Study on Collaborative Smart Farming over Digital Platform

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ABSTRACT

Collaboration in the supply chain of agriculture has become extremely salient recently due to increased global demand for high crop yields and sustainable farming practices. Limited resources, like soil, are destructible by various agents. Smart farming and the Internet of Things (IoT) provide a solution through precise application and data collection, leading to accurate farm monitoring. Research shows that greater synergy among supply chain members—farmers, processors, distributors, and retailers—enhances efficiency, reduces costs, and improves quality. Despite the necessity for large investments and time, smart collaboration in farming is still not widespread. Collaboration entails sharing equipment, data, and expertise, yet farmers often resist sharing confidential information. This study aims to address these challenges using IoT-based models to make informed decisions over digital platforms and to use digital platforms to their full potential. It involves installing sensors to collect data on a real small family farm from Croatia, in an area known for small family farms producing organic food traditionally, facing issues in enhancing their yields due to limited capacity and entrepreneurial skills.

CCS CONCEPTS

• **Computers in other domains**; • **Modeling and simulation**; • **Ubiquitous and mobile computing**;

KEYWORDS

Smart Sensing in Farming, Community Partnerships, Accurate Farm Monitoring, Sustainable Farming Practices

ACM Reference Format:
Martin, MŽ, Žagar, Dua, DW, Weraikat, Kristina, KŠ, Šorić, and Mateo, MS, Sokač. 2024. Study on Collaborative Smart Farming over Digital Platform. In *Central and Eastern European eDem and eGov Days 2024 (CEEeGov 2024), September 12, 13, 2024, Budapest, Hungary*. ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3670243.3670264

1 INTRODUCTION

Sustainable farming turns out to be a very pressing issue with the growth of the world's population. Research has shown that by 2050, food production will have increased by 85% to meet the demands posed by an estimated 8 billion people. With this, smart farming is an emerging prospective domain, which aims to bring advancement in productivity and sustainability with the help of technology and IoT [1]. The Internet of Things has drastically changed various sectors, including agriculture.

It is a network that makes it possible for connected devices to be able to collect and transmit data, so as to provide valuable insights useful in improving decision-making. In agriculture, this application of such an abundance of IoT devices, including sensors to monitor every parameter of the fields, like moistness, temperature, pH level, and maybe even growth, results in the resources being used in a more efficient way, which results in more crop yields. Furthermore, with the help of the IoT, food safety and quality have been enhanced, whereby sensors are used in recording the facilities in storage if the temperatures and humidity levels are recommended to standards. Nowadays, drones are used as a mounted camera and sensor aid, so that the farmers would be able to get adequate data regarding the growth of crops and their health status, as well as potential yield, so that accordingly, they may take appropriate strategies about planting and fertilization and control pests. Where efficiency will be realized in this case, real-time data with the help of sensors is going to be evident, with regards to the performance that can be tracked and monitored for making quicker decisions, say, in the scheduling of maintenance and repairs more efficiently by the farmer [2]. The IoT enables remote control and monitoring of equipment. That simply means that farmers can make a choice on how to run operations from a distance and save a lot of time and money that would never be worth using by traveling around, sampling, and taking measurements.

For example, Nawandar and Stapute [3] managed to monitor water usage and identified smart irrigation systems. They, on the other hand, would use MQTT and HTTP to let the user know about the status of the farms even from a remote location. Agriculture is in the process of digital transformation with the help of artificial intelligence systems, which are, in turn, extracting value from increasing data. Machine learning, a subfield of artificial intelligence, has enormous potential for the envisaged scope, even including the various challenges in farming. In their recent literature review regarding crop, water, soil, and livestock management, Benos et al. [4] found crop management to be the center of focus. Artificial Neural Networks (ANN) and other machine learning algorithms were found efficient, and the research aimed at various crops like maize, and wheat, and animals like cattle and sheep. Despite smart farming and IoT bringing with it a host of benefits that include

CEEeGov 2024, September 12, 13, 2024, Budapest, Hungary

ACM ISBN 979-8-4007-1709-3/24/09
https://doi.org/10.1145/3670243.3670264

enhanced decision-making through higher efficiency and effectiveness in resource utilization, such technology is costly and requires time to be implemented.

