

## Risk management system for the monitoring and control of a small lettuce greenhouse

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### ABSTRACT

The management of agricultural risks is a scenario that allows knowing the probable factors that can affect a crop, knowing the variables allow designing control and mitigation of projects in case of any affectation, failure to do so may cause loss of production, the objective This research was the design and construction of a monitoring system for greenhouses that would allow to carry out a small-scale control of the environment, through knowledge of the behavior of the different agroecological variables that intervene in the process, allowing to generate different scenarios For the control of the different variables of nutrition, irrigation, and lighting, it was possible to carry out a set of experiments that showed that the system allows controlling the production in the established time, as well as the effect of the control on the quality of the vegetables.

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## 1. INTRODUCTION

One of the sectors with the greatest economic and social impact worldwide is agriculture, where according to the world bank, the growth of the sector is the most effective in increasing the income of the poorest. In 2016 they found that 65% of the poor working adults made their living from agriculture [1]. Likewise, the domestic market for agricultural products covers the highest percentage of production, but there has been an increase in the international market [2] traditionally the management of crops in the sowing phase is carried out in open crops [3] which are exposed to different environmental and anthropic conditions [4] which affects the impact on the environment V [5] spatial planning [6], [7] and key agricultural production processes.

The negative impact can be evidenced through the loss of food [8], [9] where in the world it occurs largely in the production stage, from the moment it is sown until the moment of harvest [10] in the case of the South American country of Colombia, this is equivalent to 40.5% of the total food produced [11]. Another impact is the use of pesticides on crops, which could cause health problems [12]. Within the problem, the little technification in crops was identified [13] especially in medium and small ones, where the use of technologies [14] for the monitoring and automation of crops is low [15] affecting the competitiveness of producers [16], [17].

Around 1.3 trillion tons of food is wasted annually in the world [11] which is equivalent to 33% of the entire global food supply for human consumption. Of this 33%, 54% corresponds to losses and 46% corresponds to waste. Likewise, agricultural production and consumption have the highest share of global losses and waste with 26% and 34%, respectively [18].

The highest percentage of losses in Colombia occurs in the first links of the chain, 40.5% that is, 3.95 million tons, are discarded during agricultural production. To this are added the 342,000 tons lost in post-harvest and storage (3.5%), losses due to spills, and deterioration of the products during handling, storage, and transport between the farm [19] and distribution.

In the Colombian capital, Bogotá, the losses are mainly due to two factors: on the one hand, there are hail storms [20] that cause damage to crops either due to excess water or damage to plants directly due to hail; the second factor is frost since the temperature drops too low and in a very short period, these extreme behaviors negatively affect production [21]. Another factor is climatic conditions [16] the above factors cause product losses, high cost of fertilizers, and water, reducing the opportunity to compete in the market [22], approximately 40% of the product that is sown is lost due to bad practices [23]. Similarly, the quality of alluvial groundwater in rural areas is sensitive to pollutants originating from agricultural chemicals, that is, nitrate fertilizers and pesticides that are frequently detected in the water supply and are a concern for the community's health.

To mitigate the above factors, risk management models have been developed [24], [25] in farms where different elements that can put people and the infrastructure represented in crops at risk are analyzed, through agricultural systems of early warning agricultural extension workers (AEWS) for the knowledge of risk through the analysis of threats [26] vulnerabilities, risk calculation, and its evaluation to strengthen decision-making as described in the processes of Figure 1.



Figure 1. Risk management processes

The main contribution of this work is the business architecture [27] for the knowledge of risk, Figure 2 which manages to integrate the need of the sector with data, communications, and information analysis within the subcomponents of the AEWS architecture [28] within the subsystems, that of risk information, allows generating the risk scenario and identifying potential impacts, as well as vulnerable groups and sectors that may be affected by risks to agricultural production, the communication subsystem, whose the objective is to communicate timely information about the danger, with an emphasis on vulnerable groups [29] taking into account mitigation measures, potential risk scenarios and preparedness strategies through which strategies and actions are developed to reduce the damage generated. Due to the disaster, the second contribution of this work is the design and implementation of an environmental control and monitoring system. entity and nutrition for the cultivation of lettuce through which data are acquired and the behavior of the variables in the system of each of the processes is known.

