Stockholm Junior Water Prize
2022

Internet of Things Based Smart and Autonomous Agricultural Irrigation System

Cem Ege Ergün
Ahmet Ömer Erkenci

Bahçeşehir College İzmir 50th Year
Science and Technology High School

Republic of Turkey

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SUMMARY

One of the global problems of our age is the insufficiency of usable water resources. Agricultural irrigation is the area where usable water resources are consumed the most (~70%) in the world and in Turkey. Utilizing technology in agricultural irrigation makes significant contributions to the sustainability of usable water. With smart irrigation technologies, better quality products can be grown while using less water.

This study aims to reduce water use in agricultural irrigation systems without reducing the product yield. For this purpose, the Internet of Things software and electronic system have been developed, which determine the irrigation days and the daily water need of the product according to the agricultural product by using the weather data, and ensure the irrigation at the time when evaporation is the least, using solar energy.

The Node-RED platform was used to calculate the plant irrigation amount and time (according to weather data, seed information, and "Penman Monteith Reference Evapotranspiration (ET_0) Equation") by the prepared system. The interface of the system is also designed on the same platform. API (Application Programming Interface) service was used to pull weather data into the system. A database was established for seed information and other weather data. A Communication System has been established to send calculation information to the Irrigation and Renewable Energy System. The connection between Raspberry Pi used in the Communication System and Node-RED is provided by ThingSpeak, an internet of things platform. Data exchange between the communication system and the Irrigation and Renewable Energy System is provided with the nRF24 connection. Arduino Nano microcontroller was used in Irrigation and Renewable Energy System. A solar panel is used in the Renewable Energy section, which provides the energy needed by the Irrigation Department, which has a solenoid valve, water meter, communication module, and microcontroller. The energy provided by the solar panel was used by being stored in Li-ion batteries. Thus, a smart irrigation system that can be observed remotely, does not require any external energy, and performs daily data analysis autonomously has been developed.

The work carried out has achieved its purpose in the tests carried out to control the operation of the smart irrigation system. It has been determined that the features offered by the developed system are more useful than the alternatives used today.

Keywords: Smart irrigation, Internet of Things, Node-RED, ET_0, Autonomous system.

AIM

The aim of the project is to reduce the use of water in agricultural irrigation systems. For this purpose, a software, electronics, and a mechanical equipment, which determine irrigation days, calculate daily water need (plant irrigation amount) and the optimum irrigation time (the hour when evaporation is the least) according to the type of agricultural product, using hourly, daily, and monthly weather data, have been created.

Today, there are different studies on agricultural smart irrigation systems. However, an autonomous system that calculates the water need of agricultural products according to daily and monthly meteorological data and irrigates at the optimum time has not been encountered.

INTRODUCTION

The total amount of fresh water in the world is approximately 35 million km³ (2.5% of the total water in the world), of which only 0.3% (approximately 105,000 km³) consists of freshwater resources suitable for ecosystem and human use (WWAP, 2019). Global climate change, rapid urbanization, industrialization and agricultural activities are rapidly consuming insufficient usable water resources. When water scarcity is analyzed on the basis of Turkey, it is understood that meteorological drought of varying severity is effective in almost every region of Turkey, and this situation becomes a more serious problem as the years progress (MGM, 2021). At the same time, below-average rainfall in more than one season last year affected Turkey's drinking water supplies and groundwater reservoirs (NASA, 2021).

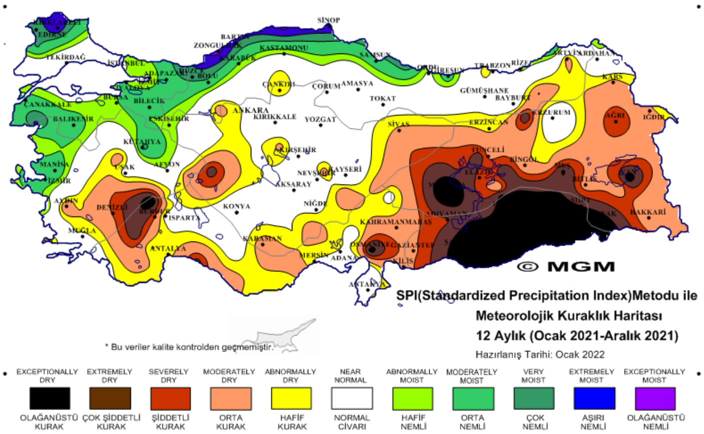
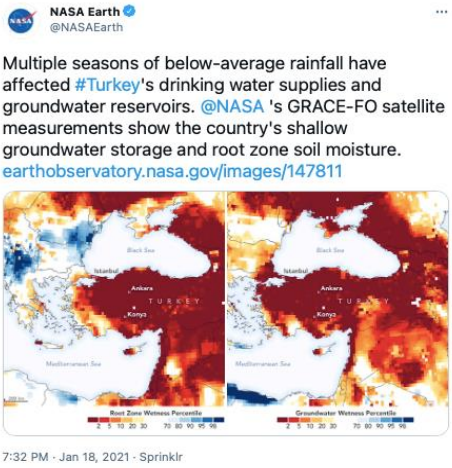


Figure 1: MGM Meteorological Drought Map for 2021



NASA Earth @NASAEarth

Multiple seasons of below-average rainfall have affected #Turkey's drinking water supplies and groundwater reservoirs. @NASA 's GRACE-FO satellite measurements show the country's shallow groundwater storage and root zone soil moisture. earthobservatory.nasa.gov/images/147811

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Figure 2: NASA Research Shared in 2021

Approximately 70% of usable water resources in the world are used in agricultural irrigation (FAO, 2020). In our country, 75% of usable water resources are used in agricultural irrigation (DSİ, 2020). These data shows that saving water in the field of agricultural irrigation is the most important factor in the sustainability of usable water resources.

The fact that most of the agricultural irrigation is conducted with traditional methods and the low use of modern methods such as drip or sprinkler irrigation causes inefficient consumption of our water resources (Sertyesilışık, 2017). In the irrigations developed by the Devlet Su İşleri, surface irrigation is used in 62%, sprinkler in 21% and drip irrigation in 17% (DSİ, 2019). In recent years, the use of modern irrigation methods such as sprinkler and drip irrigation has increased rapidly. When the specified irrigation methods are supported with smart irrigation systems, product quality increases along with water and time savings. In smart irrigation systems, reducing water consumption and increasing product quality are among the main objectives (Xiao et al., 2010).

Internet of Things technology is used in some smart irrigation systems. The concept of the Internet of Things (IoT) can be defined as a network structure in which devices and machines communicate data among themselves, collect data and make decisions based on the information created, without the need for human intervention or data entry (Aktaş et al., 2016). With the developing technology, products that used to be composed of only mechanical and electrical parts have turned into complex devices, even some into platforms, that connect to each other in numerous ways over the internet and combine hardware, sensors, electronics, and software (Oral et al., 2017).

The use of IoT technologies in the agricultural sector will make it possible to monitor the agricultural activities of the farmer and the status of the fields or greenhouses in real time with sensor networks and the data collected through these networks. It will also be possible to reach very different information and inferences from the data to be obtained (Comart et al, 2018). Monitoring weather conditions using IoT makes important contributions to irrigation systems. The internet of agricultural objects is promising in terms of increasing agricultural product and food production in the future by methods such as increasing product quality and product efficiency, reducing unnecessary chemical use, preventing environmental pollution, protecting resources, and controlling costs. Ensuring adequate water supply is important for the agricultural sector, as crops may be damaged due to water abundance or water scarcity (Comart et al, 2018). In addition to soil moisture and weather conditions, irrigation time is also particularly important in smart irrigation systems (Kamienski et al., 2019). The reason for this is to save water by reducing the amount of evaporation and to prevent the plant from being damaged by irrigation.

