ADAPTING SMART IRRIGATION SYSTEMS - SUSTAINABLE SOLUTION FOR THE FUTURE

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Abstract: *The paper provide an analysis of the nowadays Smart Irrigation Systems. After a presentation of actual trends in irrigation for precision agriculture, followed by a SWOT analysis, the paper presents a case study regarding the concept of a combined micro-irrigation dripping system using rain water buffered by regular water network and how to calculate the collecting and storage system;*

Key words*: Smart irigation, precision agriculture, dripping system, rain water*

INTRODUCTION

In Europe, a huge quantity of cubic metres of water every year are used not only for drinking water, but also applied in farming, manufacturing, heating and cooling, tourism and other service sectors. With thousands of freshwater lakes, rivers and underground water sources available, the Europe water supply may looks without limits, lasting for ever. In fact, after a deeper analysis, situation looks a little bit different due to population continuous growth evolution, urbanization proceses, high pollution and the already visible strong effects of the climate change, such as persistent droughts, not only on European water supply, but also on its quality. In fact, water stress is a problem that affects millions around the world, including over 100 million people in Europe [14].

Similarly to many regions in the rest of the world, worries over water stress and scarcity are increasing in Europe too, amid an increased risk of droughts due to climate change. About 88,2 % of Europe's freshwater use (drinking and other uses) comes from rivers and groundwater, while the rest comes from Reservoirs (10,3 %) and Lakes (1,5 %) [8], which makes these sources extremely vulnerable to threats posed by over-exploitation, pollution and climate change.

In this regard, water consumption became one of the most worring environmental problem, and not only in Europe, but in many areas around the globe. The main objective of many researchers focus nowadays to reduce the volume of water wasted with clasical irrigation systems by different solutions (dripping, applying AI methods) creating water management systems able to optimize the usage of the water in agricultural irrigation.

SMART IRRIGATION SYSTEMS

Water is the universal "growth" regulator for agricultural crops. Too much or too little, in the wrong time of the cropping or growth cycle can be disastrous. Access to a continuous supply of high quality water is an essential fact for high quality and high yield of the crops. Because it is expected that in the near future the industrial and municipal water use will out-compete agriculture, we have to find solutions to mitigate the risk.

Irrigated agriculture depends of several water sources. It can be withdrawn from flowing streams or rivers, provided by canals from major rivers, pumped from lakes and reservoirs formed by building dams on major rivers, pumped from lakes, ponds and tanks formed by collecting rainwater, and pumped from ground water.

"Water quality" generally refers to the presence or absence of dissolved substances that the water contains, as salts (NaCl, and Ca, Mg carbonates, derived from fertilizers, including nitrates, phosphates, and sulfates), pesticides, heavy metals, fecal coliforms [3].

Irrigation has been practiced in various forms since the earliest days of crop production. The crop characteristics, availability of power, capital investment, and ability to manage technology must be considered when determining which technology will be used. Efficiency of water use varies drastically depending upon the system used.

There are different types of irrigation systems [13]:

1. flooding: levees are drawn around the area to be irrigated, and the area is flooded periodically to satisfy crop demands.
2. furrow irrigation: crops are planted on ridges or beds in level fields, and water is flooded into the furrows between rows;
3. sub-irrigation: drainage ditches are dammed and flooded so that irrigation water "backs up" into the drainage system and penetrates into root zone by capillary action;
4. overhead irrigation: water under pressure is sprayed (sprinklers, irrigation gun, or center pivot) or dripped (LEPA (low energy precision application)) onto crops from overhead;
5. micro-sprinklers: water under low pressure is sprayed from low volume emitters located at the base of trees or in containers;
6. drip irrigation: water under low pressure is "leaked" from plastic tubes (T tape) or porous rubber tubes; fertilizer may be added (fertigation);
7. subsurface drip irrigation: as in drip irrigation except the drip tubes are buried under rows within the root zone;
8. hand watering; water is applied by worker using hose and hose-end water breaker;
9. watering robot; water is applied in greenhouse by overhead boom fitted with coarse nozzles that traverses benches periodically;
10. capillary matting: water is dripped onto water-retentive porous matting upon which pots are placed; pots take up water by capillary action; sand beds often used for same purpose in outdoor nursery container production;
11. ebb and flood: greenhouse containers are placed in water proof trays fitted with drains; trays are flooded periodically (daily or every-other day), and pots take up water (and nutrients) by capillary action; after watering cycle, solution drains into storage tank where it is held until the next irrigation cycle.

