v. 3, n. 11, 2023

Journal of
Agricultural
Sciences
Research

BIG DATA WITH APPLICATION AND MANAGEMENT TO ENVIRONMENTAL MONITORING IN A PROTECTED AGRICULTURE SYSTEM

Judith Arlette Villasana-Rojas
Universidad Autónoma de Nuevo León, Agronomy course, San Nicolas de los Garza, Nuevo León, Mexico

Edgar Vladimir Gutiérrez-Castorena
Universidad Autónoma de Nuevo León, Agronomy course, San Nicolas de los Garza, Nuevo León, Mexico

Emilio Olivares-Sáenz
``Universidad, Autónoma de Nuevo León``, Agronomy course, San Nicolas de los Garza, Nuevo León, México

Rigoberto Eustasio Vázquez Alvarado
``Universidad Autónoma de Nuevo León``, Agronomy course, San Nicolas de los Garza, Nuevo León, Mexico

Martin Espinosa Ramírez
``Instituto Nacional de Investigaciones Forestales``, Agriculture and Livestock, Northeast Region Research Center, Rio Bravo, Tamaulipas, México

Abstract: The monitoring of environmental factors, such as temperature, relative humidity, soil temperature and radiation, is important because they have a direct influence on the production and yield of greenhouse crops. An environmental monitoring system was installed in a low-tech greenhouse with sensors compatible with Arduino technology, which consisted of 27 DHT22 temperature and relative humidity sensors fixed at nine points and three heights (1, 3 and 4.5 m), four DS18B20 soil temperature sensors at 4 depths (30, 60, 90 and 120 cm). In addition, radiation outside and inside the greenhouse was recorded with three pieces of equipment (UV radiation, Global Radiation and Luxometer), considering 9 points and 2 sampling levels (1 and 3 m). The Big Data integrated more than 145,000 data, analyzing them with the SPSS program, performing linear regression models and analysis of variance by factor. The temperature results showed that the crop generated a microclimate that prevented the average temperatures from being exceeded; however, the highest temperatures were located at the perimeter and at the top of the greenhouse. The soil temperature was higher as the sampling depth increased, however, the sensor at 30 cm had a greater influence of the ambient temperature. The radiation in the greenhouse was sufficient for tomato production, registering an average of more than 10 MJ/m2/day. The condition of the plastic did not represent a significant difference in radiation between the points, however, it was less than one meter due to the capture of radiation by the crop. The installed system turned out to be a promising tool for monitoring environmental factors in order to modify their dynamics in order to increase productivity in a low-tech system.

Keywords: Sensors, Arduino Technology, Temperature, Relative Humidity, Radiation

INTRODUCTION

Precision agriculture contributes to the recording of information from digital sensors generating Big Data to obtain databases to interpret the main factors involved in agricultural production (Achour, et al., 2021, Córdoba & Buitrago, 2013). This technology is applied to monitor environmental parameters in protected agriculture, such as temperature, relative humidity, soil temperature, radiation, etc. (Wang et al. 2020). Real-time monitoring allows timely decision-making to modify and adapt conditions in order to maximize production (Duque, 2017, Shamshiri et al., 2018), the location of the sensors is important so that the data is representative of the production system (Lee et al., 2019b) because microclimate zones are generated within the greenhouse (Kochhar, & Kumar, 2019). Temperature, relative humidity and radiation are fundamental parameters for development, being determinant for productivity (Shamshiri & Ismail, 2013, Lee et al., 2019a). Soil temperature has an effect on the availability of water for crops, as well as on the decomposition process of organic matter and mineralization (Escobar et al., 2020), so environmental factors have an effect on soil temperature and its behavior on the surface and along the profile (Onwuka et al., 2018). In the present investigation, an environmental monitoring system was developed from the installation of sensors to generate Big Data in order to know and explain the dynamics of their behavior in a low-tech greenhouse.

MATERIALES AND METHODS

The environmental monitoring system was installed in a 1,000 m2 low-tech sawtooth greenhouse located in the Faculty of Agronomy of``Universidad Autonoma de Nuevo León`` in Escobedo, Nuevo León. The monitoring of the environment consisted of the placement of a network of 27 DHT22 sensors for relative humidity and temperature, arranged in 9 points equidistantly within the greenhouse arranged in three levels which were one, three and four point five meters from the ground. The sensors send the signal to an Arduino board that converts the analog signal to digital to record the value of each parameter, which were recorded every hour for each sampling point, recording the data in a micro SD memory to export the data for analysis. The registration period ran from December 15, 2020 to June 30, 2021.