The business architecture Figure 2 contains four processes which in order are the analysis of agricultural risk where the scenario is updated using technological tools, and the vulnerability is defined in the place and with the change of environmental, and agro-ecological variables, for which constant update of the inventory of variables in the risk area is generated, with the above, the second process analyzes the vulnerability and determines the possible threats, so that in the third process the risk is calculated and the risk is evaluated according to the change in conditions possible loss of the crop, thus the fourth process assesses the risk and from the technology architecture, the variables of possible risk scenarios are controlled.

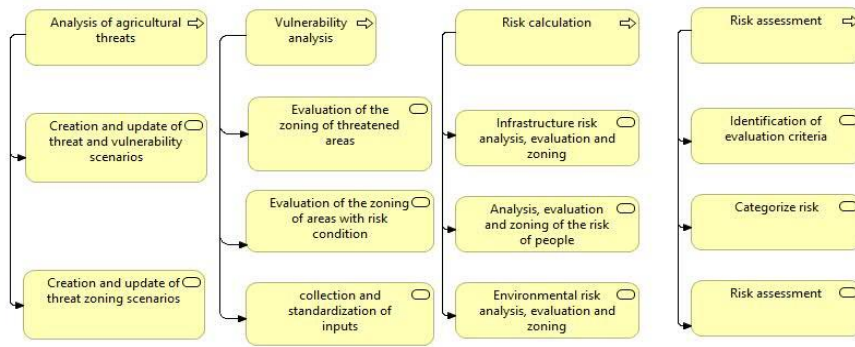


Figure 2. Description of the processes of knowledge of agricultural risks

## 2. MATERIALS AND METHODS

The design of the agricultural IoT architecture was based on the collection of data through a group of sensors as a protocol for the monitoring and tracking of air quality, Figure 3(a) describes the data architecture, where they are defined the inputs that come from the station, for which a set of sensors are grouped where the data is sent to a service platform where it is stored in a database and from there it is taken to present the information, the software platform The selected IoT was ThingSpeak where the information is stored, processed, analyzed and presented, likewise Figure 3(b) presents the technological architecture where a development card was used that as inputs have six different sensors, it has the monitoring and control processes of outputs and data transmission through WiFi communication, for which special modules were used for the TCPIP stack [30].

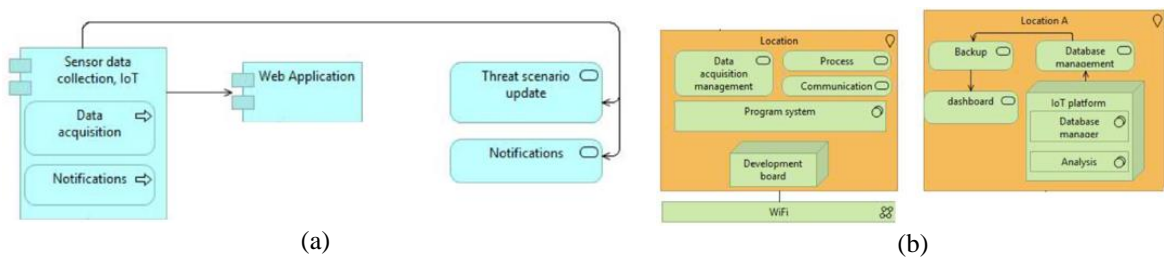


Figure 3. Togaf for a control system of a small lettuce greenhouse based on (a) data architecture and (b) technology

In the process of analysis of agricultural risks, the work was carried out in situ through the compilation of qualitative data, collected through interviews where the traditional cultivation system was evidenced in Figure 4 that is used for the production of this vegetable.



Figure 4. Traditional lettuce cultivation system

The prototype scheme is detailed in Figure 5 having as input six types of sensors that are; temperature, humidity, solar radiation, rain, soil humidity, and a hygrometer, to guarantee the quality of the data, a real-time clock DS321 was used to add the time of data collection to the plot. electrically erasable and programmable ROM (EEPROM) memory is a temporary database, the system contains the processes of the

day and night scenarios that define the main actions that are the control of the environment, irrigation, supply of nutrients, and opening of the roof to take advantage of solar radiation.

The environment control system has two stages, the first is local supervision and the second is remote supervision, for WiFi communication an ESP8266 module was used, for the TCP/IP protocol with output through port 80.

