An Intelligent Management System to Support Sustainable Urban Agriculture: the Case Study of the CIRC4FooD Platform

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***Abstract*—The objective of this work is to improve the management of a vegetable garden through an Intelligent agriculture management system based on IoT, where the activities of a garden are handled through an online monitoring platform. The platform has been developed within the project 'A circular economy inspired food production system' (CIRC4FooD) as a part of the intelligent management system for the urban vegetable gardens, with the wider aim to engage the user and to promote and inform about circular economy and sustainable food systems. The CIRC4FooD integrated system consists of a garden equipped with a rainwater harvesting system, composting bin, and intelligent management system, namely the platform and incorporated Internet of Things (IoT) technologies: various sensors for soil and air parameters, rainwater tank and compost. The implementation of a dynamic rule engine consisting of three modules: i) environmental, ii) water tank, and iii) compost, allows the users to get notifications about any actions required or recommended from their side to keep the garden in proper condition, but also to assure environmental benefit (i.e., saving water resources by using harvested water, watering the garden only when the real need arises, use of compost as fertilizer, etc.). In this paper, the preliminary system and platform design are presented, which might be further improved, followed by the next steps that will be scheduled within the CIRC4FooD project to test the platform in real-life conditions and on different scales.**

Keywords-intelligent management system; platform; dynamic rule engine; urban agriculture; sustainability.

I. INTRODUCTION

In the original conference paper [1], about CIRC4FooD platform, we briefly introduced the project's benefits, focusing on the system's main functionalities. Thereafter the study aims to introduce in depth the additional developed features of the intelligent management system, highlighting the support for sustainable agriculture.

Food production poses a significant environmental burden that accounts for 10%-30% of an individual's environmental impact [2]. According a recent report from the Food and Agriculture Organization [3], current food production systems are facing several challenges: (a) growing demand for food, driven by increasing world population and urbanization; (b) diminishing land and water resources and their declining quality; (c) climate change, and at the same time significant contribution of the agricultural sector to this phenomenon; and (d) too few investments in solutions contributing to sustainable agriculture.

Due to the environmental stress on water bodies, harmful land use practices, soil depletion, and greenhouse gas emissions, the need for sustainable agriculture solutions is rapidly growing. The ever-present efforts to improve agricultural yield with fewer resources and labor have resulted in significant innovations throughout human history. Despite those efforts, the growing population rate never let the demand match the actual supply. Demand for food is growing at the same time the supply side faces constraints in land and farming inputs. The world population is expected to reach 9.8 billion in 2050, increasing approximately 25% from the current figure [4].

The listed challenges, in line with the destructive effect, that the traditional, linear economy has on the food system, pose increasing pressure on the food system, creating urgency for resilient and sustainable food systems.

CIRC4Food project introduces a solution for local food production systems, contributing to the following:

- the promotion and dissemination of a sustainable food system
- the facilitation of social interaction between residents
- the transformation of physical space
- the increase in awareness of healthy eating
- the education about affordable and fresh food production.

CIRC4Food system for food production consists of a vegetable garden equipped with a rainwater harvesting system and a composting bin. Many studies have proven the numerous environmental, social, and health benefits of urban vegetable gardens [5-7]. The CIRC4FooD system will be supported through an intelligent management system and will introduce a user-friendly CIRC4FooD platform with user-engaging functionalities to promote the sustainable use of natural resources.

The rest of the manuscript is structured as follows. Section II describes the smart farming concept and the integrated system for application in urban vegetable gardens proposed by the CIRC4FooD project. Section III describes the system design, including user requirements collection, as well as user journey and user flow, user types and the concept behind reward system to be developed. Section IV addresses the platform design including its architecture, the rule engine and the platform view. Finally, Section V concludes on the work and outlines next steps. The work is closed by acknowledgements.

II. SMART FARMING AND CIRC4FOOD

The introduction of technology in agriculture aims to an intensive increase in food productivity as well as removing any apprehensions concerning the scarcity of food in the future. The technological applications related to agricultural aspects were classified into three categories, namely data sources and collection, machine learning (ML) methodologies for agricultural data, and intelligent knowledge acquisition. Considering the imperative need for action in the promotion of sustainable food systems, in Figure 1 are highlighted the key drivers of technology in the agriculture sector.

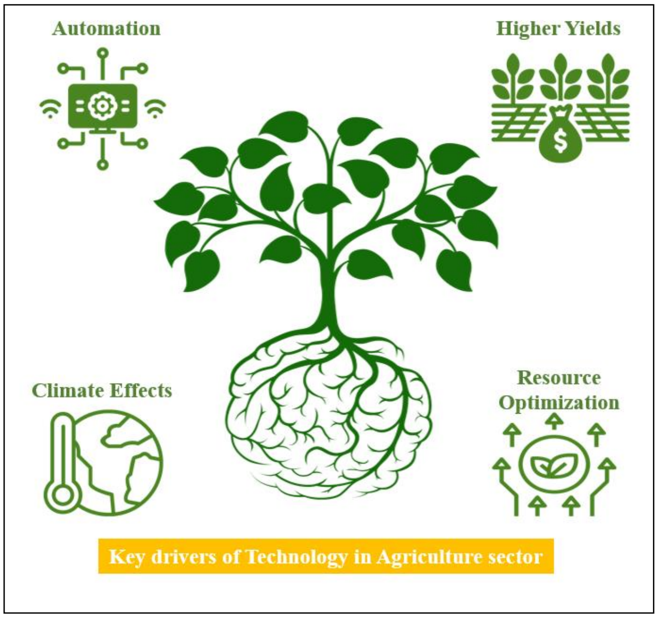

Figure 1. Key drivers of Technology in Agriculture sector.

Smart farming, as a coupling of information, communication, and control technologies in agriculture, is an idea that gains ground gradually. Smart farming is a management concept of using modern technology to increase the quantity and quality of agricultural products. The concept involves an integration of information and communication technologies into machines, sensors, actuators, and network equipment for use in agricultural production systems [8].

These applications are the driving force for the development of innovation in precision and sustainable farming. Although, there are some notable barriers regarding the technology implementation in smart farming, presented in Figure 2.