In such cases, this kind of problem issues smart farming with collaboration, where farming is shared among the farmers with their resources and knowledge on implementing technologies. The research was able to establish that collaboration with all stakeholders of the supply chain, including the farmers, processors, distributors, and retailers, leads to more efficiency, reduction of costs, and enhancement of the quality of the product, among other benefits [5]. Similar findings were established in another study, which depicted the fact that collaborative relationships between the farmers and processors had positive effects on improved communication and coordination. The same source outlined that this resulted in cost reductions and effective deployment of the resources of both parties.

The study also found that collaboration led to upgraded product quality and increased customer satisfaction. Another study was conducted to assess the implications of such collaborative relationships between farmers, distributors, and retailers along the organic food supply chain. This significantly increased the sharing of information and coordination, which will support efficiency, cost reduction, and sustainability of the business [6]. Other research has focused on the role of technology in facilitating collaboration in the farming supply chain to increase the use of digital platforms and tools that can enlarge communication and coordination among supply chain partners, therefore enhancing efficiency and cost reduction. According to the literature [6], this kind of general benefit is accrued when several stakeholders collaboration takes place in the farming supply chain. Some of the advantages accrued would be increased efficiency, cost reduction, and better quality of output.

In addition, it has been brought out clearly that technology development evidence in promoting easy collaboration and, indeed, deriving greater value from it has been demonstrated [6]. In a nutshell, from the literature, though collaboration in farm supply chains can yield benefits for all involved, at the same time, most importantly, there is openness and transparency in communication and some parity of powers among the stakeholders. Besides, the role of technology and digitalization in facilitating cooperation has not been researched to a large extent, although the question has a tendency to raise much interest in the academy.

2 POSSIBILITIES OF DIGITAL PLATFORMS

Digital platforms have significantly changed the face of business. Digital platforms have also accelerated the business development and success of SMEs (where small family farms belong to), where they are now in the position to gain extra market, and customer relations channels and to build their different additional value proposition for the customers. However, a lot of business owners are still afraid of the possibilities and outcomes that digital platforms could generate because they are missing digital literacy about these platforms and the changes in their business models the platforms are generating. The findings of the internal survey we conducted at our institute reveal that many respondents believe that digital platform literacy should become a priority in modern curricula. With enabling digital platform literacy it will also be possible to overcome gender inequality. According to the WEF Global Gender Gap Report for 2020 [7], women have greater representation in roles that are being automated; but globally women face the perennial problem of insufficient access to new technologies, specifically in rural areas and entrepreneurship. That's why one of the pillars of our proposal is directed towards the women owners of small family farms where a major consolidation of existing systems and applications invokes retire/replace strategies and very demanding complex integration based on specific digital skills.

We identified the following objectives to be addressed by including digital platforms:

- Raising the awareness of digital platform usage;
- Overcoming gender inequality and full inclusiveness in digital literacy;
- Digital leadership skills;
- Analysis and visualization tool for remote sensing.

Besides obvious smart monitoring and real-time visualization of the state of the crops on the farm, the added value of digital platforms could be digital skills education for small family farm owners. That's why we intended to share our knowledge about digital skills, ubiquitous digital applications, a framework for digital platforms in management, a framework for digital platforms in finance, interdisciplinary development of digital professional skills, and the use of digital technologies for communication, collaboration, and professional development with (women) owners of small family farms. Special attention is devoted to the pedagogical competencies for learning about digital platforms as well as the development of digital strategies for small family farms as well as fostering of digital communication and collaboration between the farms.