The decision on which method to use is dependent upon many factors as cost of the technology (equipment and management scale) relative to the cropping system, availability of water, water quality, potential problems caused by leaf wetting, leaching of contaminants into ground water, skill of management required.

An efficient water management systems is a major concern in many countries and cropping systems. If we refer to clasical irrigation techniques applied in farms, it proved that most of the cases they are inefficient and waste excessive volumes of water to maintain the yields in an optimal range [4].

Unlike traditional irrigation controllers that operate on a preset programmed schedule and timers, SMART Irrigation Systems (SIS) controllers collects information from sensors, send it to the central controller which analyse and integrate with the user values and decide when and how much to open valve controlled actuators or start the pumps or start/stop the water sprinklers. There are another types of sensors which collect data and monitoring weather and soil conditions, air temperature and humidity, evaporation and plant water use to automatically adjust the watering schedule to best fit to the actual conditions of the site.

There are 2 general types of SIS, depending of their scale. One type is based of imagery data collected from sattelites or drones, identifying changes in NDVI, acting to integrate pumps/ sprinklers in the irrigation process. These are usually addressed to high cultivated areas, because of high costs involved with imagery and water controlling infrastructure. These are usually complete solutions,which can be easily integrated to IoT and AI. The second types are the SIS based on microcontrollers as Arduino, Raspberry PI, etc. which are low cost, DIY compatible and small energy consumers. These SIS collects information from affordable sensors, integrate data from soil, plants or weather with internet support and are able to provide less consumption of water with short costs of infrastructure, making it the best applied solutions for small and medium farms, providing a longterm positive impact both in farm economy and environmental sustainability.

The evolution of smart technologies has led most researchers and engineers to adopt this evolving technology into the agricultural sector. The smart irrigation system is aimed at making sure crops grown on farms have the desired amount of water needed for their growth. Diferent SMART irrigation concepts were developed during the last few years.

For example, Siyu et al. [10] developed a smart watering irrigation system where they connected an Arduino microprocessor controller to a soil moisture sensor that provides moisture in the soil. They connected an actuator to the controller which was also able to command a pump. The actuator was triggered if the soil moisture fell below the desired threshold. The data was then sent to a database server and visualized on a web interface.

Michael et al. [9] developed a smart irrigation system consisting of a timer, a Soil Moisture Sensor (SMS) and SMS controller. In their setup, the irrigation timer is connected to a solenoid valve through a hot and a common wire. The common wire is spliced with the SMS system (a controller that acts as a switch, and a sensor buried in the root zone that estimates the soil water content). The SMS takes a reading of the amount of water in the soil and the SMS controller uses that information to open or close the switch. If the soil water content is below the threshold established by the user, the controller will close the switch, allowing power from the timer to reach the irrigation valve and trigger irrigation.

Another automated irrigation system was developed by Harishankar et al. [5], system that uses solar as its source of power. The proposed irrigation system was used to drive a pump which further pumps water from a bore-hole into a tank. The outlet valve of the tank was automatically regulated through the use of a micro-controller and a moisture sensor.

Another system was developed by Archana et al. [1], in which the humidity and soil moisture sensors are placed in the root zone of the plant. The microcontroller coordinates the way water is supplied to the roots based on the readings from the sensors.

Yunseop Kim [7] proposed a different system in which the field conditions were site-specifically monitored by six on-field sensor stations.

