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Real Time Analysis of Weather Parameters and Smart Agriculture Using IoT

George Suciu Jr.[1,2](✉), Hussain Ijaz[2], Ionel Zatreanu[2], and Ana-Maria Drăgulinescu[1]

[1] University Politehnica of Bucharest, Bucharest, Romania
george@beia.ro, ana.dragulinescu@upb.ro
[2] Beia Consult International, Bucharest, Romania
{george, ijaz, ionel.zatreanu}@beia.ro

Abstract. Modern day agriculture and civilization demand for increased production of food to feed fast increasing global population. New technologies and solutions are being adopted in agricultural sector to provide an optimal alternative to gather and process information while enhancing net productivity. At the same time, the alarming climate changes, increasing water crisis and natural disasters demand for an agricultural modernization with state-of-the-art technologies available in the market and improved methodologies for modern era agricultural and farming domains. Internet of things (IoT) has been broadly applied to every sector of agriculture and has become the most effective means & tools for booming agricultural productivity and for making use of full agricultural resources. The advent of Internet of Things (IoT) has shown a new way of innovative research in agricultural sector. The introduction of cloud computing and Internet of Things (IoT) into agricultural modernization will perhaps solve many issues. Based on significant characteristics of key techniques of IoT, visualization, Libelium and Adcon can build up data regarding agricultural production. It can accelerate fast development of agricultural modernization, integrate smart farming and efficiently solve the issues regarding agriculture. Our motive is to perform the research that would bring new solutions for the farmers to determine the most effective ways to manage and monitor the agricultural fields constantly.

Keywords: Libelium · Adcon · Sensors · Smart agriculture · Environmental sensors · Precision farming · Crop monitoring

1 Introduction

Smart technology sets out for modern farms cutting edge together with the area of precision agriculture. Public administration and farmers are getting access to several multimedia browsers and auto-guidance systems supported by agro-machinery manufactures. There exist additional sensors and tools which could add new and useful features to the agro-system if they could only be integrated with it. The Internet of Things (IoT) can assist us to join all these elements. Our motivation to perform research comes up because farmers require new methods and technologies to determine the agricultural fields, such as for fertilization talks, watering, pesticides, etc. From a

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decade, information and communication technologies have been introduced in agriculture, improving overall turn over from the fields and crop production. The IoT (Internet of Things) based agricultural convergence technology is a technology that produces a higher result such as improvement of production efficiency, quality increase in agricultural products in the entire procedure of agricultural production [1–3]. The IOT technologies include radio frequency identification (RFID) technology, sensor technology, sensor network technology and internetwork communication, all of them have been involved in a link of IOT industrial chain, named as identification, sensing, processing and information delivery [4]. It is used in pattern identification fields like measurement and computing and computer and communication fields like sensing, communication, information collection and processing and proving results [5–8].

The important factors in agriculture are considered: measuring soil moisture, soil temperature, environmental weather and humidity to help farmers manage their irrigation systems efficiently. The farmers can use less water to grow a crop, but they are able to increase yields and the quality of the crop by better management of soil moisture, temperature during critical plant growth stages. Monitoring is an important phase of agriculture, knowing the condition of the crop, soil and climate is essential for farmers as their decisions to irrigate the crop, spray pesticide, apply fertilizer, etc. are dependent on their states. Physical monitoring for wide agriculture land does not bring up with good results as it is almost impossible to perform 24/7 monitoring and to keep on checking for multiple variants at a time. Sensor network technology is strongly in use to get the local microclimate measurement as well as to measure soil attributes and the plant state. The connection of technologies is also providing the gain in having a mix of various local and global specialties to take appropriate decision [9–11]. An Embedded system for automatic monitoring of an agriculture field offers a potential solution to support site-specific irrigation management that allows farmers to maximize their productivity. Current technological advances in low power integrated circuits and wireless communications have provided an efficient, inexpensive, and low power device that can be utilized in remotely sensing applications to collect the data and to analyze it on home computer system. The combination of these factors has improved the viability of using a sensor network containing many intelligent sensors, making them able to collect, process, analysis, and disseminate valuable data [12].