As one of the deliverables in this part of the proposal, we aim to develop both a methodological framework with guidelines for defining digital skills that will be shared with small family farm owners (we are aiming primarily for women owners) and a pedagogical framework with guidelines for defining digital skills. Within those frameworks, we will address digital technologies for knowledge sharing, ubiquitous digital application features, and frameworks for digital platforms in management. We plan to accomplish these by:

- Information technology technical skills as the ability and knowledge needed to perform specific tasks of visualizations of data collected from the sensors, different setups for visualizations, and time-frame analysis.
- Pedagogical skills including knowledge sharing between small family farm owners, using Case study analysis in the knowledge sharing, and online support and training – tips and tricks for online learning, discussion as a valuable teaching tool; organizing small workshops on how to organize and conduct agriculture techniques and methodologies; praxis of sharing of best practices exchange of knowledge between small family farm owners.
- Networking skills in the form of cooperative activities on how to establish a long-term partnership with companies and other small family farms; study discussions giving the opportunity to solve practical, real-situation problems using effectively obtained theoretical knowledge.

Figure 1: Integrated sensor for measuring soil temperature, pH level, light intensity, and nutrient levels (nitrogen, phosphorus, and potassium) deployed in the soil in the greenhouse of the partnering small family farm.

- Entrepreneurial skills – since entrepreneurship as a competence is defined as the capacity to act upon opportunities and ideas to create value for others. The value created can be social, cultural, or financial.

3 SETUP OF SENSORS FOR SMART FARMING

As a second part of the proposal which includes smart soil monitoring, we established collaboration with a small family farm owned by a woman from Brest Pokupski in Croatia, which is producing organic vegetables and fruits. We installed sensors on their fields to collect data on moisture levels, soil temperature, pH levels, light intensity, and nutrient levels (nitrogen, phosphorus, and potassium). We connected those sensors on the ESP32 board to process the data and send it both to the datalogger (SD card) and simultaneously over the built-in WiFi module to the ThingsBoard visualization platform [8]. On this platform, it is possible to monitor all data in real-time and to analyze different parameters and relations. The setup of the sensors deployed in the greenhouse at the farm is shown in Figure 1.

Installing sensors in the soil to monitor the above-mentioned environmental parameters involves several steps. We defined the following needs:

- Moisture sensor: Measures the volumetric water content of the soil.
- Temperature sensor: Digital sensor for precise soil temperature.
- pH sensor: Measures the acidity of the soil.
- Electrical conductivity (EC): Indicator of the total ion content in the soil, which correlates with the availability of nutrients for plants. High EC values can indicate high nutrient levels, while low EC may suggest nutrient deficiency.
- Nutrient sensors: Specialized sensors to measure nitrogen, phosphorus, and potassium (NPK) levels.

We selected the SumTech Soil Integrated Sensor for the ESP32 board via digital pins on the ESP32 using the GPIO (General Purpose Input/Output) pins. We also have matched the required power supply of 12-24VDC of sensors to match with what ESP32 can provide. Other technical parameters [9] of the sensors are:

- Output signal: RS485
- Temperature range: -40℃-80℃
- Temperature accuracy: ±0.5℃
- Temperature resolution: 0.1℃
- Water measurement range: 0-100%
- Moisture accuracy: ±3% Within 0-53%; ±5% within 53-100%
- Water resolution: 0.10%
- Electrical conductivity measurement range: 0-10000us/cm
- Conductivity resolution: 10us/cm
- Consumption: ≤0.15W
- pH Detect Range: 3-9 pH
- pH measurement accuracy: ±0.3pH
- pH resolution: 0.01pH
- Measurement range of NPK: 0-1999mg/kg
- Measurement accuracy of NPK: ±2%F.s
- Resolution of NPK: 1mg/kg(mg/l)
- Storage environment: -20℃-60℃
- Response time: <1s
- Protection level: IP68

The setup of the board connected with the SumTech Soil Integrated Sensor is shown in Figure 2. After we connected sensors to ESP/32 we used Arduino integrated development environment to write the code for the ESP32. We initialize the sensors in the code and read their outputs at regular intervals of 2 hours. We also process the sensor data as needed (e.g., converting raw readings to

