VOL. 15, NO. 19, OCTOBER 2020 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

DESIGN OF A CROP IRRIGATION SYSTEM CONTROLLED BY THE IoT APPLICATION

Fredys A. Simanca H., Jaime Alberto Paez, Jairo Cortés Méndez, Edgar Camilo Díaz and José Vicente Palacio
Systems Engineering, Faculty of Engineering, Universidad Cooperativa de Colombia, Colombia
E-Mail: fredys.simanca@campusucc.edu.co

ABSTRACT

This project was developed based on the needs and difficulties that arise in the rural sector, specifically with regard to water management and control. This important resource, essential for life and for living beings consumption, is often wasted with bad irrigation practices, generating an increase in the costs of this service for the production of agricultural activities in general. For this reason, the agricultural producer faces a series of difficulties when it comes to irrigating the crops, including factors such as: the amount of water to be supplied, the evapotranspiration, time, and other factors that directly affect the treatment of a crop. By means of the use of an Irrigation System and the information that it generated, it was possible to remotely monitor the irrigation activity, via online and through a graphic application or Internet access terminals, with a wireless sensor unit that consists of an RF transceiver, sensors, a microcontroller, power supplies, and several WSUs. These technological tools allowed us to use a sensor network spread out in the field or agricultural farm, designed and configured to be distributed in the automated irrigation system that controls three irrigation valves, allowing the management of each of the valves, in terms of dripping intensity and dripping time. This allowed for a more practical work in the agricultural farm, an important factor in reducing costs and contributing to the protection and improvement of the environmental management; it is in turn an activity that is poised to improve, in order to compete on a larger global scale, due to population growth and increased demand for food.

Keywords: system, irrigation, water, resource, temperature, automate, crops, rural, sensors.

INTRODUCTION

In coordination with the technological advances, agriculture is entering the scientific vanguard by implementing tools that allow a technological development of the sustainable agricultural activity. These processes are being developed with more determination in industrialized countries, while in the third world countries; it is generally carried out in an experimental way. The use of different technologies pro agricultural activity is one of those efforts from the information technology that is now being widely used in this area of agriculture [1]. The crop is the main issue in agriculture, and making an appropriate management of irrigation becomes absolutely necessary, therefore, it is important to determine what irrigation system has to be applied by means of soil analyses and other characteristics. Appropriate management of irrigation should be understood as the optimal combination among the water needs of the crop, the characteristics of the soil, and the means of transportation and storage of water, taking into account the technical, economic, and social conditions of the plot [2].

Monitoring different parameters of interest in a crop has proven to be a useful tool to improve agricultural production. As it has been demonstrated, crop monitoring in precision agriculture can be achieved through a multiplicity of technologies; taking into account that the use of wireless sensor networks (WSN) is the result of the implementation of low cost and low energy consumption, so it becomes an optimal option [3].

According to the figures presented by the International Fund for Agricultural Development (IFAD) [4], agriculture uses 85% of the freshwater resources that are available in the world, and this percentage will continue to be a dominant factor in water consumption due to population growth and increased demand for food.

It is therefore necessary to create strategies, bearing in mind the technological advances that are at hand for the sustainable use of water, including the improvement of agronomic, managerial, and institutional techniques. It is understood that the current implementation of technology in the crops has increased their productivity, since it allows detecting the process of the crops, according to the data that is taken with technological equipment such as in precision agriculture, where the handling of drones help promptly identify the measurement of data with which valuations of the treated crops are generated and in this way, it is possible to pay adequate attention to the crops in a punctual and localized way, activity that is not possible to be carried out in a manual way [5]. On the other hand, it has been proven that spatial data, also known as geographic data, are very useful as they generate information that identifies the geographic location of the features and boundaries on Earth, and they can be assigned and stored as coordinates and topology; Spatial Data Infrastructures (SDI) are configured by countries, regions or continents to allow access to geospatial information [6]. These tools are extremely important, and it is necessary to take them into consideration for agricultural innovation projects and for the design of the irrigation system for crops that is controlled by the implementation of the IoT. From the previous, it is possible to touch upon systems of agricultural innovation like the remote temperature canopy to automate the irrigation of cotton and maize planting using infrared thermometers, which by means of a timed temperature threshold, activates the automatic irrigation once the temperatures of the canopy exceed the threshold

ARPN Journal of Engineering and Applied Sciences

during certain time accumulated during the day, as detailed by Bustamante, Ibarra, & Weiss [7].