This paper presents an efficient agricultural environment monitoring and 24/7 weather and agricultural fields monitoring system, with the purpose of improving the productivity and managing agricultural issues regarding appropriate water and crop production. In Sect. 2, the related work is presented, then Sect. 3 describes technology and devices used in agrarian field management. In Sect. 4, the experimental part illustrates telemetry solution for weather monitoring and agricultural fields, by considering environmental parameters and condition and, finally, Sect. 5 concludes the results.

2 Related Work

The concept of smart agriculture has been in practice from more than a decade now on small level agriculture. The purpose of the paper is making agriculture smart using automation and IoT based devices and technologies. This paper gives information about field activities, irrigation issues and storage for smart irrigation system [13], monitoring the crop-field using soil moisture sensors, temperature and humidity sensors, light sensors [14]. Geocledian platform [15] is used to monitor the crop fields on large scale with efficient results.

Internet of Things (IoT) is used with IoT frameworks to have an easily view, handle and interact with data and information. Within the system, users can register their sensors, create streams of data and process them and compare data from different time periods. In addition to this, the system has searching capabilities, helping the user with a full-text query language and phrase suggestions, allowing a user to use APIs to perform operations based on data points, streams and triggers. It is also applicable in various agricultural areas. Few areas are:

- Water quality monitoring
- Monitor soil constituent
- Soil humidity
- Water irrigation
- Scientific disease and pest monitoring

To develop cost-efficient and affordable system by avoiding the necessity of maintenance, free from geographic constraints and able to access reachable services, extended “as-a-Service” framework in cloud computing can be integrated with IoT to deliver financially economical IT resources [16].

Internet of things (IoT) is an intelligent technology which includes identification, sensing and intelligence. Life and even intelligence of life itself can also be regarded as part of IoT technology. It is used in pattern identification fields like measurement and computing as well as computer and communication fields like sensing, communication, information collection and processing. The definition of IoT changes as the time of cloud computing evolves. Now, IoT is defined by cloud computing plus ubiquitous network along with intelligent sensing network. Cloud computing management platform is the “backbone” of storing and processing IoT data. It involves management of accession of cloud computing customization application by users of these IoT, computing and processing that is involved in customization service; organizing and coordinating service nodes in the data center. Ubiquitous network includes LTE, GSM, WLAN, WPAN, WiMAX, RFID, Zigbee, NFC etc. are used to gather the data and can provide restful based web services for communicating between IoT cloud and sensors in terms of ecological sustainability [17].

The research in agricultural field is enhanced in various aspects to improve the quality and quantity of productivity of agriculture. Researchers have worked on various projects on soil attributes, different weather conditions as well as scouting crops. Work has been done on plant nursery availing Wireless Sensor Technology [18]. Wireless Sensor Network based polyhouse monitoring system is illustrated in [19] which makes use of environment temperature, humidity, CO2 level and enough light detection modules. This polyhouse control technology deliver automatic adjustment of polyhouse. The development of WSN for the above mentioned parameters can be applied for agriculture using ZigBee protocol and GPS technology [20]. In some projects, rice production was enhanced through the implementation of a system that monitors the crop [21]. Leaf wetness sensors get the data until a certain point such as a gateway or fog/edge computing node [22–24]. IoT provides platform to research to maintain real time data and send notifications immediately to farmers. IoT implementation provides easy access to information that is gathered from sensor nodes. IoT is also utilized for product supply chain business process. Cloud architecture provides additional support to IoT in maintaining Big data of agriculture information visualization history information, soil properties, fertilizers distribution, image cultivation via camera and information gathered through sensors, recording information etc. Collected data is analyzed to find correlation between environment, work and yield for standard work model construction, monitoring for adverse signs and fault detection. It has been discussed in [25] the application of data mining using WEKA tool and analysis model through machine learning algorithms. In [26] authors have concentrated on crop monitoring; information of temperature and rainfall is collected as initial spatial data and analyzed to decrease the crop losses and to enhance the crop production. An optimization method is used to show progressive refinement for spatial association analysis.

3 Technical Description

We provide a description of the technology and devices being used in achieving the target of monitoring weather parameters and agriculture fields and explaining the features of a specific device, like scientific instruments or computer programs. This technology and devices help the formers to keep the track of previous weather reports and plan the strategies accordingly.

3.1 Smart Agriculture

The control architecture of smart agriculture based on cloud computing and IoT [27] consists in control platform and database, and the platform further consists in subsystems as agroecological environment control, agricultural resource control, production process control, farm produce, agricultural equipment and facility. It includes computer system and other facilities. Also, it comprises redundant data communication links and environment control facility.