In a smart farming scenario, large amounts of real-time and high-resolution data are generated from remote and automated sensor systems. The data can represent different aspects of farming, including but not limited to livestock, crops, soil, and the environment [9]. Numerous software developments are available in the market [10-11], designed to make the farmer's tasks more efficient. However, as every particular application has specific characteristics, no "one-size fits all" technology is available. To improve sustainability, there is a need for site-specific strategies for both decision-makers and farmers. Some of the specific aspects of interest of the system design and selection involve the assessment of the techno-economic and environmental impact of an urban farming system, the choice of crops and the optimization of economic and environmental parameters. The optimal design and operational plan pose a significant challenge [12]. Nevertheless, the usage of all these information in the field is usually limited to the aforementioned aspects, and for this reason, an inclusive and multipurpose monitoring platform is proposed, which explicitly supports the management and optimization of the performance of a vegetable garden, with special attention to compost fertilizers production and use and operation of water harvesting system contributing to sustainable urban farming systems.

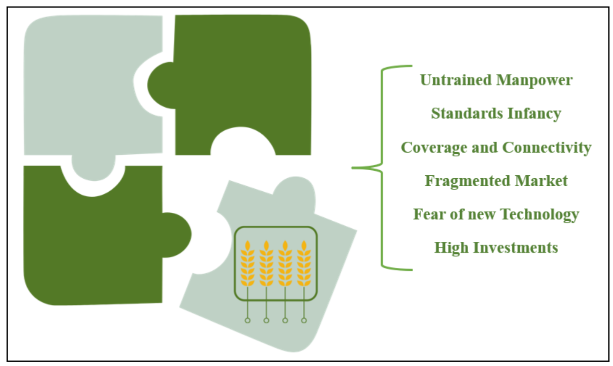

Figure 2. Notable barriers of Technology implementation in smart farming.

Most of the proposed platforms in smart farming have focused on a specific aspect of smart farming, such as crop production recommendations [13], big data technologies, data transformation [14], reliability [15], and business models [16]. In this paper, we propose the CIRC4FooD platform approach as a unified solution that facilitates smart farming applications following the sustainable use of resources. Additionally, this approach imposes learning techniques for urban farming and provides data to track crop cycle information, fertilizer, and water in a secure manner for their decisions and data management.

In regards to that, the intelligent urban vegetable gardens in CIRC4FooD project, use technological resources that help in various stages of the production process, such as monitoring of crops, irrigation and composting process control. More precise, CIRC4FooD integrated system, as revealed in Figure 3, for implementation in urban vegetable gardens consists of the following elements: i) the garden itself, ii) rainwater harvesting and storing system, iii) composting bin, iv) intelligent management system integrating on-line monitoring platform and IoT technologies (including sensors).

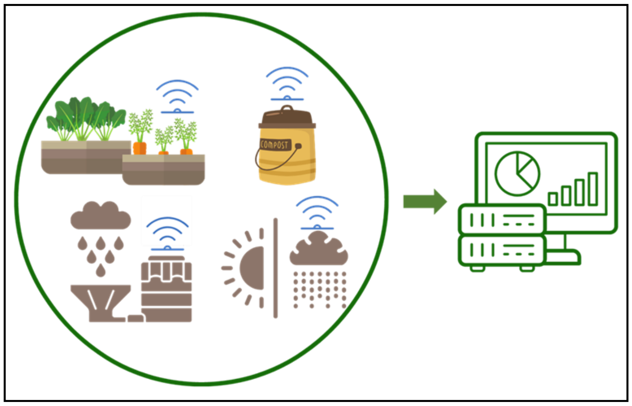

Figure 3. CIRC4FooD integrated system.

The aforementioned sensors will be acquired within the purpose of the project, and upon completion, the participating users will retain those sensors. More specifically, soil moisture sensors will be installed in the vegetable garden, humidity and temperature sensors inside the compost bin, as well as water level and Total Dissolved Solids (TDS) sensors inside the water tank.

III. System Design

A. *User Requirements Collection and KPIs clarification*

The purpose of the requirements collection is to understand the needs of the end-users and the problems they seek to resolve with the specific platform.

The process of gathering the requirements of the system followed the subsequent four main stages:

- Elicitation: In this stage, the project team collected the requirements of the end-users
- Analysis/Processing (Analysis): In this stage, the project team tried to understand the requirements of the end users and model the desired operation of the system based on their requirements.
- Specification: In this stage, the project team tried to document the functionality of the proposed software system.
- Validation: In this stage, the project team checked that the system specifications match the initial requirements of the end users.

All involved/interested members jointly came to a decision on what the final system requirements/specifications will be. For the CIRC4FooD system, the stakeholders involved in gathering the requirements were:

- Domain experts: People who have been in the field for years and could contribute to the requirements/specifications of the CIRC4FooD system since they know very well the needs that the system will cover, as well as the risks that are or may arise during the pilot period. The experts in the area are made up of experts/professionals on the cultivation, employees of the green service of the Municipality, and experts on the specific technology.
- End users: People or groups of people who will use the final product and will be able to evaluate it. The end users are the owners of non-private vegetable gardens who wish to use the CIRC4FooD system.
- Software Engineers: Engineers who will develop the system and will be able to train the end users on the innovations of the product, both in terms of hardware and software technology. The software engineers, in this case, are from the CIRC4FooD project team.

After the consideration of the aforementioned, in order to extract the requirements from the end-user's standpoint, the following factors affecting urban farming were taken into consideration:

- *Weather*: Farming mainly depends on weather conditions. Farmers face great risk in growing crops, as insufficient rainfall and water supply can damage the crop or lead to a decrease in farm produce. Considering the fact that different plants require different parameters of weather conditions, an all-purpose and simplified system – that is suitable for numerous crops – was established.
- *Lack of knowledge and skill*: Literacy is one of the most important factors affecting all the sectors. Lack of literacy results in farmers being unaware of changes occurring in the farming sector. Informing end-users about the dedicated activities regarding the vegetable garden motivates the interested parties to sustainable thinking.
- *Seeds/fertilizers/disease*: To grow crops of good quality, selection of seeds and appropriate knowledge about fertilizers are required. Additionally, timely and proper detection of plants affected by disease can save the farmer from loss and helps in gaining crop security. A repository with information about plants, their characteristics, possible diseases, and advice on handling them will be available for users.
- *Water scarcity:* A more efficient irrigation management focused on reducing the capacities of water applied and therefore optimizing the conservation of irrigation water, is conceivable through the platform which helps the end-user to plan the irrigation activities.
- *Promotion of circularity in food production:* The shift from a linear model to a circular model can meaningfully decrease the negative burdens on the environment and contribute to reestablishing biodiversity and natural resources. With this aim, the presented platform can play a relevant role in setting the paths of this transition, nurturing the shift towards a more sustainable agriculture.

