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WATER QUALITY MONITORING FOR IRRIGATION IN SITE LOCATION MOARA DOMNEASCĂ

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ABSTRACT. Nowadays, IoT platforms have key-roles in almost all domains such as smart agriculture, health, cyber security, etc. The focus of this article is on water quality monitoring which can be improved by the use of wireless sensing networks and the implementation of the IoT technology. The aim of the article is to develop an efficient solution for farmers who irrigate crops with large amounts of water. The solution provided is based on multiple sensors (water quality, air quality, consumption, and climate) so that several parameters of the environment can be monitored simultaneously. The monitored parameters are conductivity, turbidity, salinity, precipitation levels, pH, dissolved oxygen and water temperature. The collected data will be filtered and translated into legible and meaningful data using intelligent algorithms for farmers. This paper is based on the experiments developed in the SWAM project, and the location where they were performed was chosen in Moara Domneasca. The location of the Moara Domnească Experimental Base, where the case study is implemented, is located 25 km from Bucharest, in the Commune of Afumați, Ilfov County in the Subunit of the Romanian Plain. Thus, the quality of the water used for irrigation purposes can be determined following the analysis and periodic monitoring of the parameters.

Keywords. Water and air quality, IoT, wireless sensing networks, irrigation, Romania

1. INTRODUCTION

The agricultural sector uses one-third of the water utilized in Europe, influencing both the quantity and quality of water available for other applications. Many users will attempt to reach their water needs as a result of rising demand and climate change. In the event of water scarcity, industry and households can develop ways to reduce water use, but water-dependent ecosystems are at risk of irreversible damage (Du Plessis, 2019).

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Crop irrigation is an area where new practices and policies can significantly facilitate efficient water use. In southern European countries such as Greece, Italy, Portugal, Cyprus, Spain and southern France with arid or semi-arid conditions present, almost 80% of the water used in agriculture is currently used for irrigation (Truchado et al., 2021).

The Internet of Things (IoT) (Nižetić et al., 2020) is a strategy of influencing Internet and communications technologies that are still expanding. It enables individuals and things to be connected using any path, network, and service in order to make their living more manageable and increase quality of life overall.

By use of smart devices, IoT facilitates the monitoring and management of irrigation water, allowing a close and detailed inspection of certain parameters (pH, temperature of the water, dissolved oxygen, etc.) that otherwise could not be possible. Irrigation procedures are extremely important in the agricultural sector and more efficient irrigation practices are developed and implemented every day. Thus, this paper proposes an IoT based water quality monitoring system for irrigation in order to increase water distribution efficiency and quality, in order to reduce waste and increase crop yield throughout the year.

The article is based on the study conducted in SWAM (Smart WAter Management system for better environmental sustainability) project which provides a valuable tool for water management including safe and security aspects, quality monitoring, decision support and cost-efficiency management. The location chosen for the implementation of one of the use-cases of the SWAM project is at the Moara Domnească Experimental Base, Romania.

The article is organized as follows: Section 2 describes the current state of the art regarding water quality and management in irrigation systems around the world. Section 3 presents the method used for monitoring the certain parameters (some of which are mentioned above) needed in order to assist farmers in their decision-making. Section 4 focuses on the experimental results and on the conclusions drawn from said results. Finally, Section 5 relates the main conclusion of the article and describes new directions for future development.

2. RELATED WORK

Thoradeniya and colab. (Thoradeniya et al., 2019) aims to find out people's perspectives on the impact of water on agriculture in rural agricultural areas of Sri Lanka. Following the discussions, all people seemed interested in the quality of water used in food development. People pointed out that the use of poor quality water, whether surface or groundwater, has high levels of hardness, and has led to problematic cultivation. Excessive use of chemicals and fertilisers is also a major source of pollution of water bodies.

After discussions with the inhabitants of these areas the solutions could be classified as: provision of filtration and treatment systems; reduced use of chemicals; educating communities about the importance of water quality. People argued that the government should also support them in this process, as they are offered limited quality water and only for domestic use, not for agricultural activities. The government and the communities need to work together in this process as it is in the interest of both parties.