The agroecological environment control subsystem includes:

- Water quality monitoring.
- Accurate fertilization saves fertilizer
- Monitor soil constituent, soil humidity, light, wind, air, etc.

The agricultural resource control subsystem includes:

- Intelligent greenhouse that allows automatic adjustment of temperature.
- Water irrigation that can automatically control flow and save water
- Scientific disease and pest monitoring

The production process control subsystem includes:

- Identification of individual animals allows healthy cultivation
- Monitoring of animal and plant growth
- Product sorting guarantees quality

Farm produce and food safety subsystem includes:

- Get informed of the entire logistics process
- Rationally arrange storage in warehouse
- Traceability system of farm produce supply chain

Agricultural equipment and facility system include:

- Diagnosis of farm machinery breakdown
- Remote control of farm machinery
- Operation monitoring of farm machinery

3.2 Adcon

Adcon Telemetry equipment is being successfully functional in agriculture, hydrometrics, irrigation control systems, meteorology, water and air quality measurements, water management systems, measurement of renewable energy potential, plant disease management etc. ADCON supported sensors are temperature and relative humidity, solar radiation, barometric pressure and soil temperature. The remote transmissions unit is responsible for transmitting the data via radio waves from the site back to the master station at the gateway [28, 29].

3.3 Libelium

Libelium analyses the level of pollution - air pollution, agricultural, noise, water, meteorology, water management systems, measurement of renewable energy potential, plant disease management etc. Libelium supported sensors are temperature and relative humidity, solar radiation, barometric pressure and soil temperature. The data from these sensors are stored in a gateway called Meshlium [30, 31].

3.4 Geocledian Platform

Geocledian platform [15] helps in farm management systems. Up-to-date satellite information is monitored, the vegetation development or seasons and fields are analyzed. Crop health problems due to pests, diseases or missing nutrients are being detected in time so that actions can be planned. In different types of information systems, satellite images can be used for production monitoring to get an overview about agricultural activities in a region or originate statistical information.

Also, the data can be utilized in estimation of harvest, harvest loss or the area of active farmland. In agricultural advisory systems, the management practices on farms can be analyzed and improvements can be planned and monitored.

Vitality and variations products are based on the Normalized Difference Vegetation Index (NDVI). It is based on measurements of visible and near-infrared light and ranges from +1 to −1. Vegetative areas show always positive values, whereas bare soil and rocks approach 0. The NDVI is a measure of plant vitality. It correlates with biomass, leaf area, chlorophyll content and plant health. The data for parcels will immediately be updated as soon as new measurements are available.

Analysis functions available are:

- NDVI & other vegetation index time series statistics per parcel
- Phenology statistics on a variety of specialized parameters
- Notification messages
- Crop type verification
- Parcel comparisons & benchmarking
- Others on request

The basic Monitoring package provides a REST API supporting typically GET, PUT and DELETE commands keys. For accessing the API, one needs a user key and the base URL. This stack is updated as soon as a new sensor measurement is available. It makes the most sense to register parcels with one single crop. Parcels with mixed crops can be used, too, but some API functions may not deliver the precise required results. Parcel is being registered as follows:

- Geometry of the parcel.
- Crop types.
- Planting date.
- Harvesting date.

4 Experiments

To have a proper view of the comparative measurements of the Adcon and Libelium telemetry stations, those were installed in the same analytical perimeter. The communication protocol and data transmission modalities for Adcon and Libelium telemetry station are presented in Table 1.

Table 1. Data transmission and communication protocols

Telemetry station	Data transmission	Communication protocol
Adcon	addUPI	GPRS
Libelium	HTTP	4G

A fixed period for environmental parameter analysis has been chosen. The data acquired from the sensors was centralized into a database and was used to highlight the sensor events, based on timestamps and sensor types. Figure 1 explains the whole phenomena that occur from collecting data to transmission, integration and visualization. The presented architecture is inspired from [32].