Based on the above-mentioned factors and through a dedicated questionnaire that was conducted during the CIRC4FooD project by e-Trikala, which is the responsible partner for the implementation of the urban vegetable gardens in the city of Trikala during the CIRC4FooD project, user requirements were collected. With the completion of the user requirements, as it emerged from filling out the questionnaire, the analysis/processing of the results followed, where the next step was to better understand the user requirements and to model the desired operation of the system based on the gathered requirements.

Moreover, in addition to the requirements that focus on factors affecting urban agriculture, called standardized data (sensor data, weather data, user data, or coded data), another set of requirements was selected, which focus on functional requirements. Finally, the users, beyond the functional requirements that they wish the system to perform, also have expectations for how it should work. The characteristics that fall into this category are how easy a system is to use, how fast it is, how often it fails and how it will be able to handle unforeseen conditions. The above are features or quality factors of the software and are part of the non-functional system requirements. These characteristics are difficult to define, but in order to perceive the success or failure of the systems, compliance with the non-functional requirements plays an important role. Therefore, while eliciting the requirements, the quality expectations of the users also were taken into consideration.

Functional requirements describe the functional capabilities or services of the system and depend on the type of software, the expected users, and on the type of system in which the software is used. On the other hand, non-functional requirements describe system properties that are usually expressed based on form characteristics: Performance, Usability, Security, Legislative and Privacy. In other words, they describe how (or how well) the system will support the functional requirements and are considered "constraints" that limit the ways in which users can realize the functional requirements. Some of the functional and non-functional requirements used to finalize the user requirements are as follows:

- Personalization
- Authentication/Security
- Authorization
- Scalability
- Reusability
- Usability
- Performance
- Localization

Having concluded on user requirements, Key Performance Indicators (KPIs) were clarified, which will measure the performance of the pilot applications of the project, as well as the indicators that will be able to identify the social acceptance and social impact of CIRC4FooD. The methodology followed is, on the one hand, based on the initial objectives set when designing the food production system inspired by the CIRC4FooD circular economy, but also on its expected results and on the other hand, on the design of the system and the characteristics of the pilots.

In addition to the quantitative objectives related to the performance of the system, the environmental, economic, and social benefits expected as a whole from the implementation of CIRC4FooD, but also from its specific applications at three scales within the city of Trikala, were taken into account. The methodology followed is described in Figure 4.

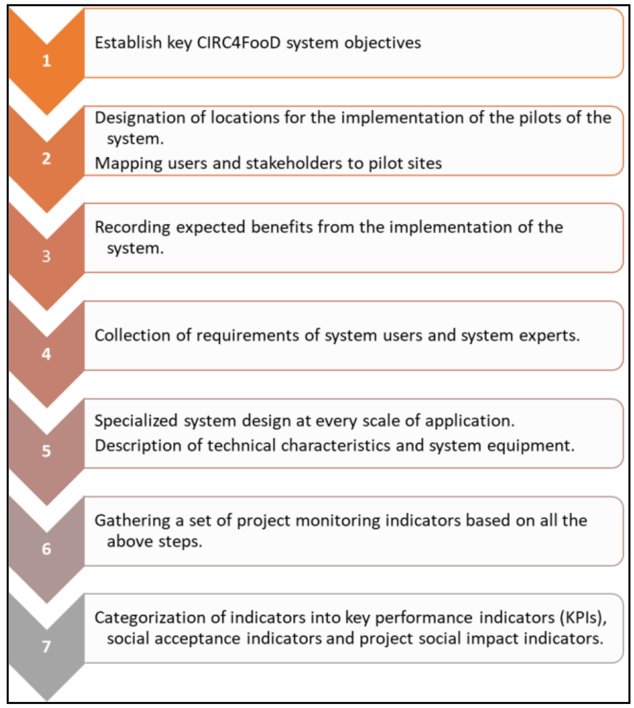

Figure 4. CIRC4FooD indicator selection methodology.

The user journey and flow were considered to guarantee that the interaction process between the users and the system will be effective and are analysed in the following section. While both tools are used to communicate the design of the system through the lens of the users' goals, they aren't synonyms because they focus on different aspects of the created system.

B. *User Journey and User Flow*

User Journey refers to the scenarios in which the user interacts with the product. This visual representation is commonly created as a timeline of actions or steps by a facilitator, built up on feedback collected methodically (via observations, interviews, focus groups, etc.). As a result, the technique's main function is to assume and demonstrate the current and possible way in which the user can interact with the process. User Journeys deal with the emotions, pain points, and motivations of the end-users [17]. For this aim, the establishment started with the completion of a user journey map. The developed map is a visualization of the step-by-step experience as the user goes through the platform, following the diagram as shown in Figures 5 and 6 for climate and sustainability activities.

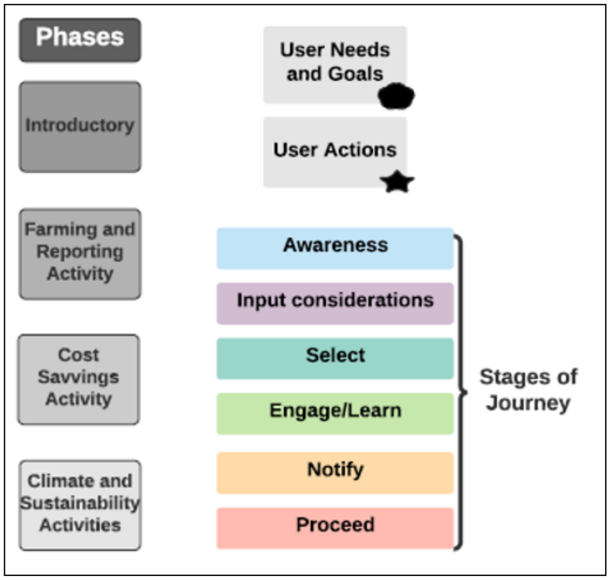

Figure 5. Concept of User Journey.