Improving water quality faces many obstacles due to agri-environmental policies (Berthet et al., 2021). The problems are due to payment restrictions on farms. Innovative proposals have been worked on over time to overcome these constraints. To find a solution for water quality, 62 innovative agri-environment schemes have been analyzed. These have been grouped into nine types of instruments that can deliver water quality benefits and three main drivers for change have been identified: rewarding environmental investments, environmental performance, farmer collaboration and certification of agri-environmental practices.

Based on the analysis carried out, the rationale behind the problem is rewarding the environmental results provided, or encouraging collaboration between agricultural stakeholders. The diversity of schemes used in application reflects the variety of contexts. They depend on the geographical or historical context of the area.

De Mello and colab. (de Mello et al., 2020) highlights the importance of water quality in Brazil and the factors that threaten its quality. The expansion of the agricultural sector in Brazil underlines the need to keep water quality at optimum levels. Increasing deforestation, agricultural expansion and urban sprawl in Brazil highlight the need to protect water quality to ensure immediate human needs and to maintain the quality of water supplies in the long term. Related to land use/land cover patterns (LULC) have been identified as a significant cause of water quality deterioration. Mining and urban areas are the main factors affecting water quality. Water quality variables respond differently at different spatial scales, so spatial extent is a critical issue to consider in studies and management. Watershed modelling was applied to simulate the future impact of LULC changes on water quality.

Singh and colab. (Singh et al., 2018) describes the quality of water used in agriculture in India, which is also one of the main activities for which the country is known. Ensuring high water quality has become a challenge in India due to the fact that population and industry are continuously growing, and therefore causing water pollution. India's standards for water quality are based on four parameters as follows: sodium percentage, residual sodium carbonate, electrical conductivity and sodium percentage. In this paper, the water quality classification is done using indices. These are based on 12 parameters that classify water into 5 categories according to its quality, from the highest to the lowest. The proposed index will benefit water management authorities to ensure high water quality in agriculture and therefore more prosperous crops.

Bortoloni and colab. (Bortoloni et al., 2018) highlights the assessment of water quality in arid and semi-arid areas of the Mediterranean and the irrigation of agricultural areas where water parameters fall within certain limits depending on the type of crop to be irrigated. An irrigation water quality tool called IWQT has been developed to assist farmers in semi-arid and arid areas in irrigating their crops. The most important water parameters have been classified into three quality classes according to their effects on soil fertility, human health and irrigation systems. These indicators are agronomic quality indicators, hygiene and health quality indicators and management quality indicators.

Shah and colab. (Shah et al., 2019), studied the minimization of water quality with population growth and poor water management. The studies were carried out on 11 water samples collected from different sources, in which several physico-chemical parameters such as pH, electrical conductivity, cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (Cl^-, HCO^{3-}, SO_4^{2-}) were analysed. Irrigation water quality was assessed using indices such as Kelly ratio (KR), permeability index (PI), sodium uptake ratio. Water from different rivers was used to irrigate several crops. The water quality index (WQI) was used to determine the suitability of water for different types of crops. It was discovered that some characteristics are connected with each other and that there are fewer peripheries in the data set using statistical parameters such as correlation matrix or dendrogram. From the analyses, it was concluded that most of the collected samples are not suitable for either drinking or irrigation.

Gerdes and colab. (Gerdes et al., 2022) studies the quality of water used by farmers to irrigate their crops so that the quality of vegetables/fruits does not deteriorate. Farmers must carry out a microbial water quality profile of 20 samples for each water source used for irrigation, with five samples per year. They must use the MWQP (Microbial Water Quality Profile) to establish a geometric mean of less than 126 CFU/100 ml and a statistical threshold value of no more than 410 CFU/100 ml of generic Escherichia coli.