A different irrigation system was conceived and realized by Sonali et al. [11] in which soil parameters such as pH, humidity, moisture and temperature are measured for getting high yield from the soil. Their system was fully automated which turned the motor pump on/off as per the level of the moisture in the soil.

R. Subalakshmi [12] proposed a system that makes use of a microcontroller and data sent over GSM. Based on the sensed values from soil moisture, temperature and humidity sensors, the GSM module sends message to the farmer when these parameters exceed the threshold value set in the program.

Las, but not least, Kansara et al. [6] proposed an automated irrigation system where the humidity and temperature sensors are used to sense soil conditions and based on that, a microcontroller controls the water flow.

Thus, Figure 1 presents the findings after the asessment of irrigation systems swot analysis.

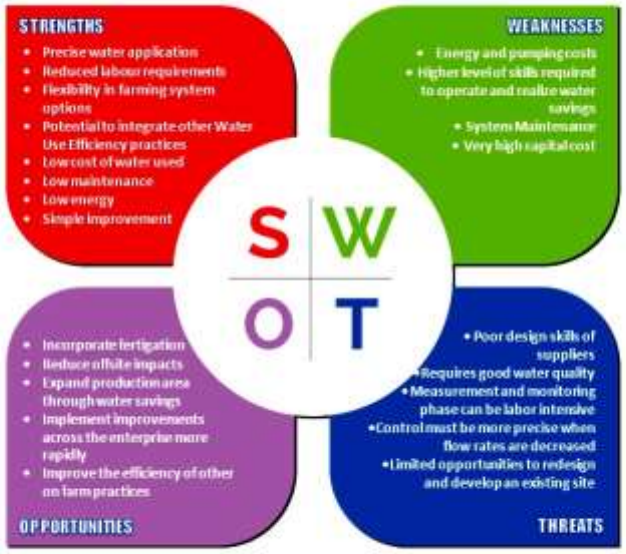


Figure 1. SWOT Analysis of Irigation Systems

COMBINED MICRO-IRRIGATION DRIPPING SYSTEM

The initial experimental dripping irrigation installation was established for a corn plantation, in order to test the efficiency of the dripping irrigation system and the entire system's possibility for scaling, without using the mulch top cover.

Figure 2. Rain Water Calculator for Small and Medium size Farms

Length of the corn lines were set-up as 435 meters, and the entire crop surface was 38,9 Ha. Can be observed from the photos that at the end of the corn lines water exists, the pipes being arranged between each second corn line.

With this configuration, the experimental results have shown increased water-use efficiency (up to 67,7%), increased nitrogen-use efficiency (up to 161,9%), and increased crop yields (up to 21,1%). Results from this summer wheat crop have shown even greater success, but these numbers can vary greatly depending on annual rainfall.

Having these proved results, we decided to continue improve and develop our concept and to test the efficiency of the mulched dripping irrigation system for a tomato crop.

If we are talking about rainwater, collecting process can provide a really high-quality water source, which can be a good risk management strategy where other water sources limit growth of a green small farm business or when there are challenges in the quality of their existing water, offering a real opportunity in preserving water sourcesand diminishing the effects of the climate change.

As presented in the JRC report, the projected changes in regard to the climate changes showed that the annual average precipitation will increase in northern and north central Europe, while it will decrease in southern Europe. Annual precipitation patterns will also change. Southern Europe will experience lower rainfalls all year round. There will be less precipitation during summer time in Atlantic and continental Europe, but more winter precipitation. Decreases in annual average precipitation in southern and central Europe can be as high as 30-45%, and as high as 70% in the summer in some regions. As a result of this, and warmer summer temperatures, the risk of summer drought is likely to increase in central Europe and in the Mediterranean area [2].