The soil temperature was recorded with the DS18B20 sensor, installing four of them in the center of the greenhouse arranged at 30, 60, 90 and 120 cm depth. The sensors are connected by means of UTP cable to a control box, in which they deliver a digital signal that is connected to an Arduino board, under it with the same process of temperature and relative humidity. This variable is monitored from November 1, 2021 to March 31, 2022. The data was collected every week to reduce loss of information, which was taken to the computer for storage and processing.

The recording of incident radiation was carried out with three pieces of equipment: the Digital Ultraviolet Radiometer (UV) Model 5.0 of the Solarmeter Total UV (A+B) brand, which has a recording range of 0 to 199.9 mW/cm2 with a response length of 280-400 nm, the Global Solar (GL) Power Meter Model 10.0 of the Solarmeter Solar Visible + Near IR brand, with a reading range of 0- to 1999 W/ m2 with response length of 400-1100 nm and Luxometer (Lx) HI 97500 Hanna brand response range 0.001 to 199.9 Klx with photodiode with response from 400 to 700 nm.

The readings were taken every fortnight from March 11, 2021 to March 15, 2022, in three periods of the day at 9:00 a.m., 1:00 p.m., and 5:00 p.m., considering two sampling heights (1 and 3 m) at the nine points inside the greenhouse. To the above, the external sampling point was added to compare the environments.

The statistical analyzes for radiation were carried out according to the conditions in which the plastics were found, due to the fact that damage to the cover occurred during the development of the investigation.

The temperature, relative humidity, soil temperature and radiation data collected were analyzed with the SPSS 21 IBM® statistical program, performing simple and multiple regression, in addition to generating response surface graphs with the Sigma Plos program.

RESULTS AND DISCUSSION

The environmental monitoring system based on digital sensors installed in the greenhouse generated a Big Data that allowed the analysis and interpretation of the information obtained, the critical points of temperature and relative humidity were identified, similar results were reported by Avoits et al., (2019) where the information collected allowed to propose management alternatives for the production system.

Liang et al., (2018) developed an environmental monitoring system for protected agriculture where they validate that the sensor network is a reliable and practical monitoring alternative for greenhouse management. Vimal & Shivaprakasha (2017) developed a system based on Arduino technology, obtaining fast and reliable information regarding the parameters they evaluated, implementing techniques for the control and management of the environment, coinciding with the work of Liu et al., (2021).

For the temperature variable, a multiple linear regression analysis was carried out to generate a response surface with respect to the greenhouse points, the database was reduced by obtaining the average considering date, time and height, creating a general linear regression model of temperature (T), considering the orientation of the greenhouse being significant ($p< 0.05$) with a: $R^2=0.988$.

$$T = 29.295 - 3.038NS - 3.280EO + 0.749NS^2 + 0.815EO^2 - 0.013\ EOxNS$$

A similar work was reported by Taki et al., 2016, as well as by Doan and Tanaka (2022) in which mathematical models were established through multiple linear regression analysis to explain the relationship between tomato growth index and greenhouse environmental factors.

The model of the temperature inside the greenhouse is represented in figure 1 with the response surface graph, the average temperature ranged between 22 and 25 °C. The crop had an influence on the behavior of the temperature, by registering the lowest temperatures in the canopy area, this is due to the microclimate that is generated with the transpiration process, evidencing the need to increase the movement of air inside the greenhouse in search of homogenizing the conditions within it.

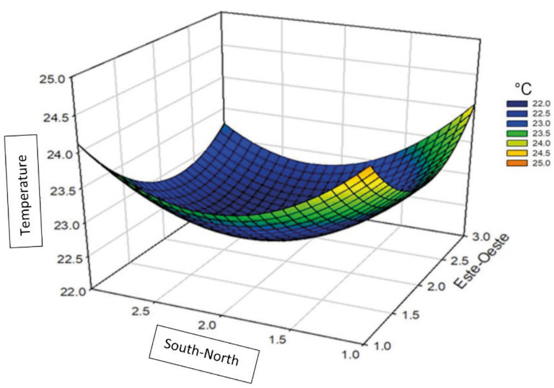

Figure 1. Graphic representation of the model generated from the temperature data of the 27 sampling points.

The analysis of variance showed a significant difference ($p < 0.05$) for height with respect to the position of the sensor, at one meter the average temperature ranged between 20 and 25°C, at three meters the average between 23 and 25°C, recording the highest temperature at four point five meters high with an average between 23 and 26°C, as shown in figure 2.