Samples were collected from freshwater tidal rivers and ponds in the Mid-Atlantic region of the US over two years to determine if testing frequency could be reduced without compromising accuracy. Analyses of the water samples concluded that MWQP could be generated on more than 20 samples, reducing the economic burden on farmers and maintaining a representative MWQP.

3. MONITORING METHODS

Regarding the monitoring method, we make use of the advantages of the SWAM platform, an IoT based platform, through the sensor network and paradigm implementation (Drăgulinescu et al., 2021). A number of carefully selected sensors is used in order to monitor important parameters of the environment simultaneously such as: water quality, air quality, resource consumption and climate change. The MQTT (Message Queuing Telemetry Transport) protocol is utilized to transfer the data collected by the sensors, mainly for its low resource consumption and lightweight overall. However, because MQTT requires an active Internet connection, the WiFi protocol is also used. The data is then processed into something more manageable and meaningful with the help of intelligent algorithms (Drăgulinescu et al., 2021).

The chosen location for the case study is the Moara Domnească Experimental Base, 25 km from Bucharest in the Commune of Afumați - Moara Domnească, Ilfov County in the Vlăsiei Plain, a subunit of the Romanian Plain. The site is located at

400 30 ‘north latitude and 260 13’ east longitude, at an altitude of 90 m above sea level.

Detailing the values of the main climatic elements, the area is characterized by average values of air temperature of 10.50°C, precipitation amounts of 564 mm and annual averages of relative air humidity of 78.6%.

The Libelium Water Xtreme (Skarga-Bandurova et al., 2020) station is used for the monitoring of pH (the activity of hydrogen ions in the measured solution), average water temperature, dissolved oxygen, oxidation-reduction potential, conductivity, turbidity and water level (the amount of rain or precipitation that can affect the water quality of surface water and also the amount of groundwater). The station also consists of several wells: OPTOD - optical sensor for dissolved oxygen, C4E - conductivity and salinity sensor, PHEHT - pH sensor, ORP MES5 - sensor for measuring solid suspensions, turbidity and sludge level, Radar level Vegaplus C21 - water level sensor that indicates the volume of water in the pool.

The station is located near a place of water accumulation from the groundwater in the urban area, being powered by a solar panel in order to achieve independence from the energy point of view and versatility regarding location and placement (Figure 1).

Fig. 1. Libelium Water Xtreme station

The sensors used to measure the parameters (dissolved oxygen, ORP, pH, water conductivity, water temperature) are connected to the actual station by means of long cables that stretch from the water storage site as seen in Figure 2. Thus, with periodical measurements, it is monitored the quality of the irrigation water.

Fig. 2. Cables that connect to the sensor

4. EXPERIMENTAL RESULTS

The measured parameters were monitored for two weeks, in order to draw conclusions regarding the quality of the water. One of these parameters is pH, which is significant in agriculture because it has the capacity to regulate plant nutrient availability by influencing chemical reactions and altering the chemical forms of different nutrients. This way, crop and soil productivity is linked to the pH value of the water, different crops requiring different concentrations. Below, there is a graph from the Grafana dashboard showcasing the pH levels observed in the water during the aforementioned two weeks (Figure 3).

Fig. 3. Quality of water - pH evolution (2 weeks)

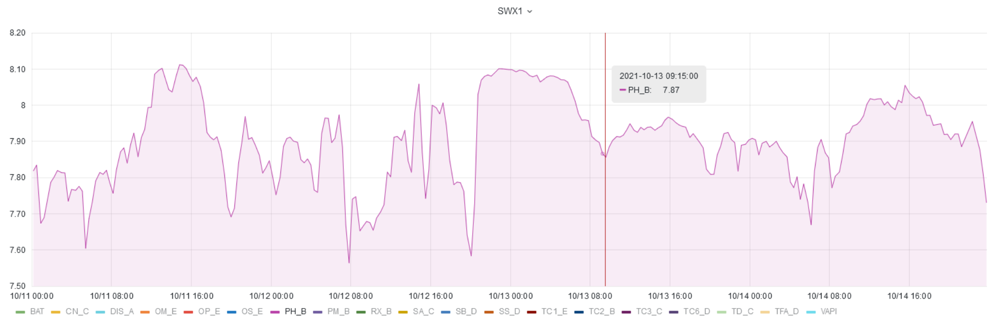

Fig. 4. Quality of water - pH evolution (10/11 – 10/14)