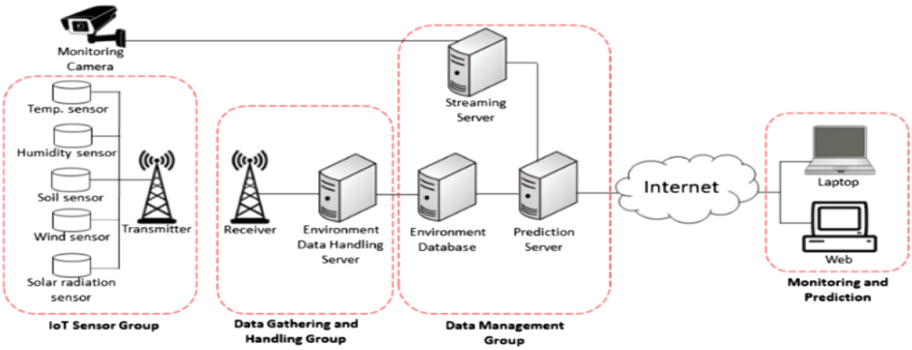

Fig. 1. IoT service architecture based on [32]

Smart Agriculture is characterized as “a method to recognize the basic requirements as well as the changes in the current environment due to external factors built on the information and utilization of compiled data to optimize sensors’ operation or influence the operations of actuators to change the current environment.

Using above mentioned technologies, we performed experiments and collected the data in their respective platforms. Adcon station installed provides 24/7 weather related data as seen in Fig. 2.

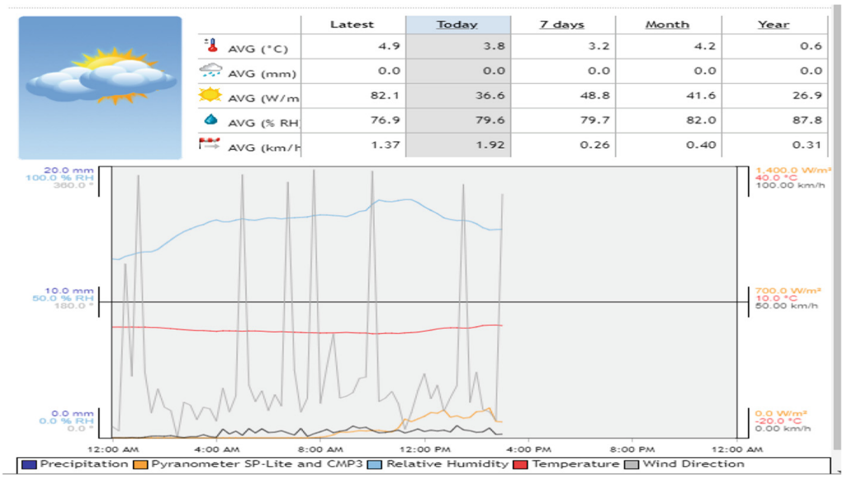

Fig. 2. Adcon telemetry station readings at BEIA office

Libelium devices has been installed in fields nearby Bucharest, Romania, setting up the data transmission time, sleep time and channel through programming codes. After running the codes, we get the readings of the installed sensors in Meshlium platform, it can be seen in the picture below (Fig. 3).

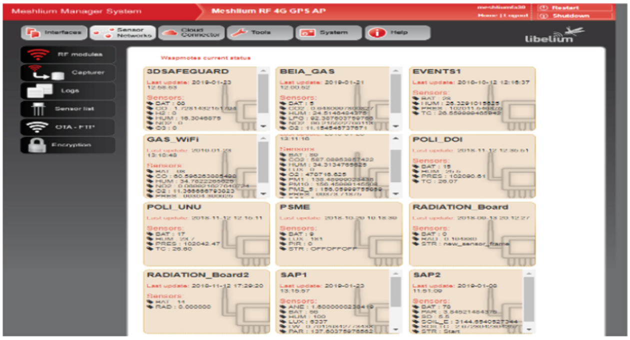

Fig. 3. Meshlium dashboard

The variation of the values for the measured parameters (temperature, solar radiation) are presented in Figs. 4 and 5.

