors from FAO; data of soil properties include: moisture limit the field (FC), point wilts (WP), the initial moisture content (by % of weight).

Results of suitable timing and amount of water for grapes in natural conditions of Ninh Thuan shown in the Table 1. Table 1 shows the need of water to grape is more than the need of coffee trees in the month. From May 12 to August next year, demand of water for grape irrigation more than the September to November 11. The peak of the dry season as May and June is the months demand the most of irrigation water. It is about 16 - 17 liters/tree/watering. In addition, there is the time that had activity of the hot dry West wind, evaporation is strong, so demand for crop irrigation water increases. Therefore, it is necessary to supply the suitable water for the growth and development of plants. Especially, in flowering stage should combine the suitable irrigation regime with suitable air humidity to keep the flowers are not be “wax cotton” and reduce the productivity.
Table 1. Determining the amount of watering for Ninh Thuan’s grapes

| Month | 1   | 2   | 3   | 4   | 5   | 6   |
|-------|-----|-----|-----|-----|-----|-----|
| Kc    | 0.75| 0.75| 0.5 | 1.22| 1   |     |
| R(mm) | 21.77| 11.75| 9.88| 39.04| 95.24| 69.25 |
| Rc (mm)| 3.06| -2.95| -4.07| 13.42| 52.19| 31.55 |
| ET\(_o\) (mm/day)| 5.17| 5.45| 5.60| 6.01| 6.12| 6.35 |
| Etc (mm/month)| 160.40| 114.46| 130.16| 90.14| 232.14| 190.47 |
| I (mm/month)| 157.34| 117.41| 134.23| 76.72| 179.95| 158.92 |
| n (day) | 1 | 1 | 1 | 1 | 1 | 1 |
| I (m\(^3\)/1000 m\(^2\) time) | 5.67| 4.73| 4.79| 3.28| 6.88| 6.35 |
| I (l/plant.time) | 14.17| 11.83| 11.99| 8.21 | 17.2| 15.86 |

| Month | 7   | 8   | 9   | 10  | 11  | 12  |
|-------|-----|-----|-----|-----|-----|-----|
| Kc    | 0.75| 0.75| 0.5 | 1   | 0.5 | 1.23|
| R(mm) | 73.86| 44.49| 129.64| 217.1| 235.59| 114.9 |
| Rc (mm)| 35.09| 16.69| 79.71| 149.68| 164.47| 67.92 |
| ET\(_o\) (mm/day)| 6.28| 6.06| 5.99| 5.66| 5.37| 5.06 |
| Etc (mm/month)| 145.92| 140.96| 89.83| 175.41| 80.62| 192.79 |
| I (mm/month)| 110.84| 124.26| 10.12| 25.73| 0.00| 124.87 |
| n (day) | 1 | 1 | 1 | 2 | 1 | 0 |
| I (m\(^3\)/1000 m\(^2\) time) | 4.53| 4.80| 0.52| 1.15| 0.00| 5.01 |
| I (l/plant.time) | 11.31| 12| 1.31| 2.87| 0 | 12.52 |

Note: P value: Percentage of annual average sunshine hours for the day of the month in an irrigation cycle by the formula Blaney – Criddle; ET\(_o\): The amount of potential evapotranspiration (mm / day); Etc: Water requirements of plants (mm / day); Kc: crop coefficient; T\(^\circ\)C: The average temperature in January (2016); I: The amount of water per day (mm / day); Pe: Effective rainfall (mm / month); P: Observed rainfall (mm / month).

Figure 1, Figure 2 and Figure 3 show the model for irrigation on vine in Ninh Thuan Province, Vietnam with the area of each type of tested crop is 1000 m\(^2\), experimental layout on 3 soil samples (1000m\(^2\)/sample to determine the number of repetitions). Model 1 is a model of economical smart irrigation system installation and fabrication; the same test is carried out with Model 2 and 3 that also has 1000 m\(^2\)/sample using traditional irrigation and irrigation method saving such as spray irrigation. Other farming techniques such as fertilizer, care, and pest management were not interfered (as farmers’ control). The model is expected to arrange 10 sensor sensors/1000 m\(^2\) of crops.