This technological innovation has been a great support and has generated benefits for farmers. In older times, when the agricultural producer had to do his work manually, the irrigation was controlled by calculating water supply in an empirical way, so the quantities of water that had to be dosed on the soil were not measured; instead, the farmer checked the humidity of the soil and determined if it was well irrigated or not just by observation; same methodology was used to check the times of the day that were appropriate for irrigation. Nowadays, with the use of the application, those processes have improved and are ready to be used in a standardized way, which is very important taking into account that water absorption is the first step for germination, without which the rest of the germination process can not take place [8], as during this phase there is an intense absorption of water from the different tissues forming the seed. Seed germination is a three-phase process that begins with an initial rapid absorption of water (phase I), a plateau phase with little change in water content (phase II), and a phase in which the water content increases and that coincides with root growth (phase III) [9]. The process above is very difficult to analyze when developed manually, therefore, applying technology with the purpose of capturing this data by means of a system or application translates into an important advance for Colombian farmers, in as much as it is not only the need of farmers to increase their production, but also the fact that technological advancement allows them to improve, since the performance of growers is directly related to their provision of human capital, which includes natural and learned skills [10].

In agreement with this, it can be determined that it is possible to monitor irrigation remotely using online systematized information. Via a graphic application and Internet access devices, and by configuring a network of distributed automated sensors, the farmer or user will have control over the irrigation for his crops from any site, using a computer that can be connected to Internet and by means of the design of an IoT application for Irrigation System, which will decrease the water consumption in the crops, and thus move towards the care of the environment and adequate management of the natural resources.

MATERIALS AND METHODS

In order to control the Irrigation System through "App Garden", it was necessary to carry out a suitable analysis of the information or data that had to be programmed in the system when using it in the crop, given that the results that are generated depend on these pieces of information, and because of the irrigations that are usually raised when putting the system into practice. As in any improved productive activity, the irrigation agriculture can lead to the environmental contamination if it is not managed in an adequate way. When the use of chemicals is incomplete or inefficient, or when water is applied in excess, the resulting runoff and filtration eventually end up in drainage systems or in the recharge of aquifers underneath the cultivated land. [11].

The "APPGarden" software, was developed and structured including two components:

a) The programming of microcontrollers through Arduino for the control of the valves.
b) The development of the APP in Android Studio for the control of the Arduino board and a graphic view for the user.

It was carried out by analysis with different development methodologies, from which the Open Up methodology was chosen. Open Up is an agile methodology, therefore, it allows adapting other processes easily and its implementation can help reduce the possibilities of risk, allowing the discovery of early errors through its own iterative cycles [12].

All the functions for each button, field, and other software implements were specified from Android Studio; after that, we proceeded with the construction of several classes and methods that allowed to implement the code of the IoT application for Irrigation System expeditiously.

System Architecture

The development of the mobile application was based on the architectural design pattern of the MVC software, which works to classify the information [13], the system's logic, and the interface that is presented to the user. In this type of architecture, one will find a central system or controller that manages the system's inputs and outputs, one or several models that are in charge of searching for the necessary data and information, and an interface that shows the results to the user.