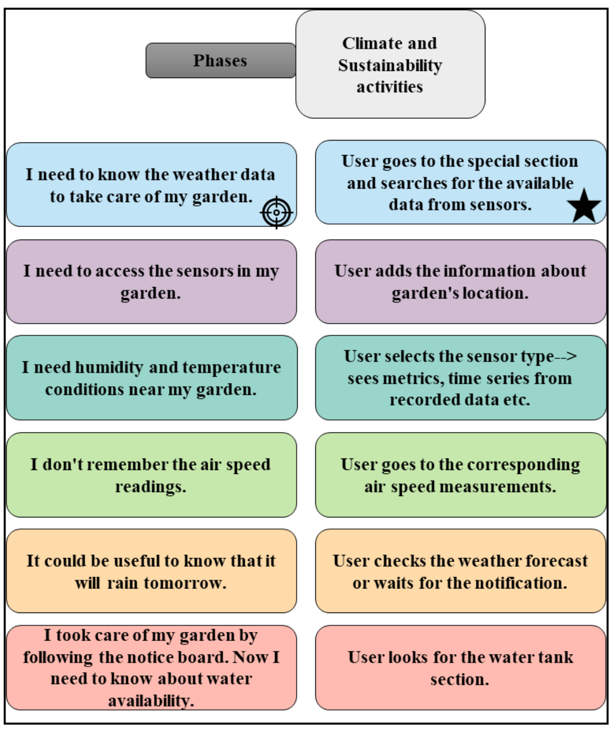

Figure 6. User Journey for climate and sustainability activities.

In order to put the users' needs and wants at the forefront of this design process, a guaranteed way to achieve this is via user flows. User Flow refers to the process in which user takes advantage of the complex routes through a series of templates designed for a product to accomplish their goal. It is created to predict and show the possible routes through which the user interacts with the product. User Flows are usually depicted by flow charts, and they are a set of steps taken by a user to achieve a goal using a digital product. Rather than demonstrating how the users are supposed to feel, a User Flow is the breakdown of the actual user interface. Designing how a user interacts with a product is a key step in figuring out where the issues may arise in task flows [18].

Having finalized the User Journey and the User Flow, user types were selected, and ways to accomplish user engagement with maximum impact were identified in order to understand users, challenge assumptions, redefine problems and create innovative solutions to prototype and test.

C. *User Types and Reward System*

To assure comprehensive and effective knowledge acquisition, users of the platform are assigned into one of the following user types: novice, advanced beginner, competent and experienced. The assignment is based on the self-assessment performed by the user based on the information provided for each level of expertise and adapted from [19] for the needs of the platform. Nevertheless, the platform is able to accommodate a variety of user types besides the intended core set of users.

After identifying the core qualities of the target users, the benefits of a reward system in any working environment were explored [20]:

- It boosts the user base and encourages more users to get on board with the system.
- It improves confidence and esteem towards the system.
- It makes the users share this concept with others.
- It helps the users develop a trust factor for the system when they see some positive benefits of the system.

A reward system will be implemented during the user training phase and will be based on user engagement, allowing the users that are most active to be upgraded to higher levels of expertise as they gain knowledge and know-how. One of the excessive aspects of rewards is that they gather much larger sets of data. Simple rewards may incorporate a few data elements. More sophisticated rewarding rules may aggregate scores from multiple more attentive rewarding rule sets and integrate important supplementary metrics. With the capability of rewarding rules to summarize data, decisions and actions can be made much faster.

CIRC4FooD platform follows a method of reward with points and scores, which are the most common type of reward. Points and scores were the results of a change in behavior. Aiming to support sustainable urban agriculture through this intelligent management system, the points of the reward system are inextricably linked with the rule engine of the platform (described below in Section Dynamic Rule Engine). Furthermore, some points are awarded based on some of the users' actions that are directly related to the work in their vegetable garden, and some points are related to more simplified actions (e.g., rate of visiting the notification page, signing in, etc.).

The role of a reward aligned with personal values may serve as a driver of integrated sustainability, thereby increasing motivation to apply conservation practices over time. To increase the likelihood that motivation is maintained or enhanced, CIRC4FooD recommends that specific values of rewards should be explored in future interventions after the user training phase. A survey will be distributed to participators to determine whether the positive motivation for the use of the platform predicts the scale for satisfaction with urban farming and sustainable practices in agriculture. This survey will contribute to relevant issues by identifying factors that could be improved to enhance learning and adaptation to circular economy practices.

IV. Platform Design

A. *Architecture*

The architecture of the web platform follows the principles of a MERN full-stack development. MERN stack is a JavaScript stack, that is used for easier and faster deployment of full-stack web applications. MERN Stack comprises of 4 technologies namely: MongoDB, Express, React and Node.js and it is designed to make the development process smoother and easier as depicted in Figure 7.

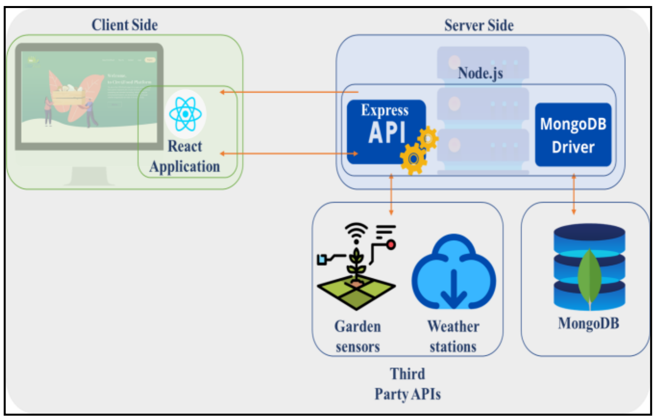

Figure 7. Architecture of the CIRC4FooD platform (own work).

MongoDB is an open-source document database built on a horizontal scale-out architecture that uses a flexible schema for storing data [21]. In the CIRC4FooD platform, MongoDB is used to store as object-collections information related to the system users, their integrated system and the notifications extracted from the rule-engine.

Express is a prebuilt Node.js framework that can help creating server-side web applications and APIs faster and smarter. Simplicity, minimalism, flexibility and scalability are some of its characteristics, and since it is made in Node.js itself, it inherited its performance as well.

On the client-side part there is React.js. React is an open-source, component-based front-end library, responsible only for the view layer of the application. It is maintained by Facebook. Using functional programming, hooks and JSX, React designs simple views for each state in the application, and will efficiently update and render just the right component when the data changes. As a front-end framework, React communicates with the back-end by making API calls on the endpoints created by Express.