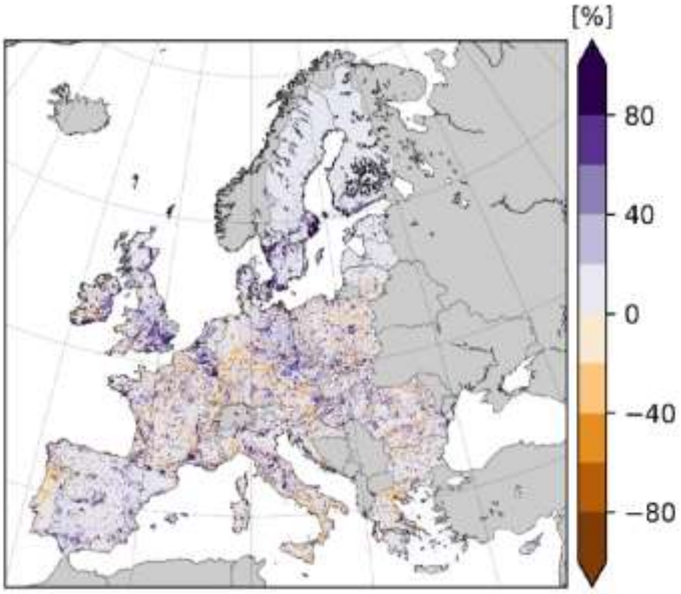


Figure 3. Projected changes in water demand by 2050 as compared to 2010, for all sectors except irrigation. These changes are due to projected population, GDP and GVA changes mainly

Source: JRC, 2018

So, the our concept comes to counterstrike the future increasing demand of water used for irrigation combined with the previewed reduction of the precipitation quantity, especially in the Southern Europe.

The functioning principle of the SMART Irrigation system is presented in Figure 4, an Arduino-based automated irrigation system that involves switching the irrigation drive as per the real time data provided by the soil moisture sensor has been proposed.

It can be observed that it consists of two parts, the transmitter and the receiver. Each of the both parts are using an Arduino board. On one hand, the transmitter collects data from the soil moisture sensor (Soil Hygrometer Humidity Detection Module Moisture Sensor Geekcreit for Arduino) and the temperature and humidity sensor (DHT11), which transmit data using a radio through a 433Mhz Wireless RF Transmitter Module Geekcreit to the paired 433Mhz Wireless RF Receiverer Module Geekcreit Receiver, mounted to the Arduino Receiver.

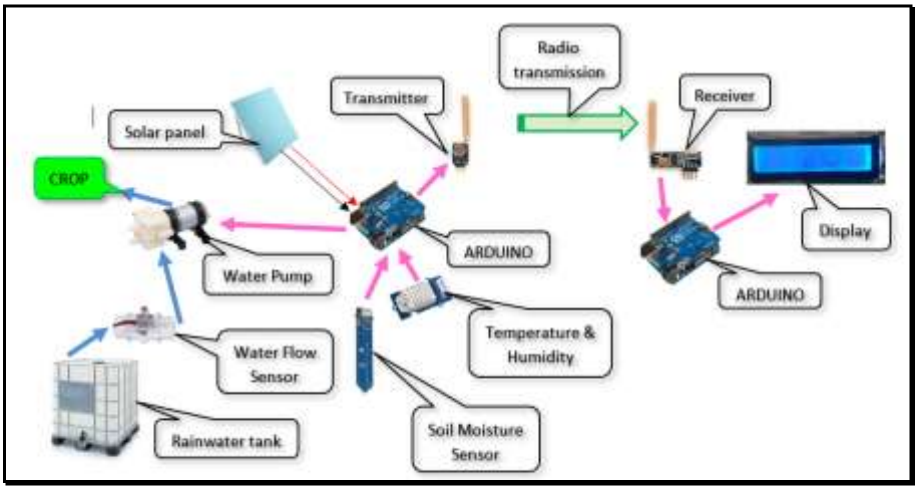
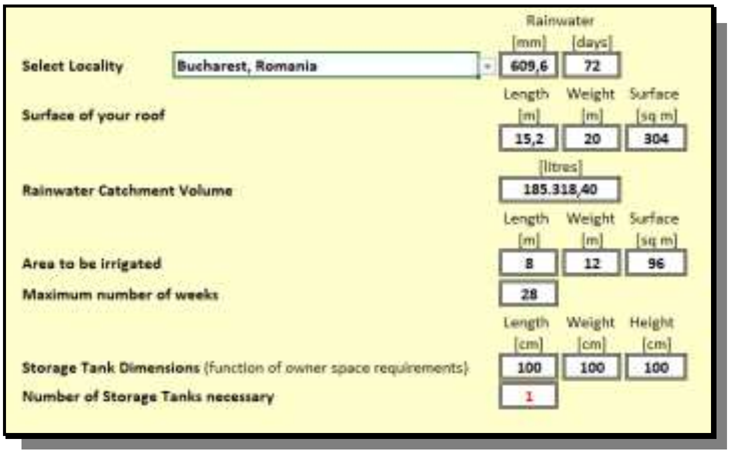