Environmental control seeks to manage the internal temperature of the greenhouse and, to a certain extent, humidity, therefore, these two variables are the main ones of the control system, the initial process described in Figure 6 defines the reading of the variables that also, if they are transmitted to the platform, it defines if the internal temperature sensor is below the minimum established for the plant, in response a halogen bulb is activated to increase the temperature, also if the value read is above the maximum established for the plant, a fan is activated that will recirculate the cold air from the outside to the inside of the garden, lowering the temperature, if the rain sensor and soil humidity are low, the roof is opened to take advantage of the rainwater, on the other hand, if the humidity of the land registers a value higher than the maximum established for the plant and it is raining, the roof will be closed to prevent flooding inside the garden. or testing, if the light sensor is closely related to the rain sensor since the main function of the light sensor is to open the roof of the garden whenever it is daytime and to close it if it is at night.

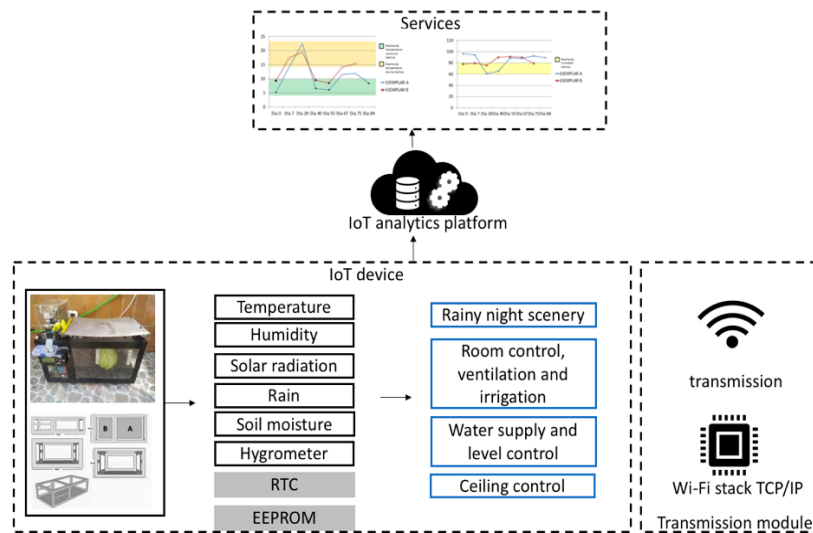


Figure 5. Prototype schematic

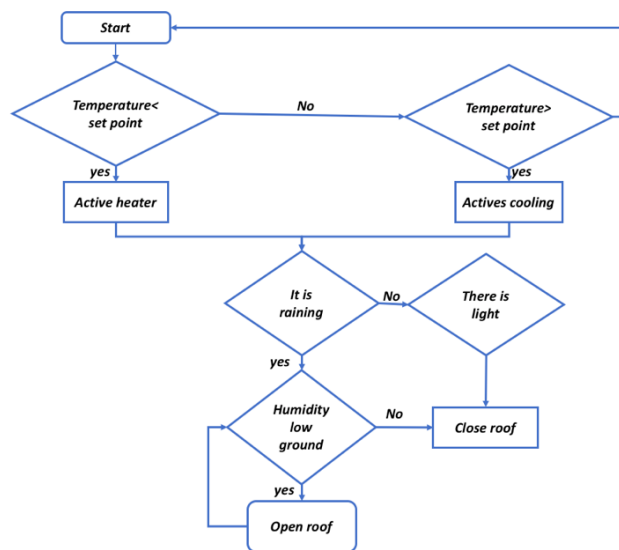


Figure 6. Process for environmental control

### 3. RESULTS AND DISCUSSION

The comparison was made with the data of the experiment as observed in Table 1, of the specimen planted outside and the specimen inside the system, in Figure 7 the images of the growth of a vegetable are described, the lettuce has a time of harvest that ranges between 65 days and 90 days maximum, for this, 8 days of data observation were proposed throughout the entire process, from sowing today 90.

Table 1. Collecting data from lettuce samples

Date	Vegetable plot	Outside plant	Time	Stage	Substage
1-March	Sowing	Sowing	19:50	Night	Rain
7-March	Day 7	Day 12	12:20	Day	Rain
28-March	Day 28	Day 28	16:10	Day	Without rain
9-April	Day 40	Day 40	23:40	Night	Without rain
24-April	Day 55	Day 55	2:20	Night	Rain
6-May	Day 67	Day 67	9:00	Day	Rain
14-May	Day 75-crops	Day 75	8:30	Day	Without rain
24-Mal	N/A	Day 84 - crops	21:50	Night	Without rain

According to the photographic evidence, it can be analyzed that the leaves of specimen A, although they grew, show a more greenish color, which is evidence of humidity saturation, otherwise the leaves would have turned pale yellow, in addition, like the leaves were oversaturated with water, they were not able to shrink and make the final bud for harvest, on the other hand, in the photographic evidence of specimen B, it is possible to analyze that the leaves have a more solid green color compared to as a consequence of having received the necessary humidity for its growth, it is also possible to determine that, when receiving the appropriate climatic conditions, there was bud formation until the day of its harvest.