In recent years, smart irrigation methods have been developing in our country as well as in the world. The smart irrigation systems used in the agricultural sector in our country and the strengths and weaknesses of these systems can be listed as follows:

- **Electronic timer-based smart irrigation systems:** It is an irrigation system that automatically starts irrigation at the desired time interval. However, precipitation immediately after irrigation or before irrigation may cause excessive irrigation (Taştan, 2019). Therefore, the basic water need of the plant and weather conditions are not considered by the system.
- **Smart irrigation systems using sensors:** These systems, which monitors pH value, soil moisture level, temperature and humidity levels, are microcontroller based. Smart irrigation systems, created by using parameters such as weather and soil moisture together, have a more efficient irrigation potential than other traditional approaches (Taştan, 2019). However, due to the size of the agricultural areas where sensor systems are used, the cost of the system increases. Also, since sensors detect instantaneous values, sensor values cannot be used in plant water consumption equations. Therefore, how much water the plant will consume cannot be predicted in advance.
- **Smart irrigation systems using remote sensing technologies:** Many agricultural studies, especially classification of plant types with distinctive characteristics, monitoring of plant development, estimation of crop yields, determination of soil type and soil moisture, are conducted successfully with the help of remotely sensed images (Kavzoğlu and Çölkesen, 2011). Remote sensing technologies offer clear results. However, it is at a disadvantage due to the prohibitive cost of installation and the lack of instant irrigation intervention.
- **Smart irrigation systems using climate data:** Based on weather information, the water need of the soil can be determined with the help of artificial neural networks (Adeloye et al., 2012). The system automatically starts and stops watering. However, due to the use of long-term climate data, more or less irrigation than needed may be used. In addition, the basic water need of the plant is usually roughly calculated.

The advantages and disadvantages of smart irrigation systems used in the agricultural sector can be listed as follows. In the study conducted, a new smart irrigation system was designed by evaluating the advantages and disadvantages of the systems. Comparison of the features of the designed system and other smart irrigation systems used is given in Table 1.

Table 1: Comparison of Systems

SYSTEMS FEATURES	Developed System	Electronic Timer Based	Sensor Based	Remote Sensing Technologies Based	Climate Data Based
Autonomous Operation	+	By User's Choice	+	+	-
Using Weather Data	Hourly-Daily-Monthly	-	-	-	20-60 Years
Calculating Irrigation Amount Based on Seed Type and Weather	+	-	-	-	+
Determining the Optimum Hour and Irrigation Day	+	-	-	-	-
Informing the User	+	+	+	+	-
Irrigation by Measuring Soil Moisture	-	-	+	+	-

Soil moisture sensor was not used in the developed system. There are 3 reasons for this situation:

1. Soil moisture decreases at noon and irrigation in these time zones causes various damages for plants.
2. Evaporation reaches its highest values in the time periods when the humidity value decreases. Excessive evaporation causes water loss.
3. As the agricultural area grows, more sensors are needed to control the area. This increases the cost of the system.

The designed internet-based system was supported by weather data. It is aimed to calculate the amount of plant irrigation in the system and to determine the hour and day. “Penman Monteith Reference Evapotranspiration (ET_0) (total evaporation) Equation” was used to calculate the irrigation amount. Weather data required for calculating the equality over Node-RED platform was obtained via OpenWeatherMap API (Application Programming Interface), weather data and required seed information not available in this source were obtained from Cloudant NoSQL Database. The data exchange between the *Communication System* and the *Irrigation and Renewable Energy System* is realized by the nRF24 wireless communication module. *ThingSpeak*, which is the internet of things platform, provided the connection between *Raspberry Pi* whose software was made in Python language in the *Communication System* and *Node-RED* platform. *Irrigation and Renewable Energy System* is designed with Arduino Nano microcontroller, whose software is made in Arduino language. In addition, a solenoid valve, a water meter, and a communication module are used in the irrigation section. In the Renewable Energy department, which provides the energy needed for the irrigation department, a solar panel, charge controller, charge protection module, and Li-ion (lithium-ion) batteries are used to store the energy provided by the solar panel in order to obtain energy from the sun. In this way, a smart irrigation system that autonomously analyzes daily data and that can be observed remotely has been developed. With this application, irrigation can be done at the right time and in sufficient amount without the intervention of the user.

A test was conducted to check the operability of the prepared system. The test area consists of two parts of the same type of soil and the ground part between them is isolated. In both parts, irrigation was done by the sprinkler method. For the test, hazelnut radish (Raphanus Sativus var Radicula) seeds were grown and harvested. While manual irrigation was done with a mechanical water timer in one part, the smart irrigation system developed was used in the other part. The operation and design of the system are in the method section, the preparations and studies related to the test are in the method section, and the data collected in the test are in the results section.

METHOD

The proposed system is given in Figure 3. Accordingly, the basic components of the system are the *Calculation System*, where all calculations related to irrigation are made and presented to the user on the website, the *Communication System*, which acts as an intermediary for sending the output of the calculations to the system in the field of agriculture, and the *Irrigation and Renewable Energy System*, which ensures the realization of irrigation in the field of agriculture.

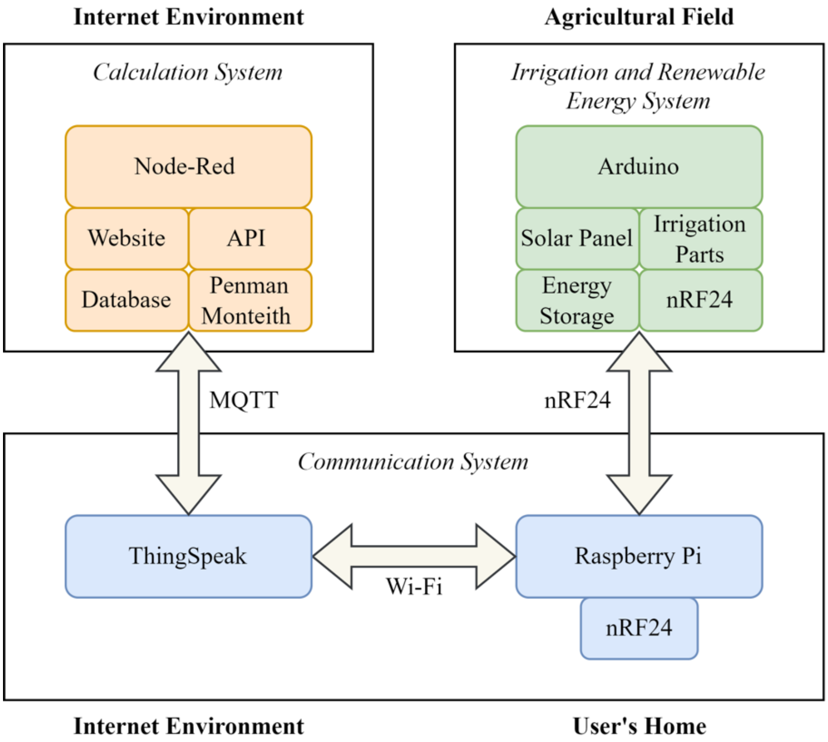


Figure 3: System Diagram

1) Calculation System

This section includes making calculations related to irrigation, collecting weather data, communicating with the *Communication System* and entering data into the interface (*Website).*

Software System:

Node-RED, an IBM Cloud service, was used with cloud technology in the system. The interface was designed with *Node-RED* and all calculations were made autonomously. The Coudant NoSQL was used as the database, and the *API service* of Open Weather Map company was used to instantly capture various weather data (Figure 4).

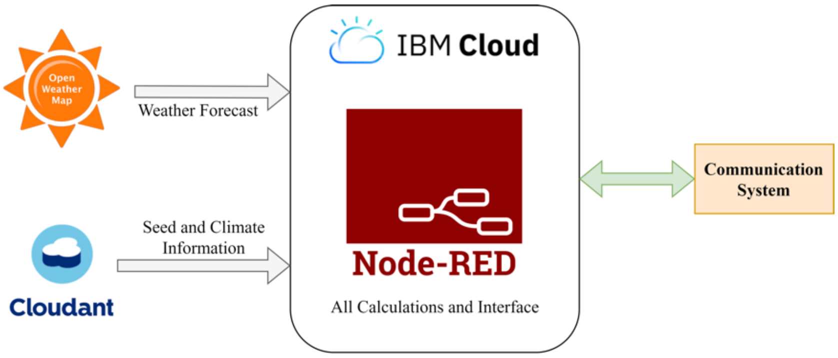


Figure 4: Software System Diagram

Software Flow:

1. User selects the seed sowing date, planted crop (seed type) and sowing area (field size) from the *Website.*

2. *Node-RED,*

   2.1. pulls daily and hourly weather data with *API.*

   2.2. pulls seed information and monthly weather information from the Database according to the seed type and planting region selected by the user (Figure 5).