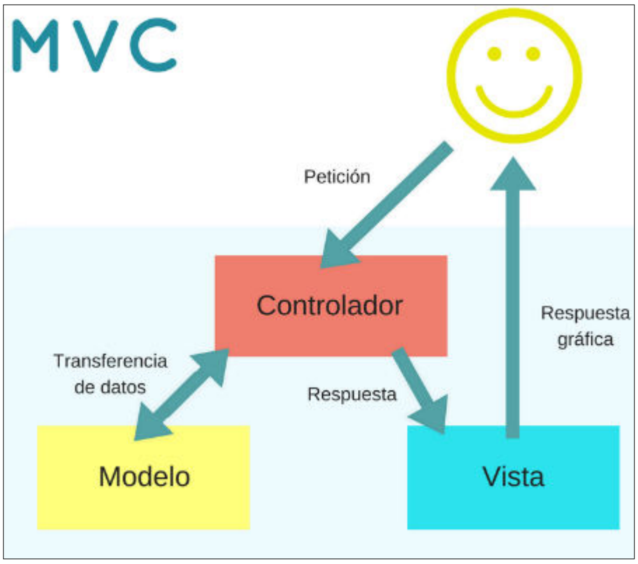

Figure-1. Architecture of the irrigation system. Source: Taken from the system.

Following the MVC pattern, and taking into account that the model is the layer that takes care of all the

VOL. 15, NO. 19, OCTOBER 2020 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

logic, it is the one that makes the representation of the data that is handled in the system.

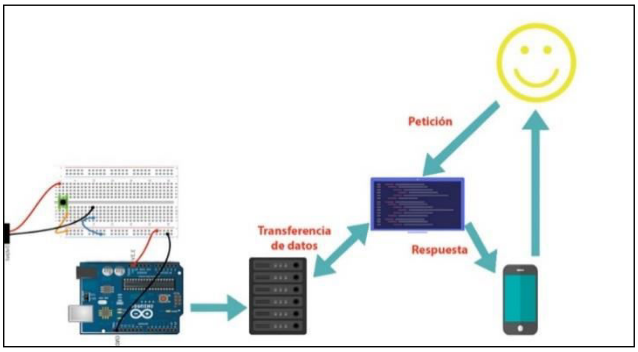

Figure-2. Representation of the circuit of the irrigation system. Source: Prepared by the authors.

It is important to note that, for surface irrigation, the water requirements module is based on the determination of both the water requirements and the frequency of irrigation, taking into account the actual conditions of the users, which are automatically identified by the system at the time of logging on to the platform [14]. These methods were developed using a DSS, which is an interactive computer system that involves the formulation and integration of three main components: a database, an administrator model, and a graphical user interface; and can incorporate the knowledge of decision makers [15].

With the application, it will be possible to follow the four specific phases of the Open Up agile development methodology, which is defined as an extensible development process to be used as a base, over which the content of another necessary process is adapted, and whose characteristics are [16]:

Open UP

- Incremental development.
- Usage of use cases and scenarios.
- Management of risks.
- Architecture-based design.

It is understandable that not all the users of APP Garden had enough technical or technological knowledge for handling the application; therefore, an easy to follow Manual was created for users' trouble-free handling. It was confirmed that practice is essential, since it allows to obtain an appropriate control of some tasks, as defined by Ologbon O. A., the educational level of the farmers does not necessarily contribute to their production and efficiency as informed in the literature [17]; their innate knowledge is very important for agricultural development, and that is obtained with experience.

For this reason, the User's Manual provides a detailed explanation of how to use the irrigation system assembled in EPS8266 and the APP Garden application. To do this, the user was given a step-by-step explanation of how to make the multiple connections from the circuit to the electro-valve system, as well as information on how to connect the system to the motor pump to make way for the water flow, and how to proceed with the respective APK installation guide of the mobile application.

RESULTS

The results were developed taking into account the following procedures:

Requirements

- Web hosting service with a minimum of 10 gigabytes storage, preferably SSD, with a minimum file transfer rate of 200GB/month; additionally, it must count with a domain configuration, unlimited FTP accounts, and cPanel access.
- Android version 4.0 or newer (ICE CREAM SANDWICH).
- The mobile application and the circuit must be connected to the same network environment.
- A 12-volt power supply, required for the microcontroller (NodeMCU).
- A 110 volt power supply, required to power the solenoid valves.
- A clock battery, required for the DS3231 module.

Initial Phase

Basic information regarding common irrigation systems was collected; this information was analyzed and based on that, the requirements to establish an optimal system were planned; then, the necessities that could arise when developing the application were established. After that, a specific analysis of the system needs was made, that is to say, materials, costs, and irrigation were established, and a project plan was proposed according to the specified methodology.