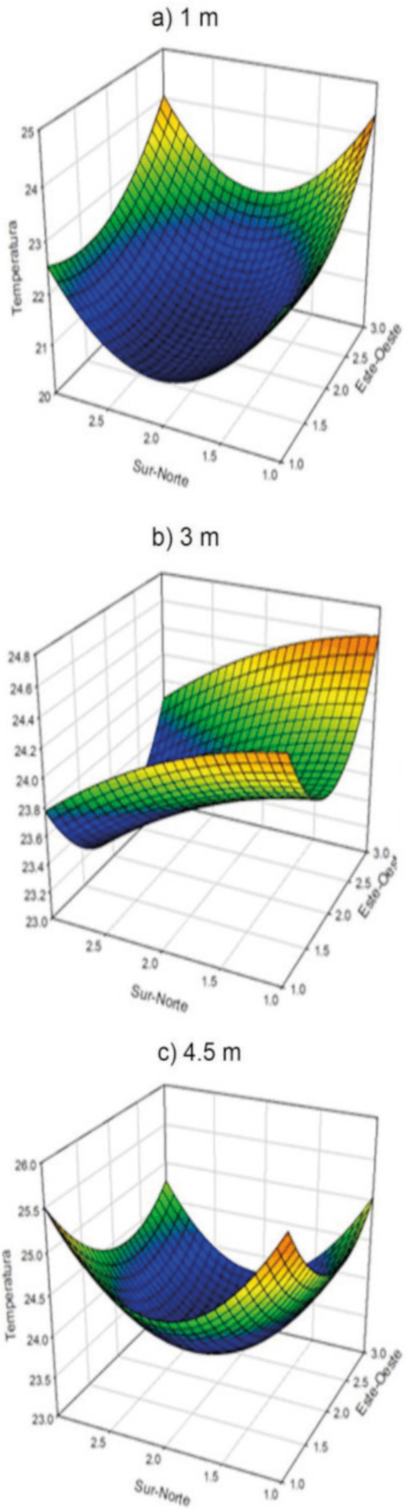

Figure 2. Graphs of response surface of the average temperature considering the different sampling levels a) 1 m, b) 3 m and c) 4.5 m.

The greenhouse temperature at 1 m and 3 m in height have a direct influence on the phenological development of the crop, affecting processes such as flowering, fruit set and fruit filling (Noreña et al., 2013), however, with the results obtained, they show that it is possible to produce with the recorded temperatures since between 21 and 27 °C all biochemical processes develop normally.

The analysis of variance of the soil temperature showed a significant difference ($p < 0.05$) for the 4 depths, comparing the means obtained, which are presented in table 1.

Depth cm	Temperature °C
30	20.2 d
2	22.1 c
3	23.2 b
4	24.1 a

Table 1. Comparison of means of the average temperature recorded at the four sampling depths.

The radiation results are presented according to the conditions of the plastics, during the first six dates the plastics were complete, so in this case the points inside and outside the greenhouse and the heights are compared.

The analysis of variance showed significant differences for heights ($p < 0.000$) and points ($p < 0.000$). Regarding heights, higher radiation was recorded at 3 m height because it had no shading effect by the plants for the three teams used (Table 2). The temperature of the plants is influenced by the environment through the energy balance of the leaves and the canopy, regulated by transpiration as a physiological response to the effects of the environment (Chaves & Gutiérrez 2017) where radiation has a direct effect.

Height	UV	GL W/m^2	Lx
3 m	1.53 a	358.64 a	382.60 a
1 m	6.94 b	229.75 b	217.99 b

Table 2. Comparison of radiation means at two heights in the greenhouse points considering the three teams.

Of the total radiation from the outside 26.58, 596.66 and 692.36 W/m2, an average of 6.3, 255.11 and 247.74 W/m2 was recorded in the greenhouse, having the effect of the cover, Ayala et al., (2011) reported a loss of 50% of the total radiation inside the greenhouse. The temperature of the plants is influenced by the environment through the energy balance of the leaves and the canopy, regulated by transpiration as a physiological response to the effects of the environment (Chaves & Gutiérrez 2017) where radiation has an important direct effect.