   - Daily weather data captured with the API does not include maximum-average sunshine duration and net radiation. Therefore, monthly averages of these data have been manually entered into the *database.* In addition, irrigation interval and plant growth coefficients depending on the seed type were entered manually. Manually entered information (source):
     - Maximum sunshine duration (Güngör et al., 2012)
     - Average sunshine duration (MGM, 2020)
     - Net radiation (Güngör et al., 2012)
     - Irrigation interval depending on the seed type (MEGEP, 2009)
     - Plant growth coefficients (Ünlükara, 2019).

   2.3. determines the irrigation days based on the crop irrigation intervals it pulls from the *Database* (Figure 6).

   2.4. calculates the daily unit water requirement of the planted crop using daily and monthly weather data and seed information (Figure 7).

   - The unit water requirement is calculated with the *Penman Monteith* Equation. Details are below.

   2.5. finds the unit plant water requirement by multiplying the unit water requirement by the coefficient of the crop planted according to the plant development stage (Figure 8).

   2.6. subtracts the unit rain amount of that day from the unit plant water requirement and finds the unit irrigation amount.

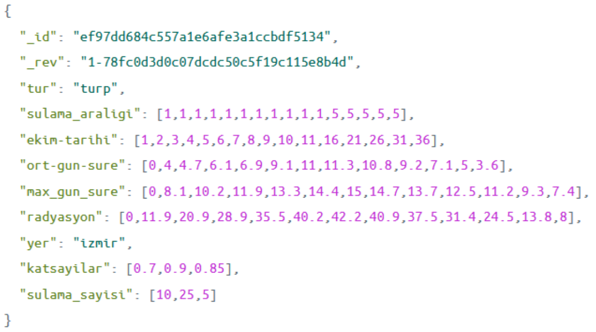
   2.7. calculates the total irrigation amount by multiplying the unit irrigation amount by the field area.

   2.8. draws hourly weather data with the API and determines the optimum irrigation time between 04:00 and 08:00 according to evaporation (calculated according to relative humidity and temperature) and wind strength (must be less than 8 units). If the wind is more than 8 units during these hours, it determines the hour with the least wind (Figure 9).

   2.9. transmits the total irrigation amount to *ThingSpeak* at the irrigation time it determines on irrigation days.

   2.10. Enters data into the *Website*.

3. On the *Website,* weather data is visualized for the user, and information about plant diseases and irrigation are displayed in tabular form.

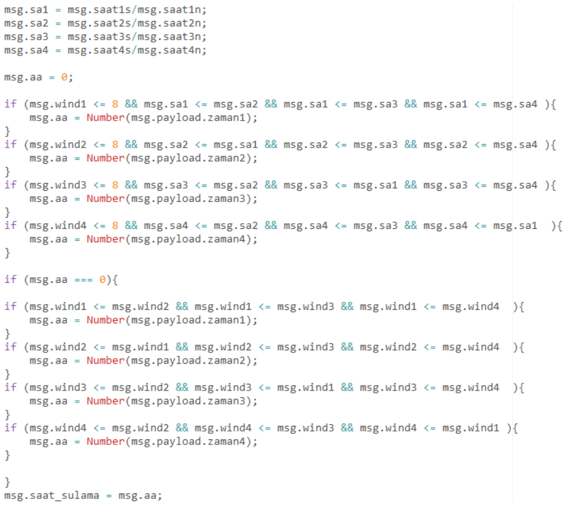


```
{
  "_id": "ef97dd684c557a1e6afe3a1ccbdf5134",
  "_rev": "1-78fc0d3d0c07dcdc50c5f19c115e8b4d",
  "tur": "turp",
  "sulama_araligi": [1,1,1,1,1,1,1,1,1,1,1,5,5,5,5,5],
  "ekim-tarihi": [1,2,3,4,5,6,7,8,9,10,11,16,21,26,31,36],
  "ort-gun-sure": [0,4,4.7,6.1,6.9,9.1,11,11.3,10.8,9.2,7.1,5,3.6],
  "max_gun_sure": [0,8.1,10.2,11.9,13.3,14.4,15,14.7,13.7,12.5,11.2,9.3,7.4],
  "radyasyon": [0,11.9,20.9,28.9,35.5,40.2,42.2,40.9,37.5,31.4,24.5,13.8,8],
  "yer": "izmir",
  "katsayilar": [0.7,0.9,0.85],
  "sulama_sayisi": [10,25,5]
}
```

Figure 5: Sample Database File

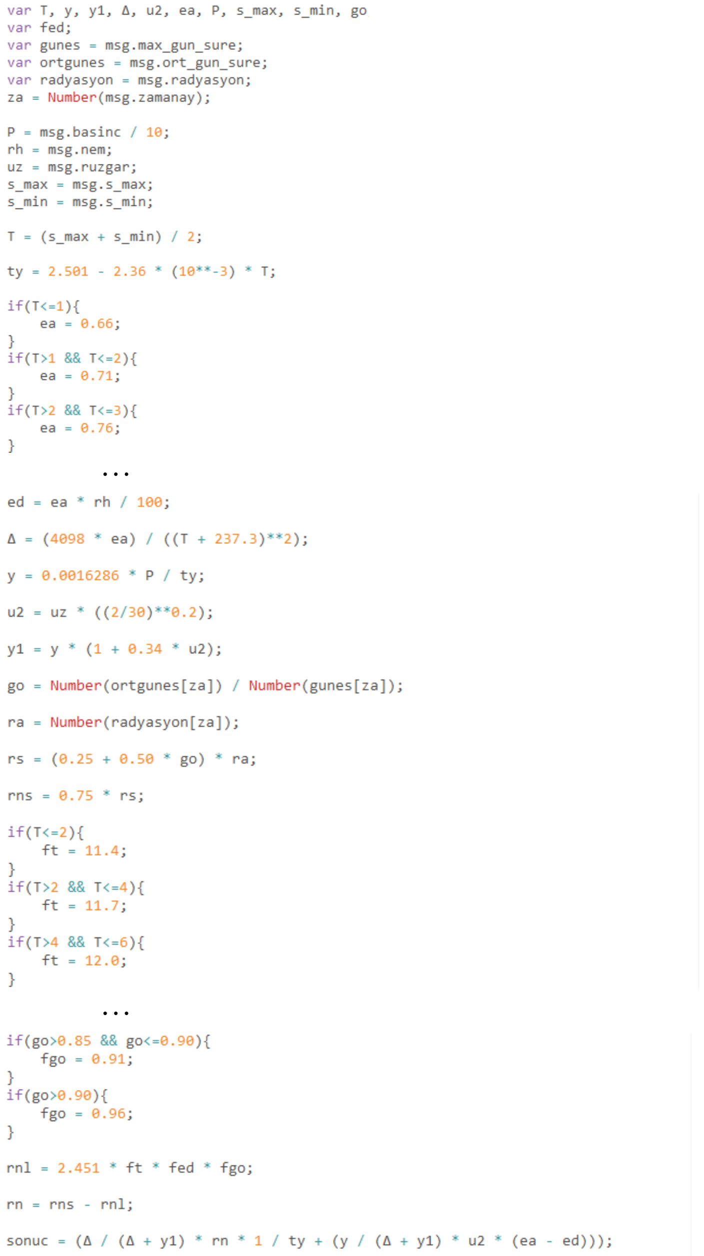
```
var zaman = msg.zaman.split('-'),
    a = zaman[0], b = zaman[1];
var sulama_araligi = msg.sulama_araligi;
var girilen_gun = Number(b);
var ay = Number(a);
var sulama_gunleri = [];
var  aygun;
var l = sulama_araligi.length;

for (i = 0; i<l; i++){
    if (ay == 2){
        aygun = 28;
    }
    else if (1 <= ay && ay <= 7){
        aygun = 30 + ay % 2;
    }
    else {
        aygun = 31 - ay % 2;
}
    if(girilen_gun + sulama_araligi[i] <= aygun){
        sulama_gunleri[i] = ay + "-" + String(girilen_gun + sulama_araligi[i
        girilen_gun = girilen_gun + sulama_araligi[i];
    }
    else{
        ay++;
        sulama_gunleri[i] = ay + "-" + String(girilen_gun + sulama_araligi[i
        girilen_gun = girilen_gun + sulama_araligi[i] - aygun;
    }
}
```