The last technology is Node.js. Node is an open-source development platform for executing JavaScript code server-side. It is intended to run on a dedicated HTTP server and to employ a single thread with one process at a time [22]. Node.js applications are event-based and run asynchronously. In the CIRC4FooD platform, Node.js has a central role as it is the one responsible for serving the client-side code, managing the Express APIs and communicating with the MongoDB database. Moreover, Node.js fetches data from a third-party API related to the current values of each sensor placed on the gardens and stores them to the proper collections in the Mongo database. Furthermore, it handles the authentication and role system for the users as long as the reward system and the dynamic rule-engine, that creates the proper notifications for the platform users. More about the rule-engine and the reward system will be presented in the following paragraphs.

B. *Dynamic Rule Engine*

The first step to develop our intelligent management platform was to know the variable inputs the system has and how they have to be handled by using a set of rules, aiming to enhance the sustainability and competitiveness of the activities taking place. The data from the garden sensors and weather stations, once pre-processed and formatted, are sent to the rule engine for rule-based processing to produce relevant outcomes. Historical database information may be required for some rules.

The process of preparing a rule base in CIRC4FooD can be divided into several consecutive steps that are presented in Figure 8 below, wherein several layers are created: data collection from several sensors (as described in Figure 3), system modelling and rule selection, environmental sustainability, deployment of rules and also system optimization. The rules guiding the dynamic rule engine were constructed to increase the productivity, effectiveness, and performance of connected sensors, with two primary purposes: i) to promote sustainability and natural resource preservation and ii) to maximize user engagement.

CIRC4FooD solution helps the end users in smart farming operations in a more user-friendly format, informing the latter about the circular economy and guiding them towards increasing productivity and reducing resource wastage. Additionally, this approach increases food security, production, and also sustainability by providing data from the installed sensors during the whole process of farming. Moreover, this solution provides an exceptional prospect for building management systems by combining data from varied sources.

In order to assure user engagement, the number of received notifications, but also their exact content, is adjusted to the level of experience of the user. The higher the level of experience, the higher number of notifications the user gets, while their content becomes less explanatory and more informative. This is illustrated well in Figure 8 and with the examples of notifications presented in Table 1.

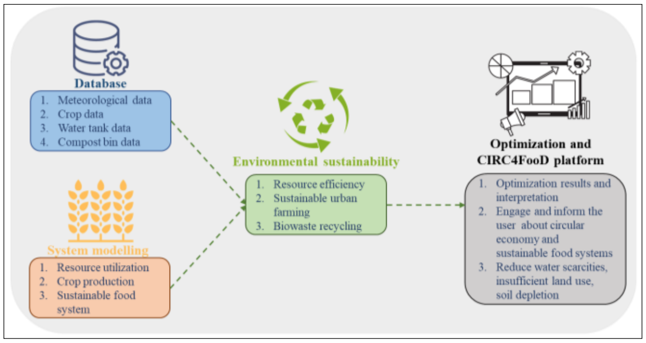

Figure 8. Outline of the process of prepearation of the rule base in CIRC4FooD.

TABLE I. EXAMPLES OF NOTIFICATIONS FOR FOUR USER TYPES

Condition	**User Type**			
	Novice	***Advanced Beginner***	***Competent***	***Experienced***
Air humidity < 30% and soil moisture <20%	The soil moisture levels are below optimal and air humidity is low. Consider watering your crops.	Crops in conditions like today's will most probably need water.	Air humidity today will be low and soil moisture readings indicate that your crops need water.	Air humidity < 30% and soil moisture <20%
Water tank level: full	N/A	Your water tank is full, now is the time to save natural water resources.	Water tank is full.	Water tank is full.
Compost moisture >60 %	Your pile moisture levels are above the optimum. To keep them within the optimal range mix in some newspaper strips, dry wood chips or pieces of cardboard.	Your compost is too wet. Mix in newspaper strips, dry wood chips or pieces of cardboard.	The optimal levels of moisture range between 40 to 60 %. Today the moisture level is >60 %. Take appropriate actions!	Compost moisture > 60 %
Probability of precipitation >60 %	Today most probably it is going to rain.	Today most probably it is going to rain.	Today most probably it is going to rain.	Probability of Precipitation >60 %
Probability of precipitation >60%, soil moisture < 20 %	The soil moisture of your crops is low and today there is a high probability of precipitation. Wait for the rain to water your crops and save water.	The soil moisture of your crops is below 20% and today there is a high probability of precipitation. Wait for the rain to water your crops and save water.	Soil moisture < 20 %, but rain is expected! Wait with watering your garden, and water it only if the weather forecast proves wrong and there is no rain.	probability of precipitation >60%, soil moisture < 20 %
Compost temperature <25°C	Have an eye on your compost, the temperature is too low, the process is not taking place! Action necessary.	Have an eye on you compost, the temperature is too low, the process is not taking place! Action necessary.	Compost Temperature <25°C	Compost Temperature <25°C
TDS >2000ppm	If water uptake is appreciably reduced, the plant slows its rate of growth. A TDS level above 2000 is completely unsafe and dangerous for any use.	If water uptake is appreciably reduced, the plant slows its rate of growth. A TDS level above 2000 is completely unsafe and dangerous for any use.	The TDS level inside your water tank is unsafe for any use. Consider not to use this water for your activities.	TDS > 2000ppm

The rule engine consists of three modules: i) environment, ii) water tank, and iii) compost. The module environment gathers rules related to the environmental parameters influencing plant growth, with special attention to those related to watering. Parameters taken into consideration in this module are the following: soil moisture, air humidity, the likelihood of precipitation, temperature, light intensity, and wind speed.

Module water tank describes the rules associated with water level and TDS amount in the water tank, but also the water level in combination with the probability of precipitation and soil moisture, to assure that water is used only when a need arises.

Module compost is built to support the composting bin notifications in relation to compost temperature and compost moisture. Compost temperature and compost moisture are two critical parameters for the process of compost production. Compost temperature is additionally a crucial parameter in compost monitoring [23]. Monitoring temperature evolution over time provides critical information about the course of composting and assures the safety of the produced material (eliminating the risk of microbial contamination) [24], as well as the safety of the process itself (avoiding fire hazards).