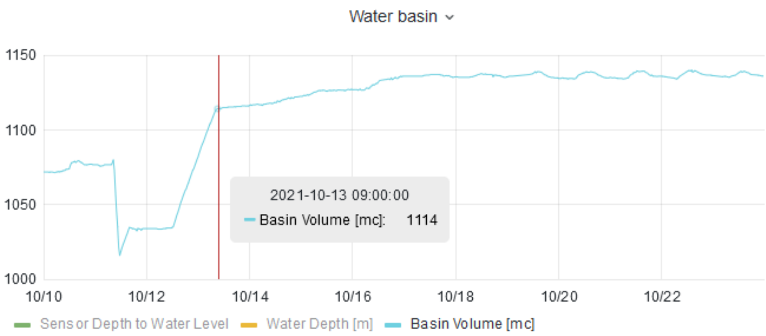

Fig. 5. Level of water on 10/13

Observing the weather during this period it is noticeable that one relatively low value of pH in the water was detected on 10/13, a day that recorded precipitation as shown by the rising level of the water (Figure 5). For a better exemplification, we chose a period of three days in which the level of water was high due to precipitations (Figure 4). Thus, a correlation between the low levels of pH in the water and the amount of precipitation was identified.

Similarly, the Oxygen Reduction Potential (ORP) level also influences crop growth and development. The ORP of a lake or river is a measure of its ability to cleanse itself or break down disintegrating waste products such as pollution and dead plants and animals. When the ORP value is high, it indicates that there is a lot of oxygen in the water. Bacteria that break down dead tissue and pollutants will be able to work more efficiently as a result.

Fig. 6. Quality of water - ORP evolution (2 weeks)

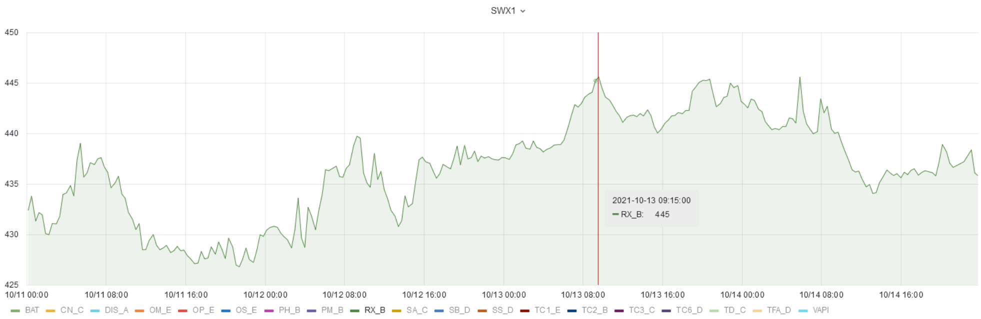

Fig. 7. Quality of water - ORP evolution (10/11 – 10/14)

In Figure 6, the recorded values for the ORP of the water for the two weeks period are presented. One high value was recorded on 10/13 (Figure 7), a day that also recorded a low pH value (Figure 4), indicating a link between high levels of ORP and low pH levels.

The conductivity level of the irrigation water is measured as a way to indicate its salinity. High conductibility usually indicates a high level of salt and other impurities in the water. These can be dangerous if they accumulate near the root, adversely affecting crop yields.