Figure 6: Sample Code for Determining Irrigation Days



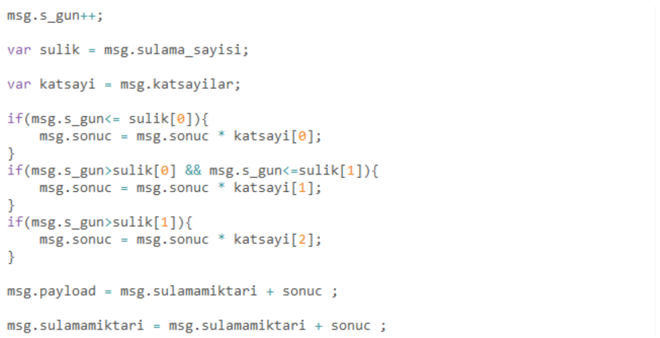
```
msg.sa1 = msg.saat1s/msg.saat1n;
msg.sa2 = msg.saat2s/msg.saat2n;
msg.sa3 = msg.saat3s/msg.saat3n;
msg.sa4 = msg.saat4s/msg.saat4n;

msg.aa = 0;

if (msg.wind1 <= 8 && msg.sa1 <= msg.sa2 && msg.sa1 <= msg.sa3 && msg.sa1 <= msg.sa4 ){
    msg.aa = Number(msg.payload.zaman1);
}
if (msg.wind2 <= 8 && msg.sa2 <= msg.sa1 && msg.sa2 <= msg.sa3 && msg.sa2 <= msg.sa4 ){
    msg.aa = Number(msg.payload.zaman2);
}
if (msg.wind3 <= 8 && msg.sa3 <= msg.sa2 && msg.sa3 <= msg.sa1 && msg.sa3 <= msg.sa4 ){
    msg.aa = Number(msg.payload.zaman3);
}
if (msg.wind4 <= 8 && msg.sa4 <= msg.sa2 && msg.sa4 <= msg.sa3 && msg.sa4 <= msg.sa1  ){
    msg.aa = Number(msg.payload.zaman4);
}

if (msg.aa === 0){

if (msg.wind1 <= msg.wind2 && msg.wind1 <= msg.wind3 && msg.wind1 <= msg.wind4  ){
    msg.aa = Number(msg.payload.zaman1);
}
if (msg.wind2 <= msg.wind1 && msg.wind2 <= msg.wind3 && msg.wind2 <= msg.wind4  ){
    msg.aa = Number(msg.payload.zaman2);
}
if (msg.wind3 <= msg.wind2 && msg.wind3 <= msg.wind1 && msg.wind3 <= msg.wind4  ){
    msg.aa = Number(msg.payload.zaman3);
}
if (msg.wind4 <= msg.wind2 && msg.wind4 <= msg.wind3 && msg.wind4 <= msg.wind1 ){
    msg.aa = Number(msg.payload.zaman4);
}

}
msg.saat_sulama = msg.aa;
```

Figure 9: Irrigation Time Determination Sample Code



```
var T, y, y1, Δ, u2, ea, P, s_max, s_min, go
var fed;
var gunes = msg.max_gun_sure;
var ortgunes = msg.ort_gun_sure;
var radyasyon = msg.radyasyon;
za = Number(msg.zamanay);

P = msg.basinc / 10;
rh = msg.nem;
uz = msg.ruzgar;
s_max = msg.s_max;
s_min = msg.s_min;

T = (s_max + s_min) / 2;

ty = 2.501 - 2.36 * (10**-3) * T;

if(T<=1){
    ea = 0.66;
}
if(T>1 && T<=2){
    ea = 0.71;
}
if(T>2 && T<=3){
    ea = 0.76;
}
          …
ed = ea * rh / 100;

Δ = (4098 * ea) / ((T + 237.3)**2);

y = 0.0016286 * P / ty;

u2 = uz * ((2/30)**0.2);

y1 = y * (1 + 0.34 * u2);

go = Number(ortgunes[za]) / Number(gunes[za]);

ra = Number(radyasyon[za]);

rs = (0.25 + 0.50 * go) * ra;

rns = 0.75 * rs;

if(T<=2){
    ft = 11.4;
}
if(T>2 && T<=4){
    ft = 11.7;
}
if(T>4 && T<=6){
    ft = 12.0;
}
          …
if(go>0.85 && go<=0.90){
    fgo = 0.91;
}
if(go>0.90){
    fgo = 0.96;
}

rnl = 2.451 * ft * fed * fgo;

rn = rns - rnl;

sonuc = (Δ / (Δ + y1) * rn * 1 / ty + (y / (Δ + y1) * u2 * (ea - ed)));
```

Figure 7: Calculation of Unit Water Requirement Sample Code



```
msg.s_gun++;

var sulik = msg.sulama_sayisi;

var katsayi = msg.katsayilar;

if(msg.s_gun<= sulik[0]){
    msg.sonuc = msg.sonuc * katsayi[0];
}
if(msg.s_gun>sulik[0] && msg.s_gun<=sulik[1]){
    msg.sonuc = msg.sonuc * katsayi[1];
}
if(msg.s_gun>sulik[1]){
    msg.sonuc = msg.sonuc * katsayi[2];
}

msg.payload = msg.sulamamiktari + sonuc ;

msg.sulamamiktari = msg.sulamamiktari + sonuc ;
```

Figure 8: Calculation of Unit Plant Water Requirement Sample Code

Interface (Website) details:

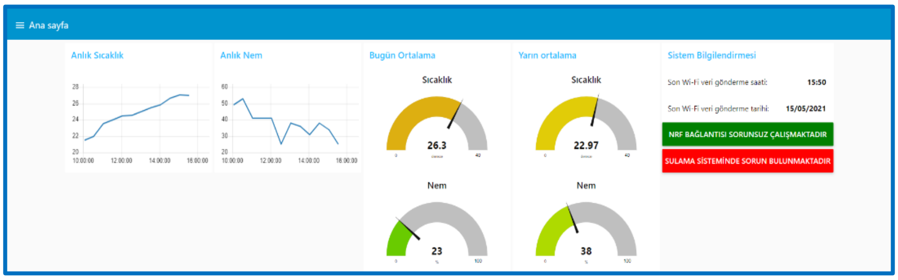
Main page: On this page, daily-instantaneous temperature and humidity data are visualized (Figure 10).

Disease page: On this page, there are diseases according to the plant chosen by the user, summary information, detailed information, symptoms, possible causes and transmission routes, precautions that can be taken, traditional and chemical control methods, what kind of problems they cause and sample pictures (Figure 11).

Elections and Irrigation Information Page: This page consists of selections and irrigation information sections (Figure 12).

- **Selections section:** The user selects the type of seed sown, the sowing date, and the sowing area. Under the sowing date selection, there is the automatically calculated harvest date information according to the seed type and sowing date.
- **Information section:** There is a table of *irrigation number*, *day*, *time*, *amount*, *control* and amount of rain. The number and day of irrigation are determined at the time of elections. The irrigation amount and rainfall amount are updated each irrigation day. The irrigation time is determined at 04:00 every day. Whether irrigation is done (irrigation control) is determined after irrigation.

In order to ensure the security of the interface, there is a username and password section that the user must fill in at the first login.



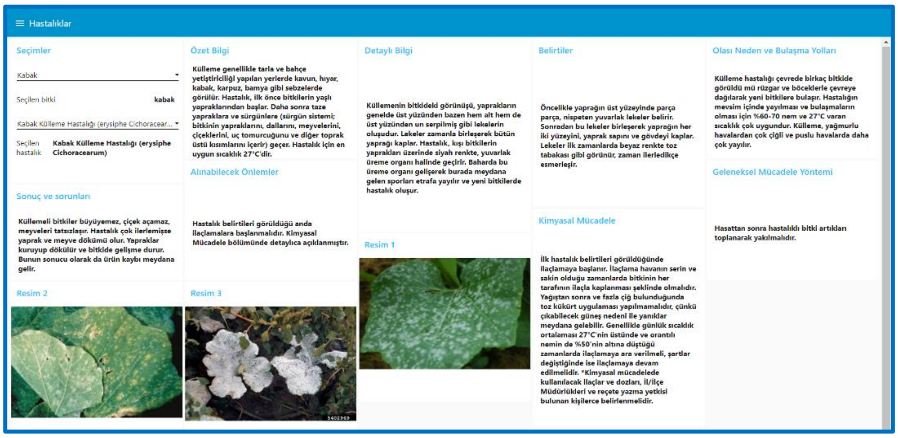
Son Wi-Fi veri gönderme saati: 15:50

Son Wi-Fi veri gönderme tarihi: 15/05/2021

NRF BAĞLANTISI SORUNSUZ ÇALIŞMAKTADIR

SULAMA SİSTEMİNDE SORUN BULUNMAKTADIR

Figure 10: Website Home Page



Seçimler

Kabak

Seçilen bitki: kabak

Kabak Külleme Hastalığı (erysiphe Cichoracear...