Figure 1. Diagram of low-range Sprinklers system combine with the humidity sensors.
Figure 2. Diagram of installation low-range and half-permanent Sprinklers combine with humidity sensor system.

Figure 3. Model of horizontal projection surface of low-range and half-permanent Sprinklers combine with humidity sensor system.

The testing pattern will be conducted for 400 grapes/1000 m², the tentacles of Sprinklers is in a height of 0.5 m and a radius of irrigation of 2 m. The pattern area is attached the humidity sensors to measure soil moisture and air humidity sensors to ensure supplied a suitable amount of water to the plant at different developmental stages. In the irrigation level, the system will automatically alarm to farmers and farmers just press the command accept, the irrigation system will start automatically and watered until reach the suitable humidity for the plant.

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

a) Design and manufacture of soil moisture sensor

Figure 4 shows capacitive sensor includes an oscillator circuit, part of the sensor probe is embedded in the ground. Frequency of operation will depend on the value of the dielectric constant of the soil. Because the dielectric constant of water (80) is much bigger than the other components of soil (soil minerals: 4, organic matter: 4, air: 1), therefore the changing the amount of water in the soil, the probe will measure the change in capacitance, which can determine the soil moisture.

Figure 4. Soil moisture sensor layout on software
b) Construction of a remote sensing system

The sensor network system including such as: central control, camera, soil moisture sensors using by solar panels, pump controllers, valve controllers. Detailed diagram of this system is shown in the following Figure 5.

![Figure 5. A wireless soil moisture sensor network](image)

A wireless sensor network consists of: central control unit (central controller 01); The soil moisture sensor (10 soil moisture sensors); water pumps and valves (01 controller pumps, valve control circuit 02); camera (01 system for observing pumps and valves of water); software monitoring and control: an application on android phone for monitoring and controlling.

Principle of activation is the soil moisture sensors measure the soil moisture, then they send the data to the central device by RF wireless. A center equipment processes it a display it on the LCD monitor, automatic control will send data on the cloud server. A center equipment allows applications on smartphones connected installation, configuration via a wireless connection. When soil moisture is outside the settings level, central device will display a warning on the LCD screen in place, sending alert messages, control play / interrupts the gateway control pumps and valves auto-matily, when the sensor reaches a suitable moisture the device will be stopped. Camera helps to observe the operation of the system of pumps and valves via smartphones. (Figure 6 and Figure 7)

![Figure 6. Simulation model assesses the ability to predict the humidity of the sensor and the sensitivity of a smart-economical irrigation system.](image)
Figure 7. All smart and economical sprinkler systems with moisture sensor system

3.3 Test results of irrigation systems for Ninh Thuan’s grape.

| Day/ hour           | Soil moisture (sensor) | Soil moisture (reality) |
|---------------------|------------------------|-------------------------|
| 18/01/2019 07:50:24 | 29.6                   | 29.95                   |
| 18/01/2019 08:00:05 | 32.52                  | 31.63                   |
| 18/01/2019 08:10:32 | 34.9                   | 33.4                    |
| 18/01/2019 08:20:55 | 31.7                   | 32.9                    |
| 18/01/2019 08:30:56 | 29.6                   | 29.95                   |
| 18/01/2019 08:40:43 | 32.7                   | 31.63                   |
| 18/01/2019 08:50:37 | 34.7                   | 35                      |
| 18/01/2019 09:00:40 | 31.7                   | 32.9                    |
| 18/01/2019 09:10:15 | 33.57                  | 33.55                   |
| 18/01/2019 09:20:48 | 33.43                  | 33.34                   |
Table 2 and Figure 8 shows the test assessed the correctness of sensors was fabricated in this work compare to the commercial sensor on vine growing land. We found that, the difference in soil moisture between the portable soil moisture meter (commercial sensor) and the moisture sensor in this work was approximately 2.5% less than the control moisture meter. Working voltage: DC 3 - 5V. average current <10mA), forecast time: 1 ~ 60 minutes/time and operation time without solar power > 16 hours. The system includes automatic sensors connected to the central controller and the pump is simplified by buttons on the electrical cabinet or on the phone application to help the farmer easily operate and control. The system ensures to provide the necessary amount of irrigation water for the plants. Smart irrigation system saves much crops by irrigating the right amount of water at the right time, ensuring productivity. This economical smart irrigation system can be applied to different local areas, different crops depending on climatic conditions, geographic characteristics and characteristics of each plant.