Figure 7. Growth within the control system from sowing to harvest

The analysis of the results obtained in the experiment was carried out through the comparison of the averages recorded per day, in Figure 8(a), the behavior of the humidity variable is described, presenting the control system with specimen A an adequate behavior, being affected the first and last days, the temperature in Figure 8(b), presents the behavior of the temperature below the external sample that is the specimen B, only having two values above the set point.

In comparison with similar works, it was found in the test with lettuce that in [31], [32] they were carried out for 12 days, achieving the sustainability of the plant, but no data analysis was found, a particular work [33] which is from the same year of this project that measures, performs the same experimentation under conditions between 28 °C and 34 °C, in difference with the ranges of this project that is between 10 °C and 24 °C, from which it is observed that the ideal temperature conditions are in the tropics at high altitudes, compared to [33] he measured temperature exceeded the desired value between 11 am and 10 pm, this could be because the room temperature was high during the day and the heat exchange mechanism employing a fan could not reduce the temperature below room temperature, for the case of this project being carried out in higher altitude conditions the ambient temperature is low which helps to ensure that the maximum values are not exceeded.



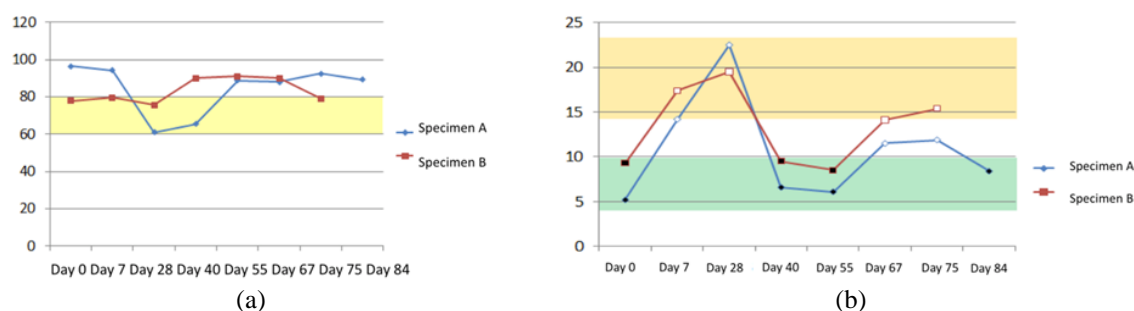


Figure 8. Analysis of average comparison results per day behavior of (a) humidity and (b) temperature

#### 4. CONCLUSION

Thanks to the field study and the information consulted on the data of the variables that affect the growth of lettuce, it is possible to conclude that although the theory is clear, the experience of the farmers is of vital importance, since the plant can behave better when faced with conditions other than theoretical; It was also possible to identify that the plant, under certain non-ideal but bearable conditions, continues its growth in a normal way, perhaps in some cases the harvest may take a few additional days, but it will eventually reach its final state.

When comparing the two lettuce specimens, it was possible to conclude that although a specimen outside the system can reach its harvest stage without much supervision, the specimen inside the garden not only managed to reach its final stage with at least one week in advance but also managed to arrive in better condition as seen in the photographic evidence.

The monitoring and control system complied with the provisions of the previous requirements, evidencing how the variables analyzed intervene in the vegetable production process, this analysis with low plant density allows to understand the dynamics of the system, providing the basis for the following process and what the control of an orchard with a larger population will be.

Different benefits and drawbacks present this type of development, among the benefits, are the ability to know the variables through IoT and thus in a dashboard understand the behavior of the variables, the above among types of scenarios are infrastructure would present a problem so Which, this project is working on the implementation of Edge Computing devices to solve the network difficulty, now a great benefit is to know the information of the system, which was experimentally verified at scale, by expanding the size of the solution and increasing more plants, the number of devices also increases, increasing the economic cost of the implementation, arising another challenge on distribution, density, and uncertainty of the system.




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