Seçilen hastalık: Kabak Külleme Hastalığı (erysiphe Cichoracearum)

Özet Bilgi

Külleme genellikle tarla ve bahçe yetiştiriciliği yapılan yerlerde kavun, hıyar, kabak, karpuz, bamya gibi sebzelerde görülür. Hastalık, ilk önce bitkilerin yaşlı yapraklarından başlar. Daha sonra taze yapraklara ve sürgünlere (sürgün sistemi; bitkinin yapraklarını, dallarını, meyvelerini, çiçeklerini, uç tomurcuğunu ve diğer toprak üstü kısımlarını içerir) geçer. Hastalık için en uygun sıcaklık 27°C'dir.

Detaylı Bilgi

Küllemenin bitkideki görünüşü, yaprakların genelde üst yüzünden bazen hem alt hem de üst yüzünden un serpilmiş gibi lekelerin oluşudur. Lekeler zamanla birleşerek bütün yaprağı kaplar. Hastalık, kışı bitkilerin yaprakları üzerinde siyah renkte, yuvarlak üreme organı halinde geçirir. Baharda bu üreme organı gelişerek burada meydana gelen sporları etrafa yayılır ve yeni bitkilerde hastalık oluşur.

Belirtiler

Öncelikle yaprağın üst yüzeyinde parça parça, nispeten yuvarlak lekeler belirir. Sonradan bu lekeler birleşerek yaprağın her iki yüzeyini, yaprak sapını ve gövdeyi kaplar. Lekeler ilk zamanlarda beyaz renkte toz tabakası gibi görünür, zaman ilerledikçe esmerleşir.

Olası Neden ve Bulaşma Yolları

Külleme hastalığı çevrede birkaç bitkide görüldü mü rüzgar ve böceklerle çevreye dağılarak yeni bitkilere bulaşır. Hastalığın mevsim içinde yayılması ve bulaşmaların olması için %60-70 nem ve 27°C varan sıcaklık çok uygundur. Külleme, yağmurlu havalardan çok çiğli ve puslu havalarda daha çok yayılır.

Alınabilecek Önlemler

Hastalık belirtileri görüldüğü anda ilaçlamalara başlanmalıdır. Kimyasal Mücadele bölümünde detaylıca açıklanmıştır.

Sonuç ve sorunları

Küllemeli bitkiler büyüyemez, çiçek açamaz, meyveleri tatsızlaşır. Hastalık çok ilerlemişse yaprak ve meyve dökümü olur. Yapraklar kuruyup dökülür ve bitkide gelişme durur. Bunun sonucu olarak da ürün kaybı meydana gelir.

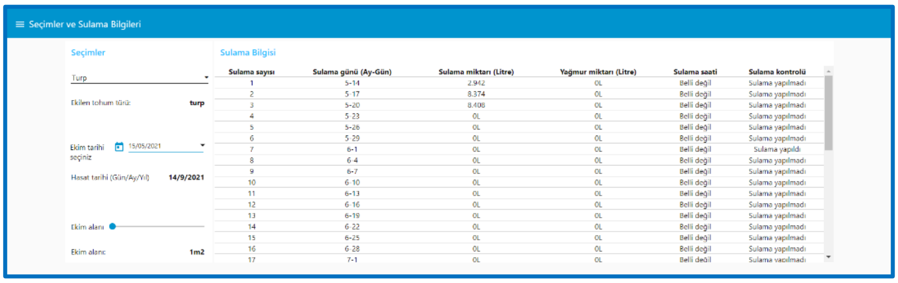
Kimyasal Mücadele

İlk hastalık belirtileri görüldüğünde ilaçlamaya başlanır. İlaçlama havanın serin ve sakin olduğu zamanlarda bitkinin her tarafının ilaçla kaplanması şeklinde olmalıdır. Yağıştan sonra ve fazla çiğ bulunduğunda toz kükürt uygulaması yapılmamalıdır, çünkü çıkabilecek güneş nedeni ile yanıklar meydana gelebilir. Genellikle günlük sıcaklık ortalaması 27°C'nin üstünde ve orantılı nemin de %50'nin altına düştüğü zamanlarda ilaçlamaya ara verilmeli, şartlar değiştiğinde ise ilaçlamaya devam edilmelidir. *Kimyasal mücadelede kullanılacak ilaçlar ve dozları, İl/İlçe Müdürlükleri ve reçete yazma yetkisi bulunan kişilerce belirlenmelidir.

Geleneksel Mücadele Yöntemi

Hasattan sonra hastalıklı bitki artıkları toplanarak yakılmalıdır.

Figure 11: Website Diseases Page



Seçimler

Turp

Ekilen tohum türü: turp

Ekim tarihi seçiniz: 15/05/2021

Hasat tarihi (Gün/Ay/Yıl): 14/9/2021

Ekim alanı

Ekim alanı: 1m2

Sulama Bilgisi

Sulama sayısı	Sulama günü (Ay-Gün)	Sulama miktarı (Litre)	Yağmur miktarı (Litre)	Sulama saati	Sulama kontrolü
1	5-14	2.942	0L	Belli değil	Sulama yapılmadı
2	5-17	8.374	0L	Belli değil	Sulama yapılmadı
3	5-20	8.408	0L	Belli değil	Sulama yapılmadı
4	5-23	0L	0L	Belli değil	Sulama yapılmadı
5	5-26	0L	0L	Belli değil	Sulama yapılmadı
6	5-29	0L	0L	Belli değil	Sulama yapılmadı
7	6-1	0L	0L	Belli değil	Sulama yapıldı
8	6-4	0L	0L	Belli değil	Sulama yapılmadı
9	6-7	0L	0L	Belli değil	Sulama yapılmadı
10	6-10	0L	0L	Belli değil	Sulama yapılmadı
11	6-13	0L	0L	Belli değil	Sulama yapılmadı
12	6-16	0L	0L	Belli değil	Sulama yapılmadı
13	6-19	0L	0L	Belli değil	Sulama yapılmadı
14	6-22	0L	0L	Belli değil	Sulama yapılmadı
15	6-25	0L	0L	Belli değil	Sulama yapılmadı
16	6-28	0L	0L	Belli değil	Sulama yapılmadı
17	7-1	0L	0L	Belli değil	Sulama yapılmadı

Figure 12: Website Selections and Irrigation Information Page

2) Communication System

This section includes making the wireless connection between the *Computing System* and the *Irrigation and Renewable Energy System (Figure 13)*. *ThingSpeak*, the Internet of Things platform, was used to store data from the *Computing System*. There is a processor and a wireless communication module to communicate with the *Irrigation and Renewable Energy System* .

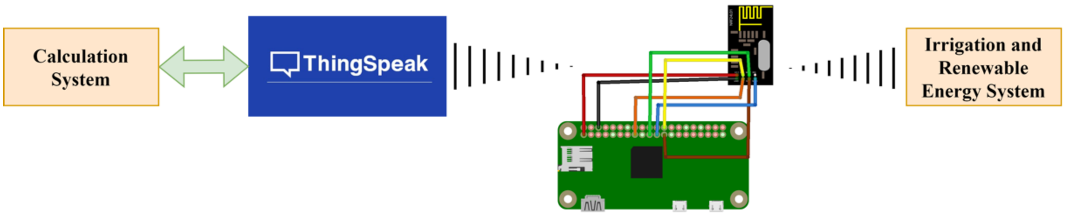


Figure 13: Communication System Diagram

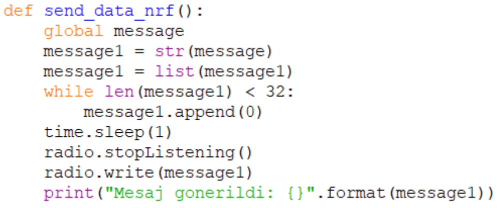
Software flow:

1. Total irrigation amount exported to *ThingSpeak.*
2. Raspberry *Pi*
    2.1. draws the total amount of irrigation from *ThingSpeak* with its built-in Wi-Fi module (Figure 14).
    2.2. uploads Wi-Fi connection information to *ThingSpeak* to indicate if there is a connection problem.
    2.3. transmits the total irrigation amount to the *Irrigation System* with an external *nRF24* connection if this data is greater than 0 (Figure 15).
    2.4. uploads the irrigated amount data from the *Irrigation System* to *ThingSpeak* after irrigation takes place.