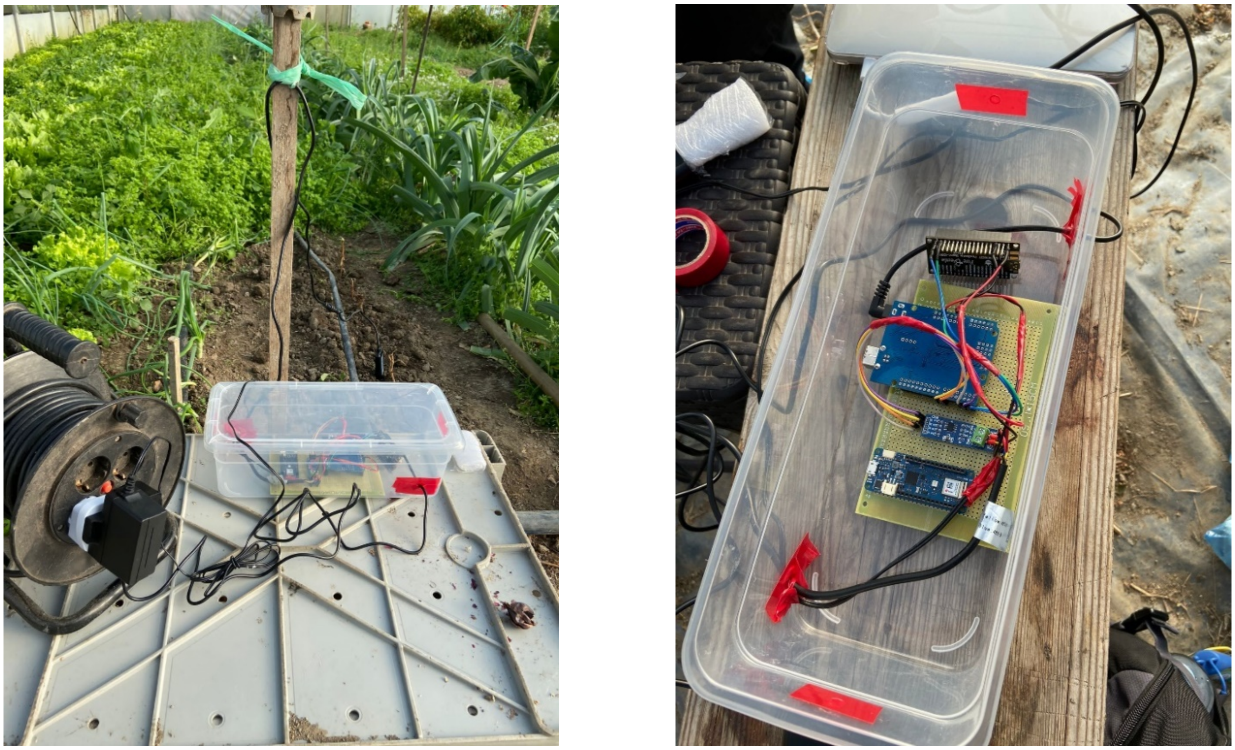

Figure 2: Setup of the connected ESP-32 board with WiFi module deployed in the soil in the greenhouse of the partnering small family farm.

1	currentMillis	Nitrogen	Phosphorous	Potassium	PH	ElectricalConductivity	Temperature	Moisture
2	2943	0	1	2	762	10	16	15
3	10981	0	1	2	768	10	17	14
4	19020	0	1	2	768	10	19	18
5	27058	0	1	2	768	10	12	13
6	35097	0	1	2	768	11	16	16
7	43135	0	1	2	768	11	14	16
8	51174	0	1	2	768	11	13	15
9	59212	0	1	2	768	11	14	14
10	67250	0	1	2	768	11	18	18
11	75289	0	1	2	768	11	15	16
12	83327	0	1	2	768	11	17	14
13	91366	0	1	2	768	11	13	12
14	99404	0	1	2	768	11	14	15
15	107443	0	1	2	768	11	13	15
16	115481	0	1	2	768	11	15	18
17	123520	0	1	2	768	11	17	20

Figure 3: Raw data collected from the moisture sensor, temperature sensor, pH sensor, EC sensor, and NPK levels in the preset timeframe.

meaningful units for pH, moisture, and NPK and adding units). For data logging, we use an SD card module connected to the ESP32. For data transmission, we use the ESP32's built-in Wi-Fi module. Finally, we used the MQTT protocol to send data to ThingsBoard.