An analysis of orthogonal contrasts was carried out to compare the external sampling point against points 9 inside the greenhouse, for the three teams and to mark the difference in the incidence of daily radiation inside the greenhouse due to the effect of the plastic film, the results are presented in table 3. The geographical location of the greenhouse, as well as the characteristics of its cover determine the quantity and quality of radiation that the crop receives, however, with the results obtained it was verified that the condition of the plastic did not influence and the minimum requirement required by the cultivation of tomato (INTAGRI, 2022).

Team	Fc	Significance	External radiation	Average radiation points in the greenhouse MJ/m2/day
UV	809.132	0.01	1.2	0.30
GL	316.015	0.01	27.92	12.35
Lx	663.324	0.01	28.25	13.77

Table 3. Orthogonal contrasts to compare the radiation inside and outside the greenhouse with the three teams.

The comparison of means with respect to the sampling height showed a significant difference ($p < 0.05$) for the three teams (Table 4), with the highest radiation reading at three meters in the tutoring line with respect to the height of 1 m, where received radiation is lost due to the shading effect of the plants.

Altura	UV	GL W/m^2	Lx
3 m	10.07 a	281.61 a	303.08 a
1 m	6.944 b	203.88 b	217.62 b

Table 4. Comparison of means of radiation received at different sampling heights inside the greenhouse with the three equipment used.

The results of the comparison of means after the repair of the plastic showed a significant difference ($p<0.05$) between the exterior and the greenhouse with the three teams as presented in Table 10, however, it did not show a significant difference with respect to the recently installed plastic in points 7, 8 and 9 with respect to points 1 to 6 that are 1 year old (Table 5).

Point	UV	GL W/m^2	Lx
1.00	5.60 b	211.708 b	233.18 b
2.00	5.50 b	198.729 b	228.31 b
3.00	5.19 b	190.188 b	220.78 b
4.00	4.73 b	172.458 b	198.74 b
5.00	4.60 b	170.146 b	191.97 b
6.00	5.02 b	183.625 b	218.67 b
7.00	1.71 c	189.188 b	215.55 b
8.00	1.71 c	189.044 b	217.18 b
9.00	1.98 cd	209.333 b	239.67 b
10.00	13.15 a	338.181 a	460.58 a

Table 5. Comparison of means of the radiation record of points 1 to 9 after the repair of the plastic, including point 10 of the exterior.

The total radiation recorded outside was 13.15, 338.18 and 460.58 W/m2, an average of 3.99, 190.49 and 218.22 W/m2 was recorded in the greenhouse, representing a radiation loss of 69%, 43% and 52% respectively, representing a radiation loss of 67%, 58% and 65% respectively, which can be attributed to the greenhouse structure or the quality and properties of the cover as indicated by Nomura et al., 2022.

In addition, a comparison of means for the 9 points was made with the three teams for height, finding no significant difference ($p < 0.05$) between them (Table 11), this is due to the fact that after the repair of the plastic in the greenhouse there was no established crop, so the radiation at both heights was very similar.

Height	UV	GL W/m^2	Lx
3 m	4.97 a	207.733 a	246.67 a
1 m	4.71 a	198.621 a	233.47 a

Table 11. Comparison of means between points inside the greenhouse with the three teams for height.

CONCLUSIONS

The Big Data generated from the environmental monitoring system established in the greenhouse allowed obtaining information on the dynamics of the behavior of the main environmental factors for the management and management of the low-tech production system. The response surface graphs allowed us to identify the distribution of relative humidity and temperature, detecting critical points to implement strategies in order to reduce the adverse effect on the crop, identifying the need to increase air movement within the greenhouse to homogenize environmental conditions. The temperature is correlated with the soil temperature at the surface and its behavior through the soil profile. The radiation equipment tested can quantify the radiation in order to determine the amount of radiation and the distribution through the plant canopy.

REFERENCES

Achour, Y., Ouammi, A., & Zejli, D. (2021). **Technological progresses in modern sustainable greenhouses cultivation as the path towards precision agriculture**. *Renewable and Sustainable Energy Reviews*, *147*, 111251.

Avotins, A., Apse-Apsitis, P., Bicāns, J., & Gruduls, J. (2018). **Development and testing results of IoT based air temperature and humidity measurement system for industrial greenhouse.** Agronomy Research 16(S1), 943-951.

Ayala-Tafoya, F., Zatarain-López, D. M., Valenzuela-López, M., Partida-Ruvalcaba, L., Velázquez-Alcaraz, T. D. J., Díaz-Valdés, T., & Osuna-Sánchez, J. A. (2011). **Crecimiento y rendimiento de tomate en respuesta a radiación solar transmitida por mallas sombra**. Terra Latinoamericana, 29(4), 403-410.