4. Conclusions
We have designed and fabricated the smart irrigation IRRIGATION using soil moisture sensor system for vine in Ninh Thuan province, Vietnam. We have designed a soil moisture sensor system using wireless sensor networks technology for remote control for watering enough and at the right time to supply crops. The Soil Moisture Sensor (Soil Moisture Sensor with accuracy: 0 ~ 50% (m³/m³) within ± 4% of working voltage: DC 3 - 5V. Average current <10 mA) with forecast time is about 1 ~ 60 minutes/time and operation time without solar power > 16 hours. Moreover, we have built a process of smart watering technology based on the Soil Moisture Sensor system and remote control for vine in Ninh Thuan province, Vietnam for the Vine farm 1000 m². The system has been tested in reality in vine research area in Ninh Thuan province, Vietnam for the Vine farm with 1000 m². The system includes automatic sensors connected to the central controller and the pump is simplified by buttons on the electrical cabinet or on the phone application, making it convenient for the farmer to operate and use. The system ensures to provide the necessary amount of irrigation water for the plants. Smart irrigation system saves much crops by irrigating the right amount of water at the right time, ensuring productivity.

Figure 8. The test assessed the correctness of sensors was fabricated in this work compare to the commercial sensor on grape growing land.
Acknowledgments
This research is funded by National project under grant number BDKH.08/16-20. Thank to Dr. Luong Vinh Quoc Danh, Can Tho University, Ms. Nhi Dang Thi Yen, Mr. Hong Minh Hoang, Mr. Pham Dang Minh, Ms. Huynh Thi Tho supported this work.

References
[1] Millán S, Casadesús J, Campillo C, Moñino M J and Prieto M H 2019 Water 11(10) 2061.
[2] García L, Parra L, Jimenez J M, Lloret J and Lorenz P 2020 Sensors (Basel), 20(4) 1042.
[3] Zhu X, Chikangaise P, Shi W, Chen W and Yuan S 2018 Int. J. Agric. Biol. Eng. 11 23–30.
[4] Smith M, Pereira L, Berengena J, Itier B, Goussard J, Tollefson L and Van Hofwegen P 1995 In Proceedings of the ICID/FAO Workshop on Irrigation Scheduling 12–13.
[5] Casadesús J, Mata M, Marsal J and Girona J 2012 Comput. Electron. Agric. 83 11–20.
[6] Shankar V, Ojha C and Prasad K. 2012 Int. J. Civ. Environ. Eng. 6 476–485.
[7] Jain S and Vani K S 2018 Int. J. Comput. Sci. Eng. 6 357–360.
[8] Joshi A and Ali L A 2017 Proceedings of the IEEE Conference on Engineering Devices and Smart Systems.
[9] Kansara K., Zaveri V, Slah S, Delwadkar S and Jani K 2015 Int. J. Comput. Sci. Inf. Technol. 6 5331-5333.
[10] Munoth P, Goyal R and Tiwari K 2016 Int. J. Eng. Res. Technol. 4 86–90
[11] Yahide P B, Jain S A and Giri 2015 M J. Res. Eng. Technol. 2 375–385.