The conditions are assigned impact values based on the literature research and the CIRC4Food aspirations, namely user engagement, awareness raising, and saving natural resources, especially water. The impact values affect the notifications scheme of the rule engine, which is built on threshold values. The user receives a notification only if the threshold value is equal to or surpasses the impact value. The threshold value (and, therefore, whether or not the notification will be received) is determined by the user type.

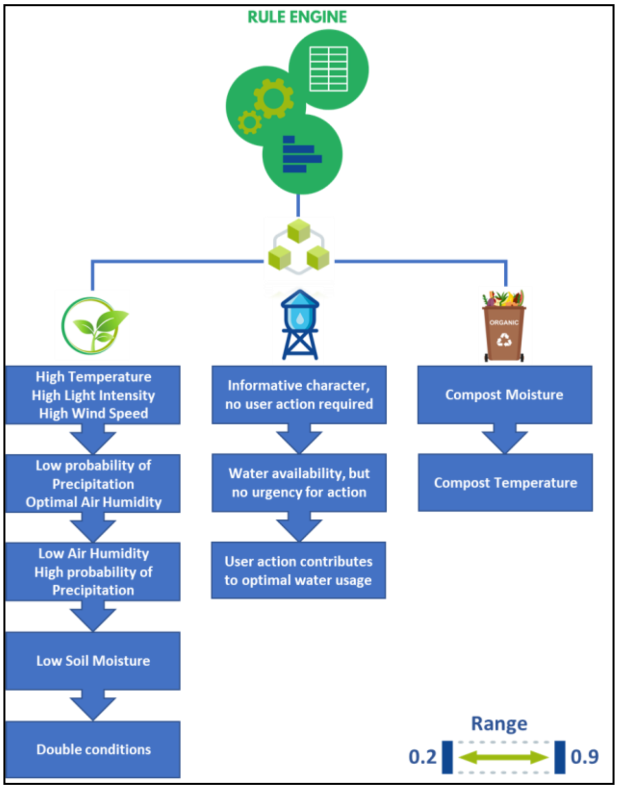

Figure 9. Dynamic rule engine for the three modules.

The dynamic rule engine is designed in such way that additional rules can be implemented if the need arises. The followed procedure for the implementation of a dynamic rule engine for the three modules is defined in Figure 9.

C. *CIRC4FooD Platform view*

The last step to make the management platform usable was to develop a user interface (UI) to simplify its use by dedicated users. Additionally, CIRC4FooD should be tested in terms of data collection and operation. In this section, the platform view development is presented, with the aim of offering from top to bottom usability level for non-IT-experts. CIRC4FooD platform integrates a web-based data-mining system (third-party APIs). The platform provides an important interaction model for the smart farming sensors by letting users acquire information related to the integrated garden sensors.

The front-end application exposes to the user a pleasant and interactive interface through which the user can access all the services exposed by the back-end application. The CIRC4FooD interface is responsive, so the user experience on the platform is of high quality regardless of the device used (laptop, PC, tablet, or phone). In addition, the CIRC4FooD platform allows end-users to explore and analyse agricultural and weather data with zero-programming efforts. The initial UI is depicted in Figures 10-16.

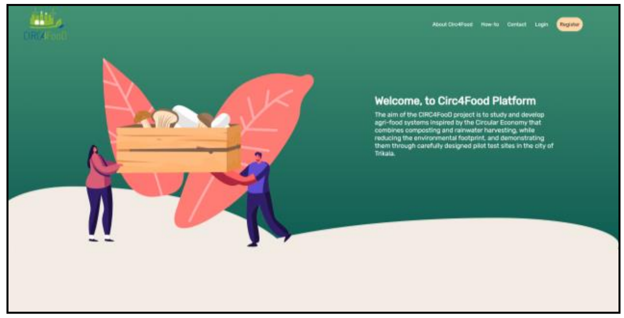

Figure 10. Welcome Page of the CIRC4FooD Platform.

Figure 10 shows the welcome page of the platform, where the user can read a few words about the project within the platform that was created, as well as log in if they are already a registered user, otherwise create their profile. For usual registration, the information that must be filled in is as follows:

- Personal data: first name, last name, email address (used for sending activation email and other platform-specific emails);
- Information used by the CIRC4FooD platform: username, password (both used for authentication), and preferred language (the default, for now, is English).

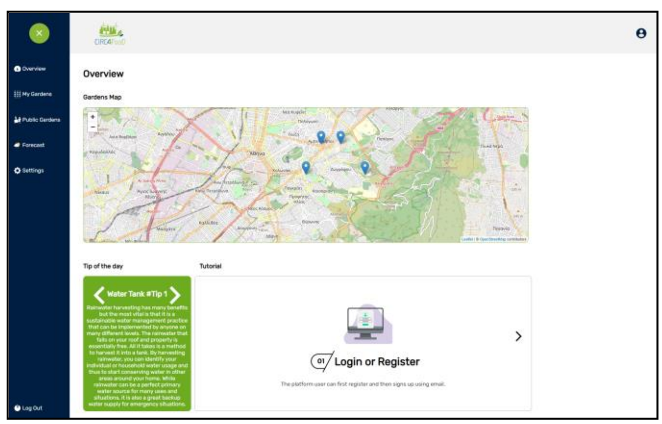

Figure 11. Homepage/Dashboard view.

When the user is logged in, the platform looks like a dashboard. The homepage contains a map which is resembling with google maps, with the difference that the location of public vegetable gardens that have been created in the city of Trikala is displayed, and the gardens owned by the current user are represented with a bold point. In Figure 11, there is the homepage of the platform. On this particular page, the user can initially be familiar with the tutorial, where useful instructions guide the user in using the platform. The user also has access to the tip of the day section and has the chance to explore useful information related to urban agriculture and the individual systems installed in the garden.

Figure 12 reflects the 'My garden' page. Here the user comes into first contact with the measurements of the sensors installed in the garden, compost, and water collection tank. Also, the user can see some of the measurements of the meteorological stations located near the garden, which are considered important for agricultural processes. Additionally, the user will have the opportunity to update the system about the actions taken regarding the three subsystems (water tank, garden, compost), as well as to see all the notifications that have been produced by the dynamic rule engine. Within the 'My gardens' page, the user can create a new garden or edit the already existing garden and must provide advanced data about the garden. The process of creating a new garden is clear in Figure 13, where the user follows five steps:

1. garden title
2. crop information
3. input of sensor IDs to connect to own garden
4. garden locations
5. declare the gardem as public garden or not.