4 RESULTS AND CONCLUSIONS

The prototype is deployed at a small family farm to track sensors and data collection. Raw sensors' measurements are presented in the data table in Figure 3, and then further processed and visualized in the ThingsBoard platform, as presented in Figure 4. We are

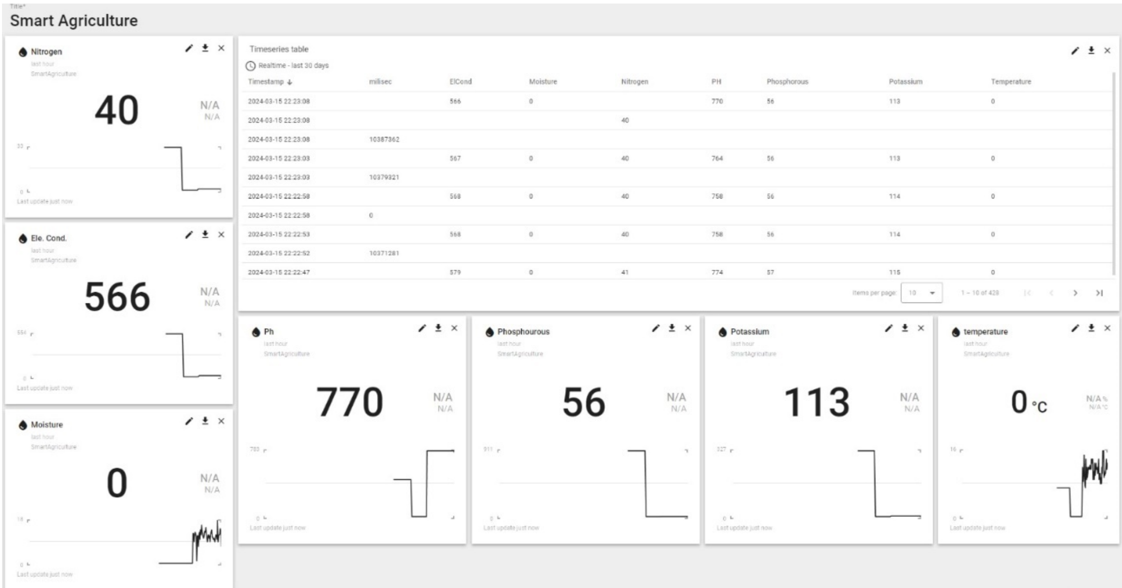

Figure 4: ThingsBoard visualization of the collected data from the moisture sensor, temperature sensor, pH sensor, EC sensor, and NPK levels in the preset timeframe.

visualizing all the inputs of the moisture sensor, temperature sensor, pH sensor, EC sensor, and NPK levels in the preset timeframe.

We also visit the farm once a week, check the sensors, and copy the backup data from the data logger. During our visits, we started with achieving goals we set regarding the application of digital platforms, in the sense of raising awareness of digital platform usage and overcoming gender inequality and full inclusiveness in digital literacy with small family farm representatives. This represents the first stage of our project with small family farms where we set the collaboration with producers, enabled the sensor setup, started with the initial education on digital platforms literacy, and already visualized collected data from the platform in ThingsBoard that are to be used to build a machine-learning model and develop a prototype for predicting the best conditions for growing the plants in the soil in the next stage of our project. In the next stage, we also plan to have two different surroundings to examine the influence of different agriculture and water resources and measure the impact on overall production, which is important to collect enough different datasets to build a machine-learning model to increase production and improve the processes in the field and in identifying the contextual factors while shaping differences observed between sites. We already started with education on technical skills needed to perform specific tasks of visualizations of data collected from the sensors, different setups for visualizations, and time-frame analysis. Finally, in the next stage, we plan to deliver the rest of our education on digital platforms with a broader group of small family farms on pedagogical skills, networking skills, and entrepreneurial skills, as planned by the education on digital platforms we presented in Section 2 when we will also provide the new report with overall outcomes of our project.

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