Connection of the Tools for the Irrigation System

After the construction of the system by using tools, the following step was to connect the power cables to the electrovalves.

Figure-3. Connection of the tools for the irrigation system. Source. Prepared by the authors.

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Once the connection was made, the power plugs corresponding to each of the valves were connected to the control box.

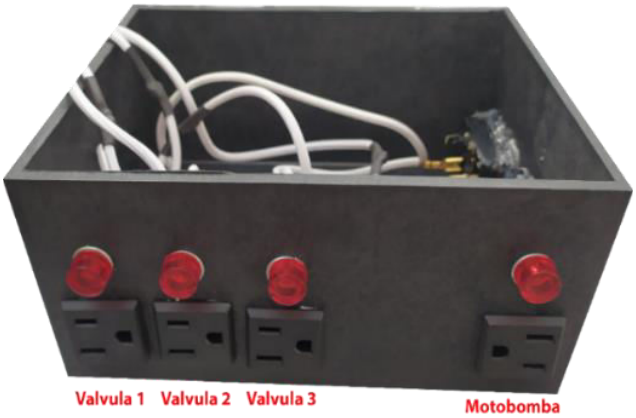

Figure-4. Control Box for the irrigation system. Source. Prepared by the authors.

Architectural Planning Stage of the Irrigation System

In this section and as indicated by Pérez D.A [18], it was necessary to carry out a lot of research in order to adapt or choose an optimal programming language, that was easy to learn and to understand, and that fitted the specified costs; sketches of the system that was to be implemented were made along with the design of the application. The possibility of working with several languages was also considered: Java, PHP, JavaScript, and .Net; in the end, the decision was to create a web application; that is the reason why Android Studio was chosen, which is an official integrated development environment (IDE) for the development of apps for Android.

Construction Phase

Simulations of the system: in order to prevent errors, a MULTISIM simulation of the circuit to be implemented together with the operation of the board was carried out before physically assembling it.

Assembly of the irrigation system: the circuit is assembled with the microcontroller, together with the electrovalves and the other materials.

Templates for the application: Android Studio presents a great variety of templates to implement; in this case and thinking of the end user, the choice was to implement one from scratch with several fields and buttons, that was pleasant to the eye and easy to use.

Transition Phase

Implementation of the system: we proceeded to implement the circuit that was assembled with the ESP8266 microcontroller and the electrovalves to a home garden, so that the tests including the use of the application could be performed.

Beta test: once the software was formalized, we performed a beta test by handing it out to other users to validate its interface and functionality. According to the information that was collected in this beta, we proceeded to make changes in the application.

Design of the Circuit

The circuit basically consists of three elements: the first one is the NodeMCU development board, which connects to the server to listen to the requests that the user has sent through the application by downloading the information from the files (JSON); the next component in the circuit is a DS3231 RTC precision clock module, as it counts with an integrated crystal oscillator (TCXO). Additionally, it incorporates a battery to maintain accurate timing even when the main power to the irrigation system is interrupted. The last element that composes the circuit is a four channel RELAY Module, which allows turning on or off each one of the electrovalves separately during the time that the clock module keeps an active signal.

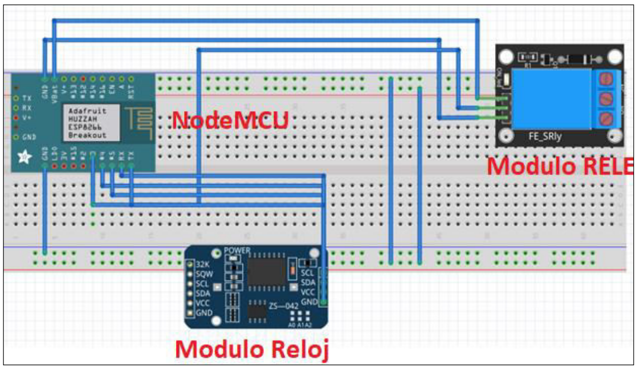

Figure-5. Design of the irrigation system circuit. Source. Taken from the system.