Chaves-Barrantes, N. F., & Gutiérrez-Soto, M. V. (2017). **Crop physiological responses to high temperature stress.** II. Tolerance and agronomic treatment. *Agronomía Mesoamericana*, *28*(1), 255-271.

Córdoba, D. M. A., & Buitrago, F. A. S. (2013). **Estado del arte de las redes desensores inalámbricos.** *Tecnología Investigación y Academia*, *1*(2).

Doan, C. C., & Tanaka, M. (2022). **Relationships between Tomato Cluster Growth Indices and Cumulative Environmental Factors during Greenhouse Cultivation**. *Scientia Horticulturae*, *295*, 110803.

Duque, S. I. O. (2017). **Monitoreo y control de variables ambientales mediante una red inalámbrica para agricultura de precisión en invernaderos**. *Revista vector*, *12*, 51-60.

Escobar, M. I., Panadero, A. N., Medina, C. A., Álvarez, J. D. C., Tenjo, A. I., & Sandoval, L. M. B. (2020). **Efecto de prácticas agroecológicas sobre características del suelo en un sistema de lechería especializada del trópico alto colombiano**. Development, 32(4).

INTAGRI SC. (Instituto para la Innovación Tecnológica en la Agricultura). 2022. **Importancia de la radiación solar en la producción bajo invernadero** (en línea).

Kochhar, A., & Kumar, N. (2019). **Wireless sensor networks for greenhouses: An end-to-end review.** ***Computers and Electronics in Agriculture***, *163*, 104877.

Lee, C. K., Chung, M., Shin, K. Y., Im, Y. H., & Yoon, S. W. (2019a). **A study of the effects of enhanced uniformity control of greenhouse environment. variables on crop growth**. *Energies*, *12*(9), 1749.

Lee, S. Y., Lee, I. B., Yeo, U. H., Kim, R. W., & Kim, J. G. (2019b). **Optimal sensor placement for monitoring and controlling greenhouse internal environments.** *Biosystems Engineering*, *188*, 190-206.

Liang, M. H., He, Y. F., Chen, L. J., & Du, S. F. (2018). **Greenhouse Environment dynamic Monitoring system based on WIFI**. *Ifac-Papersonline*, *51*(17), 736-740.

Liu, R., Li, M., Guzmán, J. L., & Rodriguez, F. (2021). **A fast and practical one-dimensional transient model for greenhouse temperature and humidity.** *Computers and Electronics in Agriculture*, *186*, 106186.

Nomura, K., Saito, M., Tada, I., Iwao, T., Yamazaki, T., Kira, N., ... & Kitano, M. (2022). **Estimation of Photosynthesis Loss Due to Greenhouse Superstructures and Shade Nets**: A Case Study with Paprika and Tomato Canopies. *HortScience*, *57*(3), 464-471.

Noreña, J. E. J., Rodríguez, V. P., & Aguilar, P. A. A. (2013). **Factores climáticos y su influencia en la producción de tomate**. Tecnología para el Cultivo de Tomate Bajo Condiciones Protegidas, 141.

Onwuka, B., & Mang, B. (2018). **Effects of soil temperature on some soil properties and plant growth**. *Adv. Plants Agric. Res*, *8*(1), 34-7.

Shamshiri, R. R., Jones, J. W., Thorp, K. R., Ahmad, D., Man, H. C., & Taheri, S. (2018). **Review of optimum temperature, humidity, and vapour pressure deficit for microclimate evaluation and control in greenhouse cultivation of tomato**: a review. *International agrophysics*, *32*(2), 287-302.

Shamshiri, R., & Ismail, W. I. W. (2013). **A review of greenhouse climate control and automation systems in tropical regions**. *J. Agric. Sci. Appl*, *2*(3), 176-183.

Taki, M., Ajabshirchi, Y., Ranjbar, S. F., & Matloobi, M. (2016). **Application of Neural Networks and multiple regression models in greenhouse climate estimation**. *Agricultural Engineering International: CIGR Journal*, *18*(3), 29-43.

Vimal, P. V., & Shivaprakasha, K. S. (2017, July). **IOT based greenhouse environment monitoring and controlling system using Arduino platform**. In *2017 International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT)* (pp. 1514-1519). IEEE.

Wang, J., Chen, M., Zhou, J., & Li, P. (2020). **Data communication mechanism for greenhouse environment monitoring and control**: An agent-based IoT system. *Information Processing in Agriculture*, *7*(3), 444-455.