Fig. 8. Quality of water - Conductivity evolution

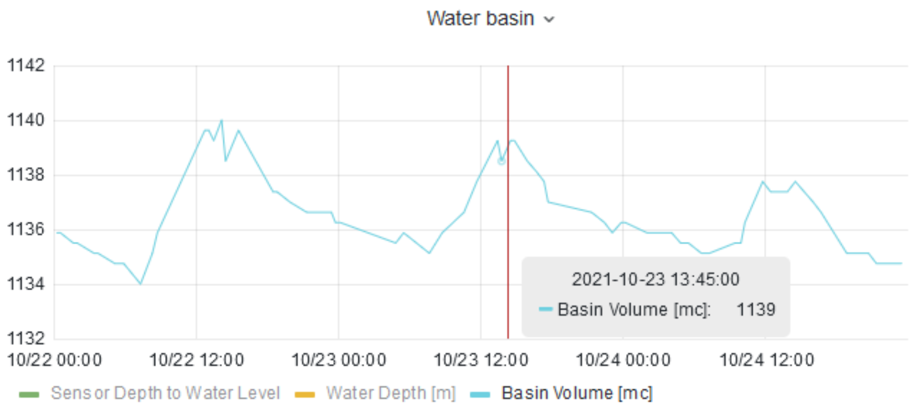

Fig. 9. Level of water on 10/23

Figure 8 presents the collected values of conductivity during the experimental period. The low value recorded on 10/23 shows a decrease in conductivity due to the amount of rain present as the day showed the presence of precipitation as well, as seen in Figure 9.

The amount of Dissolved Oxygen in the water was also measured. High levels of Dissolved oxygen are linked to an increase in a plant's overall health. An elevated level leads to an increase in nutrient uptake and conversion efficiency affecting the growth and development of roots, vegetative and flowering characteristics and thus, an increase in crop yield.

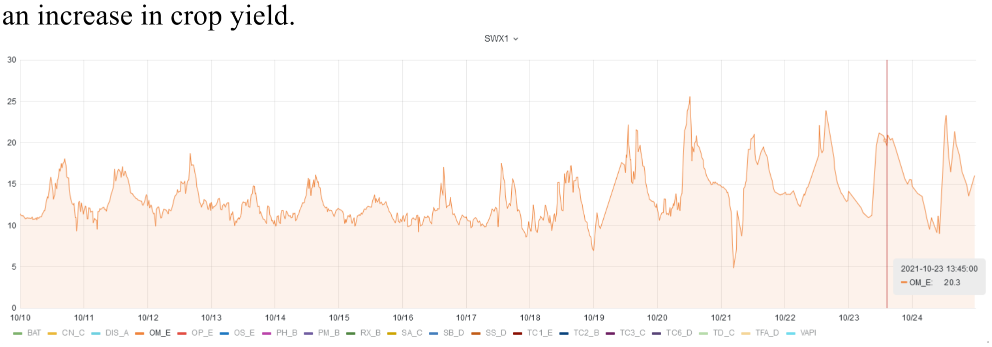

Fig. 10. Quality of water - Dissolved Oxygen evolution

Figure 10 shows an increase in oxygen levels on 10/23. Precipitation was recorded during that day, pointing to a link between high levels of dissolved oxygen and precipitation. Moreover, a link between low conductivity levels (caused by the rain) and high Dissolved Oxygen levels can be made. The lower the salinity of the irrigation water, the higher the rate of oxygen dissolution, suggesting an increase in the nutrient uptake of the crops.

Fig. 11. Quality of water - Water temperature evolution

The last measured parameter is water temperature (Figure 11). Its importance stems from the crop damage coming as a result of cold water in the irrigation system. A low temperature of the water can cause plants to go "dormant", as they try to adapt to the harsh conditions. This can have a lasting impact on crop growth and yield.

5. CONCLUSIONS

Irrigation water quality and management is beginning to play an important role in the current global dynamics, population increase and climate change accelerating the consumption and waste of increasingly vital resources. This system provides a relatively low-cost and easy to manage solution to this problem. By using IoT and smart devices, important parameters of the irrigation water can be measured and observed, giving farmers the tools to easily access and monitor the conditions of their crops with the main goal of increasing yield and reducing waste.

As for future research, a system to monitor the quality of water used on farms coming from nearby rivers is proposed, extending the capabilities of the current system.

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