Design of the component and database

The application has database access and is developed and available for installation on the Android Studio, an operating system for mobile devices (smartphone) using several libraries that allow the connection to the microcontroller and one server, which in turn responds every 60 seconds to the requisitions that are set by the user; this thanks to the OkHttp library that together with the POST method, widely used in PHP, send a parameter to the server by means of a variable. After that, it analyzes the request by creating several text files saving the record of each key, thus making it possible to open and close the requisitions, to later exercise them during the specified time.

Design of the interface

The development of the APP was performed in Android Studio, at the beginning of the application that was called "AppGarden", the initial view is shown in Figure-6.

For the manual activation of the valves, the user must start the application; immediately after, it will start to load the data that is required by the irrigation system, such

VOL. 15, NO. 19, OCTOBER 2020 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

as the connections to the server. The user must wait for this process to be completed.

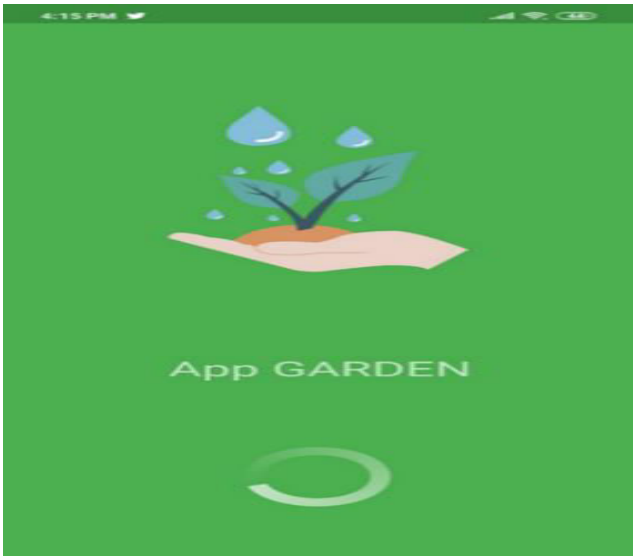

Figure-6. Activation of irrigation system valves. Source. Taken from the system.

Once entering the menu, the user must select the valve that he/she wants to configure or parameterize, and then, the time for the valve to remain open.

Figure-7. Selecting the valve in the irrigation system. Source. Taken from the system.

After that, the user must click on the "TIME" button to turn the clock hands until the desired starting time, then select the days for the process to take place, and finally save the changes by clicking on the “SAVE” button.

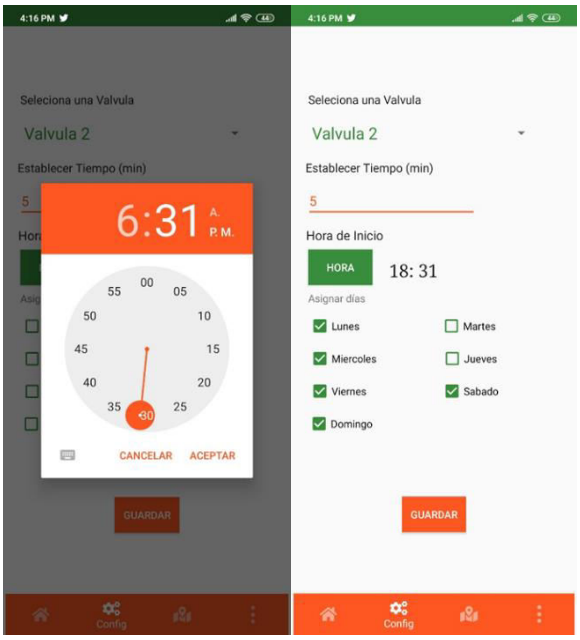

Figure-8. Selecting the time in the irrigation system. Source. Taken from the system.

Requirements Matrix

For the design of the system, the functional and non-functional requirements were taken into account and in response to them, the solution was proposed. These requirements are shown in Tables 1 and 2.

Table-1. Functional requirements. Source. Prepared by the authors.