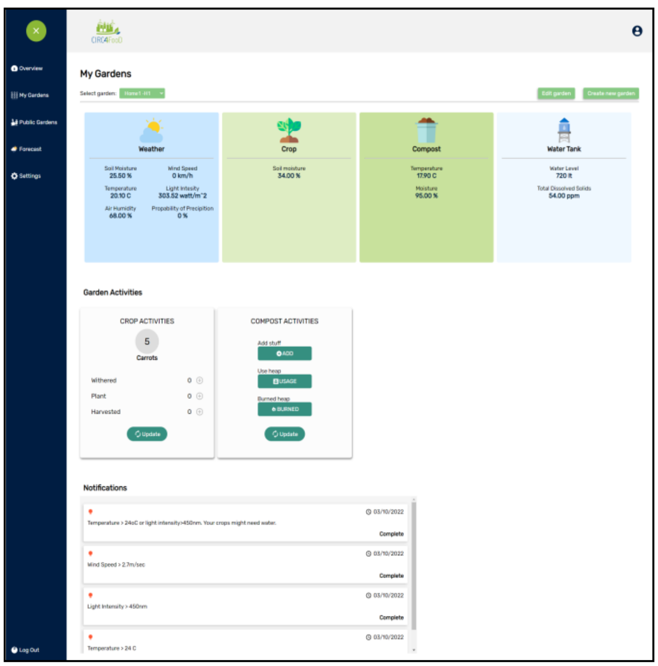

Figure 12. My gardens page.

In Figure 14, there is the 'Public gardens' page, in which the user has access only in view mode to the different public vegetable gardens in the city of Trikala. The purpose of this page is to inform the user about the development of other gardens and to educate them about the processes of urban agriculture through general information about other gardens as best practices.

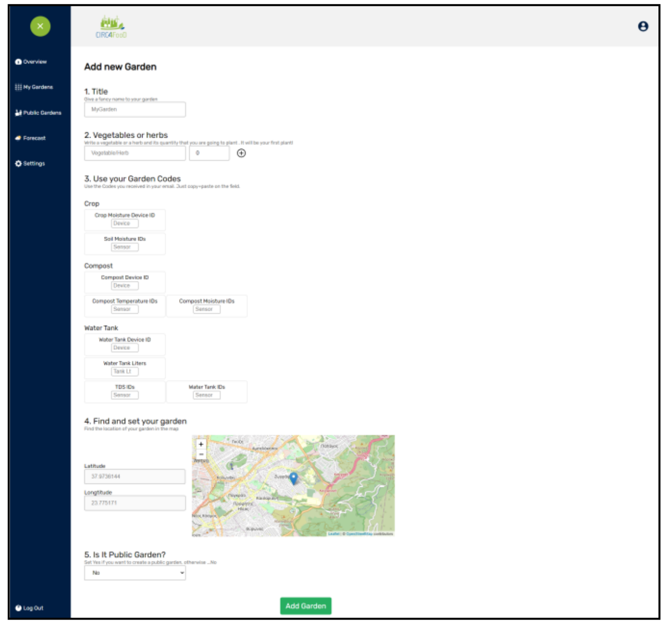

Figure 13. Add new garden page.

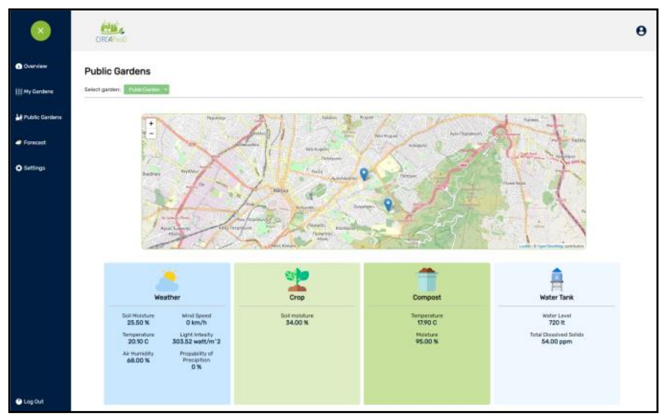

Figure 14. Public gardens page.

In Figure 15, the user can edit the existing garden, change the imported information and then update the new information about their own garden. The information regarding the sensors is provided to the user upon installation in order to make the process easier. As mentioned before, all information about the sensors comes from third-party APIs within the project, so the process of creating gardens is a bit more complicated. The goal is, after the project is over, to simplify this process as much as possible and make it more user-friendly and engaging.

In Figure 16, the weather forecast is depicted alongside weather service, in which the user can view various information about the conditions regarding each garden individually, based on its location. The user can choose through a drop-down menu the desired weather station. For each selected station, the CIRC4FooD platform displays the basic weather information (temperature, humidity, daily rainfall, hourly rainfall, wind speed, wind direction, light intensity, UV power, and soil moisture). Regarding weather forecast, the information is taken from an embedded weather widget, and the provider is called windy.com. This provider is open and can be used by anyone. Also, the platform has used some parameters to simplify the use of this widget, like the latitude and longitude of the city of Trikala and the zoom feature (value 11) to create a closer map. Moreover, this widget gives a ten days period of time forecast, and a variety of information are displayed: temperature, clouds, CO and SO_2 concertation, pressure, wind information, rainfall, real-time lightning strikes, weather radar, and much more parameters.

Some of the used units are:

- Celsius degrees (°C) for temperature;
- Cloud color, shape, and size for cloud indicator;
- Parts Per Billion by Volume (PPBV) for CO concertation indicator
- kg/m^2 for Sulfur dioxide (SO_2)
- Millimeter for rainfall;
- Knot (kt) for wind speed and wind gusts;
- Wind direction using the flag as an indication, etc.