- *Communication System* while the program is running is shown in Figure 16.

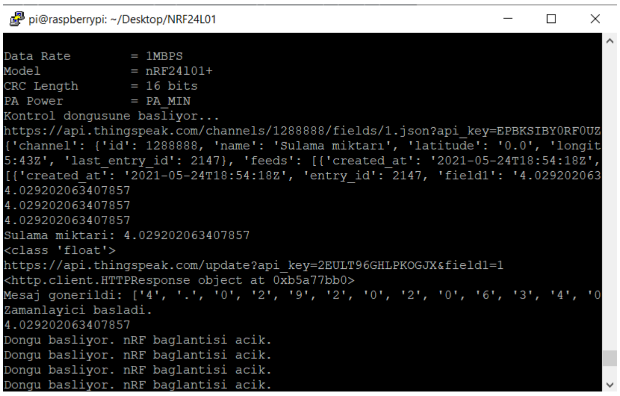
```
# Thingspeak'ten veri alma fonksiyonu
def read_data_thingspeak():
    URL = 'https://api.thingspeak.com/channels/1288888/fields/1.json?api_key='
    KEY = 'EPBKSIBY0RF0UZEM'
    HEADER = '&results=1'
    NEW_URL = URL + KEY + HEADER
    print(NEW_URL)
    get_data = requests.get(NEW_URL).json()
    print(get_data)
    channel_id = get_data['channel']['id']
    field_1 = get_data['feeds']
    print(field_1)
    t=""
    for x in field_1:
        print(x['field1'])
        t = (x['field1'])
        print(t)
    time.sleep(2)
    message = float(t)
    print(message)
    return message
```

Figure 14: Sample Code for Retrieving Data from ThingSpeak



```
def send_data_nrf():
    global message
    message1 = str(message)
    message1 = list(message1)
    while len(message1) < 32:
        message1.append(0)
    time.sleep(1)
    radio.stopListening()
    radio.write(message1)
    print("Mesaj gonerildi: {}".format(message1))
```

Figure 15: Sample Code for Sending Data via nRF24 Connection



```
Data Rate         = 1MBPS
Model             = nRF24l01+
CRC Length        = 16 bits
PA Power          = PA_MIN
Kontrol dongusune basliyor...
https://api.thingspeak.com/channels/1288888/fields/1.json?api_key=EPBKSIBY0RF0UZ
{'channel': {'id': 1288888, 'name': 'Sulama miktarı', 'latitude': '0.0', 'longit
5:43Z', 'last_entry_id': 2147}, 'feeds': [{'created_at': '2021-05-24T18:54:18Z',
[{'created_at': '2021-05-24T18:54:18Z', 'entry_id': 2147, 'field1': '4.029202063
4.029202063407857
4.029202063407857
4.029202063407857
Sulama miktari: 4.029202063407857
<class 'float'>
https://api.thingspeak.com/update?api_key=2EULT96GHLPKOGJX&field1=1
<http.client.HTTPResponse object at 0xb5a77bb0>
Mesaj gonerildi: ['4', '.', '0', '2', '9', '2', '0', '2', '0', '6', '3', '4', '0
Zamanlayici basladi.
4.029202063407857
Dongu basliyor. nRF baglantisi acik.
Dongu basliyor. nRF baglantisi acik.
Dongu basliyor. nRF baglantisi acik.
Dongu basliyor. nRF baglantisi acik.
```

Figure 16: Communication System Output

Electronic system:

Raspberry Pi Zero *W* was used as the processor in the system, and the *nRF24l01* module was used for wireless communication (Figure 17).

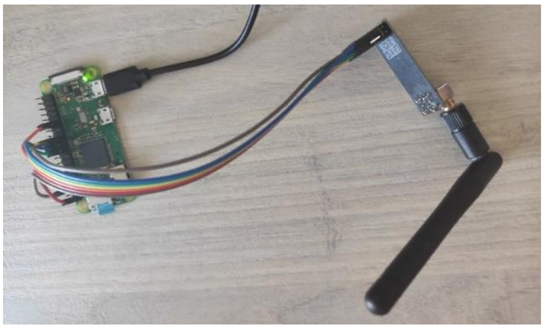


Figure 17: Raspberry Pi and nRF Module in Communication System

3) Irrigation and Renewable Energy System

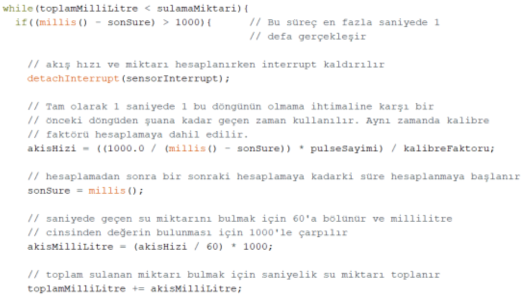
This section includes the electronic system that enables communication with the *Communication System*, irrigation in the required amount using solar energy.

Software flow:

1. *Arduino*,
    - 1.1. connects to *Raspberry Pi* in *Communication System* with external *nRF24* connection (Figure 18).
    - 1.2. sends the signal to open the valve when the total irrigation amount data is received from the *Communication System*.
    - 1.3. measures the amount of water passing through the valve (the irrigated amount) with an electronic water meter when the valve is opened (Figure 19).
    - 1.4. sends a signal to close the valve when the irrigated amount equals the total irrigation amount.
    - 1.5. sends the irrigated amount to the *Communication System* with the external *nRF24* connection.

```
void loop(void){
  radio.startListening() ;
  Serial.println("Dongu basliyor. nRF baglantisi acik.") ;
  char alinanMesaj[32] = {0} ;
  if (radio.available()){
    radio.read(alinanMesaj, sizeof(alinanMesaj));
    Serial.println(alinanMesaj) ;
    Serial.println("nRF baglantisi kapatiliyor.") ;
    radio.stopListening() ;
    delay(2000);
    radio.write(alinanMesaj, sizeof(alinanMesaj));
    Serial.println(alinanMesaj);
    Serial.println("Mesaj gonderildi.");
    String stringMesaj(alinanMesaj) ;
    sulamaMiktari = stringMesaj.toFloat();
    sulamaMiktari*=1000;
    Serial.println(sulamaMiktari);
    Serial.println("Alinan mesaj:");
    Serial.println(sulamaMiktari);
```

Figure 18: Receive Code for Total Irrigation Amount with nRF



```
while(toplamMilliLitre < sulamaMiktari){
  if((millis() - sonSure) > 1000){      // Bu süreç en fazla saniyede 1
                                        // defa gerçekleşir

    // akış hızı ve miktarı hesaplanırken interrupt kaldırılır
    detachInterrupt(sensorInterrupt);

    // Tam olarak 1 saniyede 1 bu döngünün olmama ihtimaline karşı bir
    // önceki döngüden şuana kadar geçen zaman kullanılır. Aynı zamanda kalibre
    // faktörü hesaplamaya dahil edilir.
    akisHizi = ((1000.0 / (millis() - sonSure)) * pulseSayimi) / kalibreFaktoru;

    // hesaplamadan sonra bir sonraki hesaplamaya kadarki süre hesaplanmaya başlanır
    sonSure = millis();

    // saniyede geçen su miktarını bulmak için 60'a bölünür ve millilitre
    // cinsinden değerin bulunması için 1000'le çarpılır
    akisMilliLitre = (akisHizi / 60) * 1000;

    // toplam sulanan miktarı bulmak için saniyelik su miktarı toplanır
    toplamMilliLitre += akisMilliLitre;
```

Figure 19: Code for Measuring Amount of Irrigation

```
if (sulamaMiktari == 0.0 ){
  valfiKapat();
}
else if (toplamMilliLitre < sulamaMiktari){
  valfiAc();
}
else if (toplamMilliLitre >= sulamaMiktari){
  valfiKapat();
  delay(2000);
  radio.openWritingPipe(0xF0F0F0F0E1LL);
  Serial.println("Sulanan miktar gonderiliyor.") ;
  char sulananMiktar[16];
  itoa(toplamMilliLitre, sulananMiktar, 10);
  Serial.println(toplamMilliLitre);
  Serial.println(sulananMiktar);
  radio.write(sulananMiktar, sizeof(sulananMiktar)) ;
  Serial.println("Sulanan miktar gonderildi.") ;
  toplamMilliLitre = 0;
  sulamaMiktari = 0.0;
  delay(5000);
}
```

Figure 20: Irrigation Information nRF with Send Code

Electronic system:

<u>In the Irrigation Section,</u> Arduino Nano was used as the processor; ¾ inch 12V *Solenoid valve*, TIP120 Transistor, 220 Ohm Resistor, 1N 4001 Diode, ¾ inch Water Flow Sensor were used to provide water flow; *nRF24l01* was used for communicating with the *Communication System* (Figure 21).