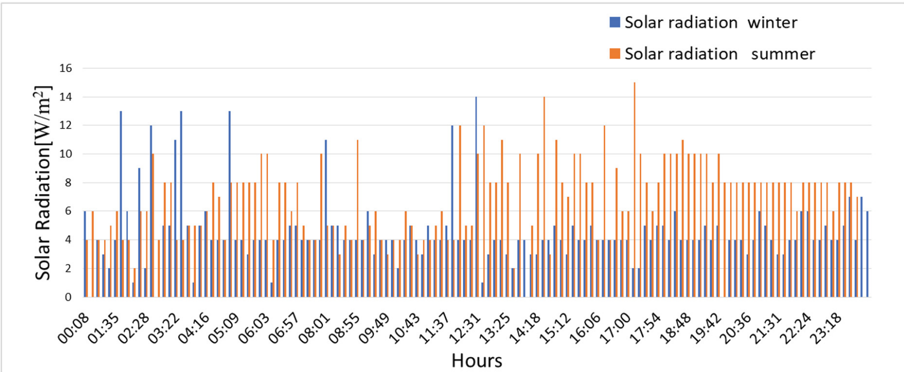

Fig. 4. Solar radiation from Libelium station

Getting the data from Meshlium platform, we compared the changes occurring in weather and field soil during summer and winter. Orange line shows solar radiation during summer and blue for winter.

To make results more significant, we used another platform called Geocledian. The platform is used for constant monitoring of the desired field parcels and helps in farm management systems using up-to-date satellite information. Also, the vegetation development, seasons and fields are analyzed. As mentioned before, using Geocledian platform, crop health problems due to pests, diseases or missing nutrients are being

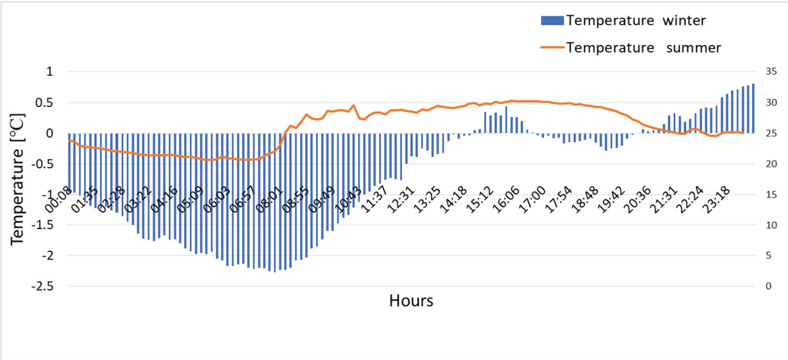

Fig. 5. Temperature variation measured by Libelium station

detected on time so that actions can be planned. The experiments have been performed on 5 different parcels chosen near to Bucharest, Romania, in 2018. Two of them can be seen in Fig. 6. One can observe the variations in vegetation index, visibility, vitality and variation with respect to time.

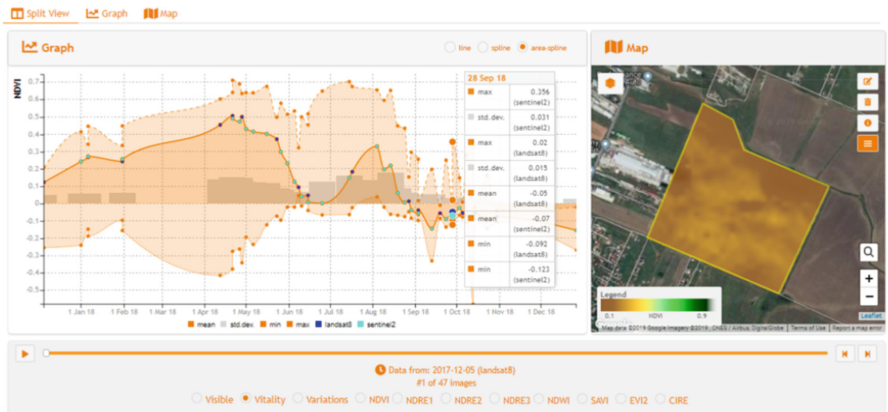

Fig. 6. Complex cultivation patterns and graphical representation

Uneven irrigation patterns: comparing the Vitality image (MIDDLE) of this irrigated field near Bucharest Romania, data from 2018-07-15 (sentinel2) to the Visible (LEFT) and Variations image (RIGHT) indicates that certain features are only visible in the Vitality or Variations, such as in Fig. 7. With the help of visibility, vitality and variation one can easily analyze what area needs to be watered and what area areas required more attention for better yield.