No	Requirement	Priority
1	Allowing the definition, validation, correction, and acceptance of changes within the software.	High
2	Allowing the definition of each of the attributes.	High
3	Allowing the definition of periods and control dates for the different stages of the process.	Medium
4	Presenting users only with the necessary work sections for each stage of the process.	Medium
5	Allowing users to check the corresponding reports.	Medium
6	Allowing one person to be in charge of the administration of the different entities.	High
7	Allowing the administration of the different valves.	High
8	Allowing the configuration of new valves.	High
9	Allowing the opening and closing of valves.	Medium

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Non-Functional Requirements

Table-2. Non-functional requirements.
Source. Prepared by the authors.

No	Requirement	Priority
1	The solution must observe the standards of appearance of mobile applications.	Low
2	The system must be stored within the infrastructure of Universidad Cooperativa de Colombia, including version repository, file servers.	Medium
3	The system must implement a changelog where information about time, date, person in charge, and detail of a change that has been made in any section of the system and stage of the process is stored.	Medium
4	Complying with the tests that have been established.	High
5	Complying with the quality tests that have been established.	High

Software Implementation

The solution was formulated according to the problems that were found during the development of the project and in order to provide good water resource management and control in the plantations of Rubelina palm; to do this, a mobile application was developed on Android Studio 3.5.2 with Java programming language and using XML tags for the design of the graphic interface.

Development Environment (Android Studio)

Android Studio is the official Integrated Development Environment (IDE) for Android app development, based on IntelliJ IDEA. In addition to the powerful code editor and developer tools from IntelliJ, Android Studio offers even more features that increase productivity when developing Android apps.

Checking Test for Errors in Code

Several beta tests were performed in order to validate interface and functionality in real contexts. These tests allowed making changes to the design and programming of the developed software.

The validation of the APP and the circuit was carried out by building a model with three valves.

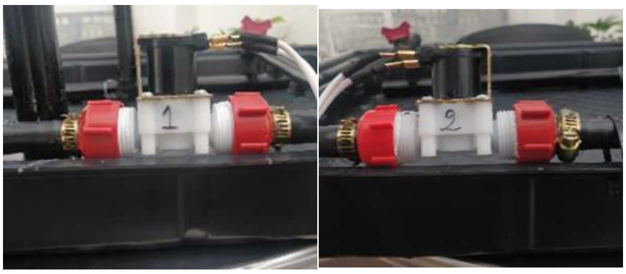

Figure-9. Irrigation system valves.
Source. Prepared by the authors.

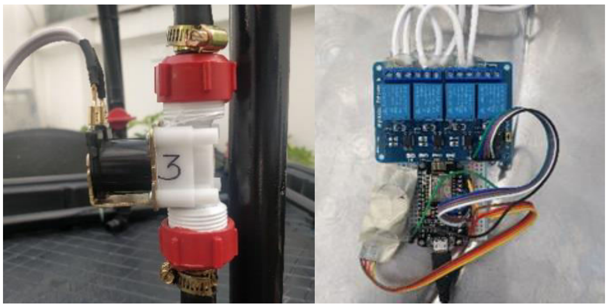

Figure-10. Irrigation system valves.
Source. Prepared by the authors.

Tests on the functionality of the APP and its connection to the electronic circuit that manages the valves were conducted. These were carried out on the built model.

Consequently, the results that were obtained, allowed verifying that the final user managed to improve the irrigation system in his crops, since he could supply the irrigation and water management by not wasting water, thus making the production process more sustainable. All the above with a good management of the application of the Irrigation System, which also provides sufficient information in real time, for decision making with respect to agricultural activity.

CONCLUSIONS

This project demonstrated that the producer faces a series of difficulties when irrigating agricultural crops. Several factors could be listed, such as: time, the amount of water to be supplied, evapotranspiration, and others that directly affect the care of a crop and make the work a time-consuming task for the producer. However, the development of this project confirmed that the use of systematized information by means of the design of a Crop Irrigation System, which can be remotely monitored online through technological tools such as a graphic application and Internet access devices with a wireless sensor unit consisting of an RF transceiver, sensors, a microcontroller, and power supplies, made it possible to control crop irrigation through the IoT APP "APP Garden", allowing to reduce in great quantity the waste of water, important factor to reduce costs and to contribute to the protection of the environment and the improvement of the management of the natural resources.