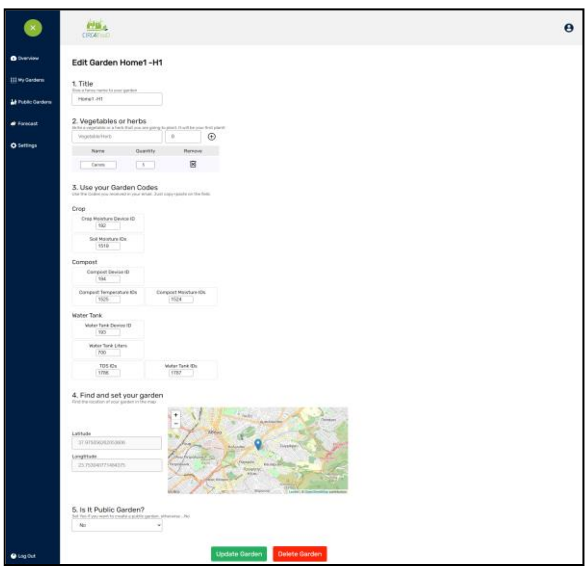

Figure 15. Edit garden page.

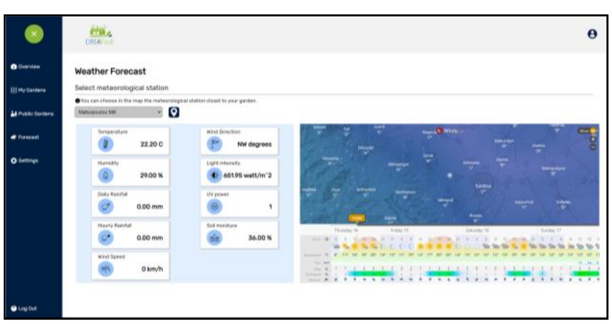

Figure 16. Weather forecast page.

The User Interface (UI) exploits concepts that the user is familiar with and facilitates further understanding (through, e.g., data diagrams, sensor devices, tutorial, etc.), as defined in the data model and the rule engine.

The UI is still a work in progress, aiming to achieve an intuitive visualization that will depict the requirements of the end-users in order to contribute to the promotion of sustainable urban agriculture. For this specific purpose, the CIRC4FooD platform is intended to integrate, in the next version, the following five key elements:

First, it will be useful for the user to click on a garden and be redirected to the garden visualization page of the clicked garden (public and private). On the right side of the platform, the user will see their profile picture (by clicking on it will have access to the profile page) along with a drop-down menu where they will access all the components offered by the platform or can go to the view page of any of their registered gardens. On its profile page, the user will have the opportunity to review any activity on the platform, like viewing registered gardens, the tip of the day, tutorial, weather forecast, etc. When watching other gardens, the number of details displayed is in accordance with the privacy options selected during garden creation. CIRC4FooD is intended to give the user the opportunity of sending an email to the users of public gardens and be informed about various procedures regarding their farming activities, with the main purpose of training and educating themselves.

Second, there will be, at the top, a navigation bar through which the user will be able to search for private gardens and public ones. The user will also be able to find a new message indicator and a notification indicator. Clicking on a specific notification will open a dropdown menu with all the notifications, while clicking on the new message indicator will open the new notifications that are not yet addressed by the user. Also, from the top bar, the platform language will be able to change. After authentication, the default language is the one chosen by the user while creating the account. For the moment, the available option is English, but in the following version, the user will have the chance to choose between Greek and English.

Third, in the current version, in order to register into the platform, the user must fill in and submit a form from the registration page. They will also have the option to use a social sign-up, choosing an identity provider from various sources (e.g., Google, Facebook).

Fourth, more weather providers will likely be available, or if the user simply wants to change the initial choice, the platform will give him the possibility to modify the selected providers or just change the color palette.

Fifth, the CIRC4FooD platform intends to add one more page called Sensor Dashboard, in which the user will have access to diagrams and a time series of data coming from all the sensors installed in the garden. The goal of this integration is for the user to have, in a more user-friendly manner, data from a more extended period of time. The user is going to have access to three types of time series:

- Daily
- Monthly

- Yearly

The aim of this extra feature is for the user to be fully informed and keep track of the measurements of each sensor. This way, the user will be able to collect all the agricultural tasks waiting to be executed and maximize the performance of the intelligent management system and the sustainability of urban farming.

V. DISCUSSION AND FUTURE WORK

A main challenge in smart farming platforms is consistency and compatibility among the utilized protocols, technologies, and actions. To address this issue, in this paper, we present the CIRC4FooD platform approach, which is an intelligent management system supporting sustainable urban agriculture. Existing smart farming platforms are not designed to support near-real-time data ingestion, quick analysis, and visualisation of large volumes of sensor data. For that purpose, one of the key components of the CIRC4FooD platform is its aptitude to deal with the high rate of sensor data by providing notification for fast and easily performed urban agriculture activities. The user interface of the platform allows complex data workflows to be collected, visualized, and executed without the need for programming skills.

Another important functionality of the platform is the ability to integrate automation on actuators based on the collected data from the sensors for optimizing food production in open or closed systems. The platform is designed in an adaptive way, able to fit in agricultural automation, enabling remote controlling and monitoring for irrigation scheduling to manage water usage for optimizing water resources. The automation functionality can be achieved through the connection with the developed dynamic rule engine, and its performance will be evaluated by monitoring the conditions of the sensors and actuators. Also, a quality assessment will be employed for adjusting the dedicated parameters of the dynamic rule engine with respect to the users' requirements.

The CIRC4FooD platform is created to enable the efficient management of urban vegetable gardens. In parallel, by engaging the user at different levels, it has the ambition to offer educational and awareness-raising advantages. In this paper, we present the ongoing work related to platform development describing the system and platform design.

An important feature requirement of the CIRC4FooD platform is to be able to scale, store, and visualize different kinds of sensors. The volume of data generated by the installed sensors is not a problem. Nonetheless, the velocity at which the data is produced is very high and results in a big set of sensor data and user data. Addressing this problem, we are aiming to do a performance analysis of the platform by measuring the load time from different sensors around the city of Trikala and specifying critical points, alongside with the adaptation of the platform from the users. The main objective of this performance analysis is to evaluate the scalability of the CIRC4FooD platform.

The CIRC4FooD platform will be tested in real-life settings in the coming months. The demonstration will last around six months in the city of Trikala in Greece and will start once the complete CIRC4FooD system is set up. Demonstrations will be performed in private gardens belonging to citizens of Trikala, in public, popular spaces of the city, and in several schools. The testing phase will be accompanied by a series of seminars of informative and educational character aimed at the users of the CIRC4FooD platform. It is expected that as a result of demonstration activities and received feedback, some features of the platform might be subject to change. Additionally, the user reward system will be implemented, and a repository for the users with information about how to use the platform and facts about the plants (e.g., preferences and common diseases) will be developed.

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