Visually comparing the Vitality images for a parcel. A Vitality time series during growth and ripening should look like the series of pictures shown in Fig. 8. As in the start of the experiment, when we started getting the pictures with the satellite and

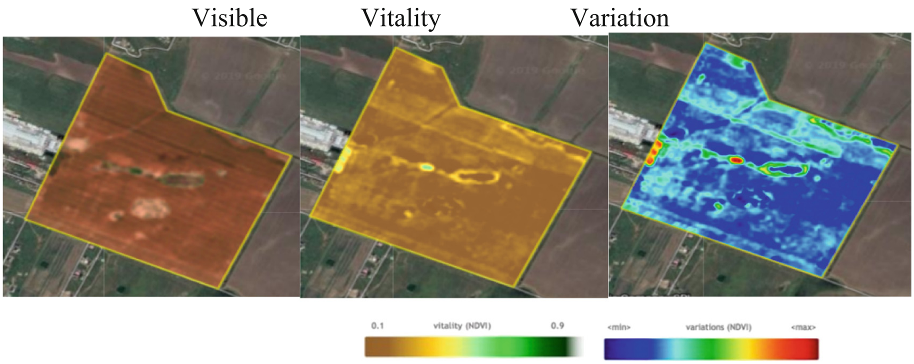

Fig. 7. Uneven pivot irrigation patterns

visualized in the platform, the land is clear, first top left picture indicating the results. As the crop starts growing, the picture changes in time, the green regions show the growth of the crop. After a period of months, it gets to the point when the wheat crop starts ripping, that is, the regions in the picture become yellowish, a fact that indicates the harvesting season.

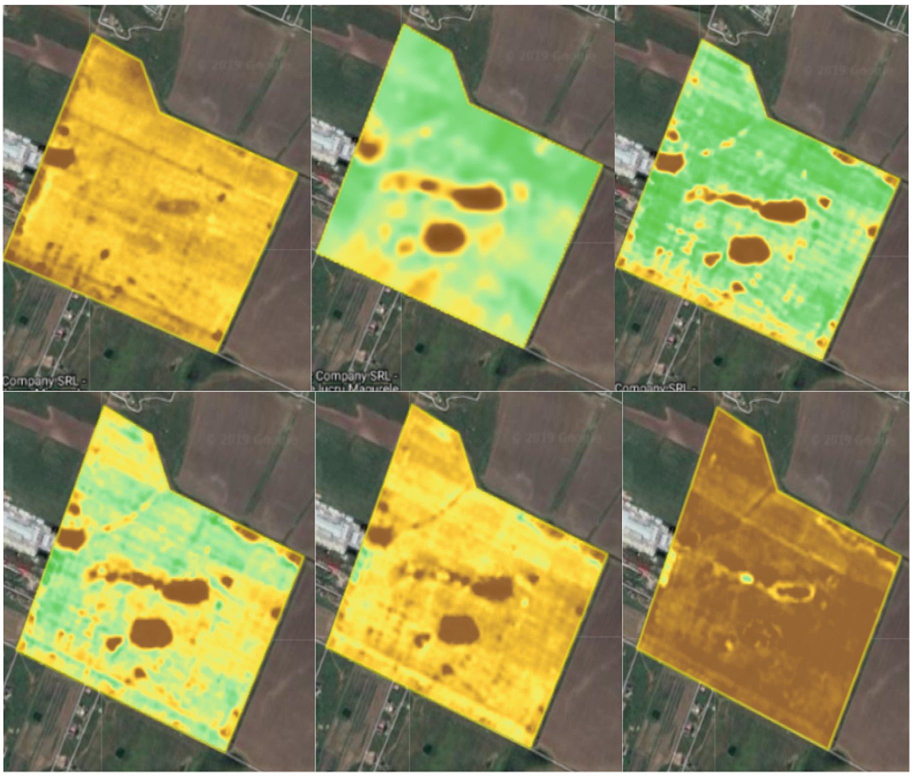

Fig. 8. Seeding to harvesting evolution in the parcel

If a crop develops normally the NDVI should follow a crop-specific development curve as in the figure above. The NDVI will steadily increase during the growth period (maybe interrupted by winter for winter cereals or bloom as with rapeseed) and reaches the maximum just before the start of ripening. The NDVI starts to decrease when ripening sets in and reaches its minimum at harvest. Normally, all pixels in a field should follow a similar NDVI curve with possibly different absolute values due to varying soil, nutrition or water conditions or management practices.