Agriculture is one of those domains where sensors and their networks are successfully used to obtain numerous benefits, and it also has played a key role in the development of human civilization. Due to the increase and demand of food, people are trying to put additional efforts and special techniques to multiply food production [19]. This allows for more a practical work in agricultural fields willing to improve their activity, so that they can compete at a larger scale in the globalized world that does not wait for technological progress.

However, it is still necessary to create strategies for the sustainable use of water in the less industrialized countries, taking into account the technological advances, including technical, agronomic, managerial, and institutional improvements.

REFERENCES

[1] S. W. Manisha Bhende. 2015. Comparative Analysis Of Topology Control Algorithms. ARPN Journal of Engineering and Applied Sciences. 10(2): 759.

[2] J. A. d. J. V. M. P. B. J. M. T. Luis S. Pereira. 2010. El riego y sus Tecnologías, Albacete: CREA-UCLM.

[3] F. G. y. J. G. H. Antonio Javier Garcia Sanchez. 2011. Wireless sensor network deployment for integrating video-surveillance and data-monitoring in precision agriculture over distributed crops. pp. 288-303.

[4] FAO. 2017. Nuevas realidades de la agricultura en el mundo. Coleccionables., Nueva York.

[5] G. A. M. A. F. S. Adrian Gonzales. 2015. Drones Aplicados a la Agricultura de Precisión, Bogotá.

[6] A. L. A. R. Subashini Panchanathan. 2015. Mygeo-Explorer: A Semantic Search Tool For Querying Geospatial Information. ARPN Journal of Engineering and Applied Sciences. 10(23): 18012.

[7] E. S. I. H. U. W. Waldo Ojeda Bustamante. 2006. Programacón Integral del Riego del Maiz , en el norte de Sinaloa, México.

[8] J. Doria. 2010. Generalidades Sobre Las Semillas: Su Producción,Conservación. Y Almacenamiento» Cultivos Tropicales. 31(1): 74-85.

[9] K. BRADFORD. 1986. Manipulation of seed water relations via osmotic priming to improve germination under stress conditions. 21: 1105-1112.

[10] J. a. F. G. Anderson. 2004. Agricultural Extension Services: Good Intentions and 2004.

[11] A. B. S. a. N. H. Hadas. 1999. Practices, soil fertility management modes and resultant nitrogen leaching rates under semi-arid conditions. pp. 81-95.

[12] O. S. Valladares. 2010. Metodología Open Up extendido para desarrollo de proyectos de business intelligence.

[13] G. Arcos Medina, J. Menéndez y J. Vallejo. 2017. «Comparative Study of Performance and Productivity of MVC and MVVM design patterns» de Simposio Iberoamericano en Programación Informática, Riobamba.

[14] E. A. H. y. O. L. Carlos I. Flores. 2010. «Un sistema dinámico de soporte de decisiones para la gestión del agua de la granja en el riego de superficie: desarrollo y aplicación de modelos» Revista chilena de investigación agropecuaria.

[15] E. A. H. y. O. L. Carlos I. Flores. 2010. «Un Sistema de Soporte Dinámico de Decisión para la Gestión del Agua Predial en Riego Superficial: Desarrollo y Aplicación del Modelo» Revista Chilena de Investigación Agrícola 70, 70(2).

[16] D. H. Zhañay. 2013. Desarrollo e implementación de un sistema de control de mantenimiento de equipos, mediante Java Server Faces-Glassfish y MySql con metodología Open up, para el departamneto técnico data market de Machala.

[17] Y. S. A. Ologbon O. A. C. 2012. Economics Of Weed Control Practices On Rice Farms. ARPN Journal of Agricultural and Biological Science. 7(7): 508.

[18] D. A. Pérez. 2011. Metodología del disfrute : Cinco habilidades a desarrollar en el proceso.

[19] S. W. Manisha Bhende. 2015. Comparative Analysis Of Topology Control Algorithms. ARPN Journal of Engineering and Applied Sciences. 1(2): 759.

[20] R. Bongiovanni. 2006. Econometría Espacial Aplicada a la Agricultura de Precisión. Actualidad Económica. pp. 9-28.