Figure 4. Functional principle of the SMART Rainwater Irrigation System

The receiver, which shows the informations on the Geekcreit® IIC / I2C 1602 Blue Backlight LCD Display Screen Module, processes the information and drives the water pump DC 12V Solar Powered Water Pump Motor Brushless Magnetic Submersible Water Pumps from the Rain Water tank, which monitors the used rainwater quantity by a water flow sensor DN15 Transparent Water Flow Meter Flow.

RESEARCH RESULTS

The first target was the development of the rain water tank calculator function of the geographical position, surface of the collecting roof and the space available for the rain storage tank. The developed calculator is presented in Figure 5.



		Rainwater [mm]	 [days]	
Select Locality	Bucharest, Romania	609,6	72	
		Length [m]	Weight [m]	Surface [sq m]
Surface of your roof		15,2	20	304
		[litres]		
Rainwater Catchment Volume		185.318,40		
		Length [m]	Weight [m]	Surface [sq m]
Area to be irrigated		8	12	96
Maximum number of weeks		28		
		Length [cm]	Weight [cm]	Height [cm]
Storage Tank Dimensions (function of owner space requirements)		100	100	100
Number of Storage Tanks necessary		1		

Figure 5. Rain Water Calculator for Small and Medium size Farms

As can be observed, the calculator uses a data base of the European regions [15], which just by accesing the location menu, consider the precipitation quantity and number of day with precipitation per year, data necessary for calculating the quantity of rain water and the size of the storage tank. The calculation algorithm take in consideration not only the average of yearly precipitation quantity, but also the frecquency of rainy days, which is essential in determination of the storage tank capacity.

Figure 6. Rainwater Tank used

Thus, for the proposed garden to be irrigated in total surface of 96m^2, in the southern part of Romania, the necessary size tank in order to insure independence of rainwater irrigation system determined was 1(one) recipient of 1000L (Figure 6), case in which we have at our disposal a collecting roof surface of 300 m^2 and an average number of 72 rain days per year.

Using the Mulched Dripping Irigation (MDI) system, an economy of 66% was realised by analogy with the statistical data of the common tomato crop.

Figure 7. Experimental SMART mulched dripping irrigation system used

During the entire period since March 2020 until September 2020, the rainwater level in the tank did not dropped under one third of the tank capacity.

CONCLUSIONS

The efficient and effective use of water in irrigation systems is of critical importance for sustainable agricultural development, food security and overall economic growth. This is particularly true in light of global population growth, climate change and the competing demand for water from other economic sectors.

Thus, MDI is considered the most efficient irrigation method because it distributes water uniformly in the soil, restricts deep percolation, and minimizes unproductive evaporation from soil. Still, the effect of mulched drip irrigation on farmland during the growing season at a landscape scale remains unclear, despite being vital for developing optimal water resource management strategies in arid areas.

MDI is considered of maximum importance due to the use of eco friendly technologies, its mitigation on global warming effects, risk management on decreasing of chemical rains, offers a centralized irrigation monitoring by using an open source integrated development environment.

In terms of economical costs, MDI is also very accessible, the costs for the proposed system not overpassing 100 €, and with minimal knowledge can be DYI.

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