The Vitality image in Fig. 9 is from a field in Bucharest, August 14, 2018. Here, the plant biomass is different due to different crop development stages and shows how the soil is during the period of experimentation. This picture helps in monitoring the area where expected crop can be less or where it can be satisfying. Wherever the crop is weak, multiple steps can be taken to make it better. For example, that area must be fertilized or watered for better yield.

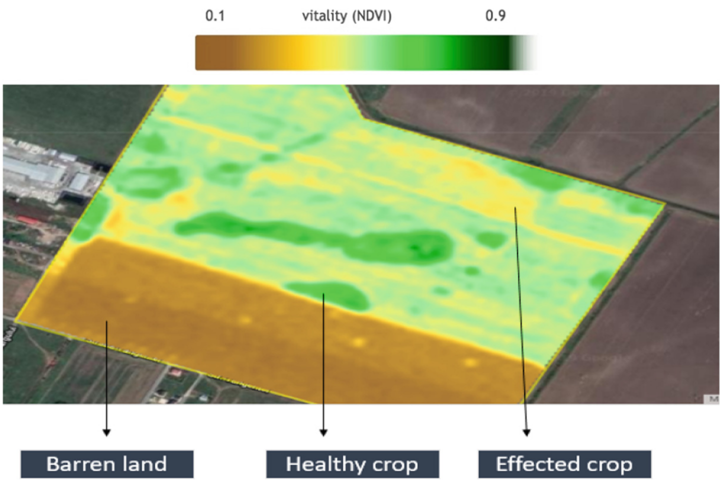

Fig. 9. Biomass variability due to different crop development stages

Uneven plant development due to soil variability. The Vitality image in Fig. 10 is from a field near Bucharest, Romania, August 14, 2018. Here, the plant development is uneven due to soil variability, also found in Fig. 9. It indicates weakness of some areas of the parcel, which requires attention to treat the area for equal results of the whole parcel.

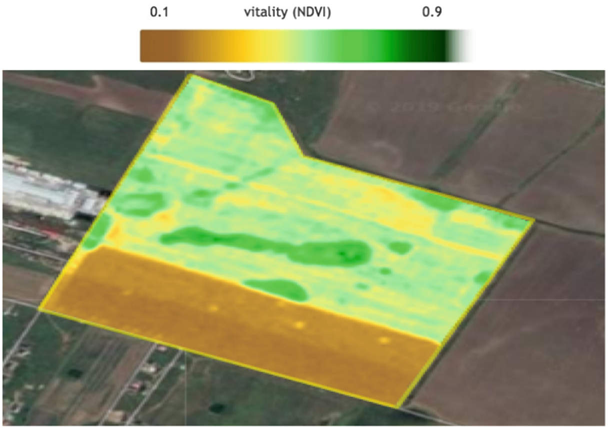

Fig. 10. Soil variability in uneven plant development

5 Conclusions

The paper first performed a survey of the existing work regarding real time analysis of weather parameters and analyzed current state-of-the-art offers Goecledian platform for analyzing irrigation management, crop disease prediction, vineyard precision farming mostly. Simplified, low cost, and scalable systems are in demand. At the same time, with the advent of modern technologies, there exist a lot of scope for innovating new and efficient systems, more specifically, low cost solution with features like autonomous operation and low maintenance. In this paper, we present a connected farm based on IoT systems for monitoring fields and smart farming, the IoT technology application in agriculture and selected wireless communication technology to obtain a remote monitoring system with internet and wireless communications combined is presented. At the same time, considering the system management, the information management system is designed. The collected data by the method provided for agricultural research and management facilities. Research shows the field monitoring system based on IoT technology can have precision in monitoring and controlling the state of agricultural fields. According to the need of surrounding monitoring, this system has realized the automatic monitoring of the environmental temperature, humidity, soil moisture, soil temperature. Thus, field condition is monitored continuously throughout seeding to harvesting. The system has offered an excellent growth condition; it is easy to operate, the interface is friendly, offering real-time environmental factors in the fields. It can revise environmental control parameters; this system realizes the operation online and, also, has the following characteristics: it runs reliably, and it is high performant. As future work, we envision investigating fruit ripening analysis using the platform presented in this paper.

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