<u>In the Renewable Energy Section,</u> 12v 10W Solar Panel, 12/24V Solar Charge Controller, 3S2P 3400mAh 18650 Li-ion Battery, 3S 40A Li-ion Battery Charge Protection Module and 2 Triple Battery Slots were used to produce and store energy with solar rays (Figure 22).

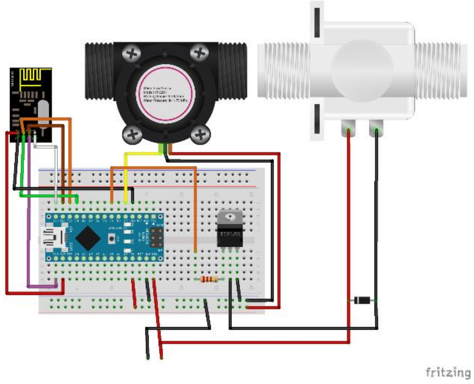


Figure 21: Irrigation Section Circuit Diagram

Figure 22: Renewable Energy Division

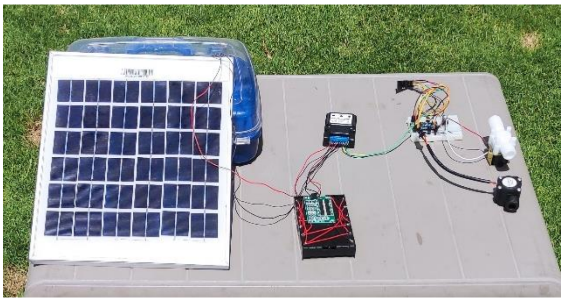


Figure 23: Irrigation and Renewable Energy System

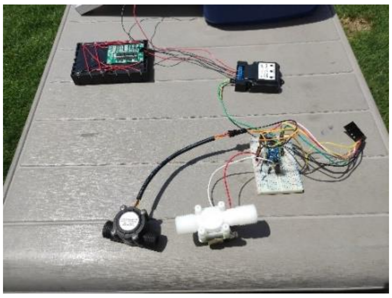


Figure 24: Irrigation and Renewable Energy System

4) Irrigation Amount Calculation Method and Usage

The consistent preparation of irrigation projects requires the correct calculation of the water consumption amounts of the plant planned to be grown.

The healthiest way to determine plant water consumption is to use direct measurement methods. However, because of the high cost and time consumption of direct measurement methods, formulas that can be used in estimation of plant water consumption have been developed. The Penman-Monteith method is the most widely accepted among these formulas.

In the experimental study for semi-arid climates, the plant water requirement results obtained by Penman, Penman-Monteith, Wright-Penman, Blaney-Criddle, Radiation and Hargreaves methods were compared with lysimeter measurements, and it was determined that Penman-Monteith method gave the best results (DehghaniSanij et al., 2004). Penman Monteith equation, which was determined to give the best result in our system, was used. The Penman Monteith equation is shown in Table 2.1. The weather data used in the calculation of the equation are shown in Table 2.2.

Table 2.1: Penman Monteith Reference Evapotranspiration Equation (ET_0)

$$ET_0 = \frac{\delta}{\delta+\gamma*}(R_n - G)\frac{1}{\lambda} + \frac{\gamma}{\delta+\gamma*} u_2 (e_a - e_d)$$

Variables:

- ET = Reference crop water consumption, mm/day
- δ= slope of the vapor pressure curve, kPa/oC
- γ* = Modified psychrometric constant, kPa/oC
- γ= psychrometric constant, kPa/oC
- Rn = net radiation on the plant surface, MJ/m2/day,
- ed = Actual vapor pressure at average air temperature, kPa
- ea = Saturated vapor pressure at average air temperature, kPa

Table 2.2: Weather Data Used in Calculating Penman Monteith Equation

Weather data (data range, source):

- Minimum temperature: Daily, OpenWeatherMap API
- Maximum temperature: Daily, OpenWeatherMap API
- Relative humidity: Daily, OpenWeatherMap API
- Atmospheric pressure: Daily, OpenWeatherMap API
- Maximum sunshine duration: Monthly, (Güngör et al., 2012) (The values for the months with low agricultural production are not included in the reference. These values were determined by a research assistant at Ege University.)
- Net radiation: Monthly, (Güngör et al., 2012) (The values for the months with low agricultural production are not included in the reference. These values were determined by a research assistant at Ege University.)
- Average sunshine duration: Monthly, (MGM, 2020)

Total evaporation (evapotranspiration-ET), which includes physiological (sweating) events on the one hand and physical (evaporation) events on the other, is defined as the amount of water vapor lost from the planted area (MGM, 2020). Since the amount of rain affects the amount of water vapor lost from the soil (ET_0), the unit irrigation amount was found by subtracting the unit rain amount of that day from the unit plant water requirement (the amount of water vapor lost from the soil, ET_0).

TEST PHASE

In the system test, it was aimed to show the water savings and functionality that the smart irrigation system we designed compared to traditional irrigation methods and to support this with data.

The test was conducted in a 650x500 cm^2 area which was located in the Bornova district of Izmir. Hazelnut radish was chosen as the test product because it is a fast-growing, moisture loving plant that is resistant to weather conditions at the time of planting. In the test area, light loamy sandy soil was used, which allowed the selected crop to grow optimally.

The test area was divided into two equal parts of 315x315 cm^2. 20 cm gap was left between them so that they would not affect each other, and the area was isolated from the ground for the same reason. A mechanical water timer (for manual irrigation, representing traditional irrigation methods) was installed in one of the separated parts, and a smart irrigation system was installed in the other.

The system was completed in November and is ready for the test phase. The General Directorate of Meteorology announced the ET_0 amount for İzmir as 36-40 mm/month in November and 26-30 mm/month in December (MGM, 2020). Seasonal normals gave the precipitation amount as 109.7 mm/month in November and 137.9 mm/month in December (MGM, 2020). Since the "unit irrigation amount" calculated by the system would be less than the amount of rain, it was predicted that our seeds would not be irrigated, and the features of the system such as the calculation of ET_0 calculation and the optimum irrigation time would not be tested. For this reason, on rainy days, the test parts were covered with a protective, waterproof cover and the rain was prevented from entering. The features of the system other than the rain amount calculation could be tested successfully, sowing and harvesting could be done.

Hazelnut radish seeds were planted in the test area with 10-15 cm between rows, 3-5 cm on rows, and 1.5-2 cm in depth (MEGEP, 2009). According to this information, 1.408 seeds were planted in each parts (total number of seeds was 2.816). The irrigation intervals (days) of the seeds were determined as every day in the first 10 days, which is the first development stage, and once in 5 days in the following stages, in line with the opinion of an expert who is a research assistant at Ege University (MEGEP, 2009). The test system and site are shown in Figure 25.

Figure 25: Test System and Field

The test lasted for a total of 40 days, with the first developmental stage of 10 days, the second developmental stage of 25 days and the third developmental stage of 5 days. The calculated unit water requirement was multiplied by the hazelnut radish plant coefficient in these stages (0.7 in the first stage, 0.9 in the second stage and 0.85 in the third stage) and the unit plant water requirement was calculated (Ünlükara, 2019).

Before starting the test, the water savings of the smart irrigation system were predicted as 15% in line with the opinion of a research assistant at Ege University. 85% of the total irrigation amount calculated automatically by the system was given to the test area where our smart irrigation system was installed, and 100% of the water was given in the area where manual irrigation was applied. Irrigation amounts in manual and smart irrigation systems are given in Graph 1 in the Results section.

Irrigation was automatically calculated by the system and carried out at the optimum time on each irrigation day in the part where the smart irrigation system was installed. In the part where the manual system was installed, one of the project members ensured that the calculated amount of irrigation was conducted at 11:00 on irrigation days.

During the test, both parts were observed, and data were collected and photographed. The important dates of these photographs are listed below with their explanations.

Figure 26.1: Test area prepared

Figure 26.2: Test area prepared

Figure 26.3: Seeds sown

Figure 26.4: Seeds have completed their first developmental stage

Figure 26.5: Seeds are in the middle of the second developmental stage

Figure 26.6: Seeds have completed their second developmental stage

Figure 26.7: Seeds are in the middle of the third developmental stage

Figure 26.8: Harvest-ready crops were collected

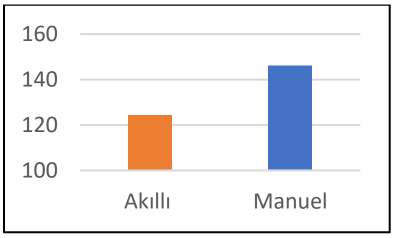
According to the data obtained as a result of the test, 15% water saving and 2-3% increase in efficiency were achieved. The data obtained are included in the Results section as graphs. These data show that our system calculates the ET_0 equation according to the weather data and irrigates successfully at the optimum irrigation time it finds.

PROJECT WORK-TIME PLANNING

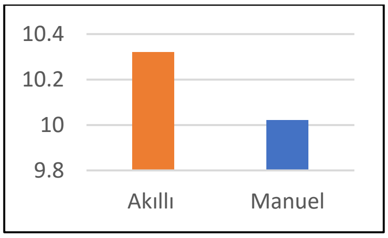
The project started in April 2020. In the project study, which was initiated to contribute to water saving, firstly, literature review and studies in the field of irrigation systems were examined. After the examinations, necessary scientific research was conducted and after the weather data was received via the API (Application Programming Interface) service, the optimum irrigation time finding algorithm and software (on the Node-RED platform) were first made in the *Calculation System.* Then, the electronic parts of the system started to be designed. Solenoid valve, water meter, communication module, and Arduino Nano microcontroller are combined for the Irrigation Section. In the Renewable Energy section, which was designed to provide clean energy to the irrigation section, an electronic circuit was created with a solar panel, charge controller, charge protection module and Li-ion (lithium-ion) batteries. Afterwards, a *Communication System* with nRF24 and Raspberry Pi was prepared in order to provide data exchange between systems. After the infrastructure of the smart irrigation system was created, the equation (ET_0) to be used in the *Calculation System* was determined and transferred to the Node-RED software. The interface is designed and prepared on Node-RED platform. Finally, in order to control the operation of the system and to prove that it provides the targeted savings, tests were conducted in November and December to collect data. After these processes were completed, the project report was written with the data obtained.

RESULTS

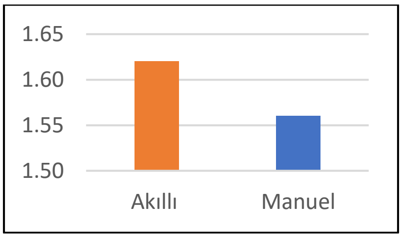
In the test conducted, the designed smart irrigation system and the manual system were compared, and the functionality of the installed smart irrigation system was checked. The findings obtained during the testing phase of the system are shown as a bar graph in Graph 1.1, Graph 1.2 and Graph 1.3.



Graph 1.1: Amount of Irrigation (L)



Graph 1.2: Average Storage Root Diameter (cm)



Graph 1.3: Average Root-to-Leaf Length (cm)

In the part where the manual system is installed, a total of 146.15 liters of water was used. The average storage root diameter of the hazelnut radishes produced in this part was 1.56 cm, and the average root-to-leaf length was 10.02 cm. In the part where the smart irrigation system is installed, a total of 124.22 liters of water was used. The average storage root diameter of the hazelnut radishes produced in this part was measured as 1.62 cm, while the average root-to-leaf length was measured as 10.32 cm.

As a result of the test, the smart irrigation system provided 15% water savings compared to manual irrigation, and a 3% increase in storage root diameter and 2% increase in root to leaf length.

CONCLUSION AND DISCUSSION

The smart irrigation system prepared within the framework of the study performed autonomous irrigation without the need for user intervention. Updating the variables in the algorithm according to the coordinated location information has enabled the developed system to achieve water savings by adapting to each geographical region and climatic condition. The prepared system has been tested and determined to be working successfully.

The project achieved at least 15% water savings during the test phase, and increased yield in storage root diameter and root-to-leaf length. Considering the 15% water savings provided by the system and the annual average 44 billion m3 water use for irrigation in Turkey, there will be an annual water gain of 6.6 billion m3 throughout Turkey (DSI, 2019). This amount can meet half of Turkey's 1-year non-agricultural water need and the 3-year water demand of Istanbul, which has a population of 15.5 million (TUIK, 2020). Thus, a contribution was made to the sustainability of usable water.

The tests of the developed system were conducted in the autumn-winter months. Evaporation will be more in the spring-summer months when agricultural production is high. Considering this situation, it is estimated that water savings will increase even more in these months.

The test of the system was made with a sprinkler irrigation system which is the most widely used method among the pressure irrigation methods. The system has been prepared in such a way that it can be easily integrated with other pressurized irrigation methods and does not require any additional costs in agricultural areas where irrigation systems are installed.

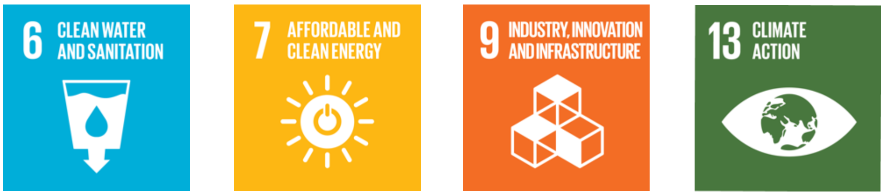
Since the preparation of the test system was completed in October, the test was conducted in the months of November-December, when the agricultural production in open fields is the lowest. The fact that the precipitation was more than ET_0 in these months caused the feature of our system to determine the amount of rain and to subtract this amount from the calculated ET_0 could not be tested.

When the test results are evaluated, it has been determined that the system supports the following objectives of the Ministry of Agriculture and Forestry in the Strategic Plan for 2019-2023:

- To ensure supply security in herbal products, to develop new varieties, methods and technologies
- To take environmentally friendly phytosanitary measures in plant production
- Ensuring the protection and efficient use of soil and water resources
- To make holistic plans in line with EU legislation for the protection and use of water in terms of quantity and quality.
- To prepare plans and projects in combating desertification / land degradation and erosion
- To measure the possible effects of climate change on agriculture and to develop suggestions for taking precautions.

In addition, the developed system supports the United Nations Sustainable Development Goals given below with the benefits it provides:

- Clean Water and Sanitation goal, with the water savings it provides,
- Accessible and Clean Energy goal, thanks to the renewable energy it produces,
- Industry, Innovation and Infrastructure goal, with its innovative design which lets it to be integrated into the infrastructure in a way that will save water everywhere
- Climate Action goal, by aiming to provide benefits against global warming.



As a result, a new smart agricultural irrigation system has been developed that will contribute significantly to the sustainability of usable water with the agricultural sector in the world and in our country. With this system, water savings have been achieved and product quality has been increased.

SUGGESTIONS

During the testing process, the system's features other than the ability to determine the amount of rain and subtract this amount from the calculated ET_0 worked smoothly and in accordance with its purpose. This feature will work properly between March and October, when agricultural production is high. As a result, the system will be able to operate under normal climatic conditions without any problems.

Since some of the data used in the Penman-Monteith Equation are not available in the OpenWeatherMap API, monthly data of the General Directorate of Meteorology were pulled from the Cloudant Database. If the General Directorate of Meteorology provides weather data as an API service, the precision of the data, the speed and operability of the system will increase.

Compared to existing systems, the developed system will contribute to the economy of countries where agricultural development is important, as it provides advantages such as calculating the water need of the agricultural product according to daily and monthly meteorological data, irrigating at the optimum hour, being an autonomous system and saving water.

REFERENCE

A resource was recommended by Ege University Faculty of Agriculture to determine the appropriate one among the Plant Reference Evapotranspiration (ET_0) Equations.

In addition, support was provided by the same university in the selected Penman Monteith Equation to correctly determine some meteorological values that could not be provided by the API.

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