IoT-BASED CAPACITIVE SOIL MOISTURE SENSOR FOR SMART IRRIGATION SCHEDULING IN WHITE CUCUMBER *(Cucumis sativus, L.)* CULTIVATION USING DRIP IRRIGATION

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ACCEPTANCE SHEET

This undergraduate thesis entitled **"IoT-BASED CAPACITIVE SOIL MOISTURE SENSOR FOR SMART IRRIGATION SCHEDULING IN WHITE CUCUMBER *(Cucumis sativus, L.)* CULTIVATION USING DRIP IRRIGATION"** prepared and submitted by **JERRAND NOLAN D. ACOSTA and CHRISTOPHER ALBERT L. JACOBO**, in partial fulfillment of the requirements for the degree of **BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING (AB LAND AND WATER RESOURCES ENGINEERING)**, is hereby accepted:

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Jerrand Nolan D. Acosta is a 23-year-old college student pursuing a degree in Bachelor of Science in Agricultural and Biosystems Engineering at Central Luzon State University. He was born on the 9th of September in the year 2000 and is the eldest of the three children of Mr. Nolan A. Acosta and Mrs. Winnie D. Acosta, who live at Brgy. IV, San Mateo, Isabela.

He started his academic journey at the age of three at Golden Values Learning Center and later continued his primary and secondary education at La Salette of San Mateo Inc. He continues to thrive on his passion for learning and later on, pursued his Senior Highschool career at Central Luzon State University, took up the Science, Technology, Engineering, and Mathematics (STEM) strand, and graduated on June 13, 2018.

As a college student, Jerrand Nolan D. Acosta is constantly seeking new opportunities for personal and professional growth. He may have a curious mind, always eager to explore new ideas and expand his knowledge not only in the four corners of the classroom but also beyond it.

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ABSTRACT

ACOSTA, JERRAND NOLAN D., AND JACOBO, CHRISTOPHER ALBERT L. Department of Agricultural and Biosystems Engineering, College of Engineering, Central Luzon State University, Science City of Muñoz, Nueva Ecija, **DECEMBER 2023. IoT-BASED CAPACITIVE SOIL MOISTURE SENSOR FOR SMART IRRIGATION SCHEDULING IN WHITE CUCUMBER (*Cucumis sativus, L.)* CULTIVATION USING DRIP IRRIGATION**

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Traditionally, irrigation scheduling relied on manual observations and estimations, resulting in inefficient water usage as well as potential yield losses. The integration of Internet of Things (IoT) technology and capacitive soil moisture sensors has emerged as a promising solution for precise and automated irrigation management in agriculture in response to these challenges.

This study was conducted to evaluate the IoT-based capacitive soil moisture sensor for automatically scheduling drip irrigation for White Cucumber *(Cucumis sativus, L.)*. Specifically, the study aims to: calibrate and interpret the capacitive soil moisture sensor for automatic irrigation scheduling; create a system that automatically irrigates the field based on the set treatments; assess the growth and yield of white cucumber; and conduct a simple cost analysis for the installation of the capacitive soil moisture sensor. Treatment 1 = 40% of AW, Treatment 2 = 45% of AW, Treatment 3 = 50% of AW, and Treatment 4 = Farmer's Practice (Control) for the percentage of MAD.

Calibration involves fine-tuning the sensor readings to match the actual soil conditions, enhancing the precision of subsequent measurements. During the program development in the Arduino IDE, the lowest and highest values were determined and

established as the wet and dry soil references for the system, respectively. Notably, the highest value was assigned to the wet soil condition because the presence of electrolytes in the soil tended to be higher when the soil was dry and lower when it was wet.

The results of the study indicated that the IoT-based smart irrigation system exhibited promising capabilities for optimizing water management, as treatments exhibited significantly higher growth rates than the control. T3 (50% AW) produced the highest yield in terms of weight (13.7 kg) and pieces (62.3 pcs) of White Cucumber produce. In contrast, all treatments have comparable development parameters throughout the study. A Simple cost analysis was done, which yielded a 16.51% return on investment when smart automatic drip irrigation was implemented. For the study alone, a total of ₱9,766.78 was used for the whole production and cultivation.

Keywords: Internet of Things, drip irrigation, white cucumber, irrigation scheduling

LITERATURE CITED

Ariffin, N., & Zin, R. M. (2021). An Internet of Things (IoT) based Plant Irrigation and Monitoring System for Cucumber Plant. *Evolution in Electrical and Electronic Engineering*, *2*(2), 70–76. https://doi.org/10.30880/eeee.2021.02.02.009

Alomran, Abdulrasoul & Louki, Ibrahim. (2011). Yield response of cucumber to deficit irrigation in greenhouses. WIT Transactions on Ecology and the Environment. 145. 517-524. 10.2495/WRM110451.

Alsaeedi A, El-Ramady H, Alshaal T, El-Garawany M, Elhawat N, Al-Otaibi A. Silica nanoparticles boost growth and productivity of cucumber under water deficit and salinity stresses by balancing nutrients uptake. Plant Physiol Biochem. 2019 Jun;139:1-10. doi: 10.1016/j.plaphy.2019.03.008. Epub 2019 Mar 9. PMID: 30870715.

Aslam, Furqan & Hussain, Saddam & Nawaz, Gul & Ahmed, Shahzad & Waqas, Ahmad. (2022). Different Irrigation Levels Testing on Cucumber in Tissue Tunnel.

Balsom, Paul. (2020). Water Usage In The Agricultural Industry. High Tide Technologies. https://htt.io/water-usage-in-the-agricultural-industry/

Bakker J.C., C. Sonneveld, (1988). Calcium deficiency of glasshouse cucumber asaffected by environmental humidity and mineral nutrition. Journal of Horticultural Science. London 63(2): 241–246

Bauder, T., Schneekloth, J., & Wardle, E. (n.d.). *Irrigated Field Guide & Record Book*.'

Boutraa, T., Akhkha, A., Alshuaibi, A., & Atta, R. (2011). Evaluation of the effectiveness of an automated irrigation system using wheat crops. *Agriculture and Biology Journal of North America*, *2*(1), 80–88. https://doi.org/10.5251/abjna.2011.2.1.80.88

Brosas, A. (2022). Siling Labuyo or Cucumber Cucumber Farming: How to Plant and Grow Cucumber Cucumber. https://agraryo.com/agriculture/cucumber-cucumber-farming-in-the-philippines/

Buttaro, D., Santamaria, P., Signore, A., Cantore, V., Boari, F., Montesano, F. F. and Parente, A. 2015. Irrigation Management of Greenhouse Tomato and Cucumber Using Tensiometer: Effects on Yield, Quality and Water Use. Agric. Agric. Sci. Proc., 4 : 440 - 444.

Budiyati, I. & Suwignyo, Rujito & Renih, H. & Susilawati, Susilawati. (2017). RESPONSE OF RED CHILLI VARIETIES UNDER DROUGHT STRESS. Russian Journal of Agricultural and Socio-Economic Sciences. 66. 361-368. 10.18551/rjoas.2017-06.43.

Cantliffe D.J. (2016). Alteration of sex expression in cucumber due to changes in temperature, light intensity, and photoperiod. Journal of the American Society of Horticultural Science, Geneva 106(2): 133–136

Clarke M, Acomb G, Philpot B (2008) Florida field guide to low impact development. Program for resource efficient communities, University of Florida.

Cultifort Business Group. (2011). Management of adverse weather conditions in cucumber https://www.cultifort.com/en/management-of-adverse-weather-conditions-in-cucumber/

Darko, R. O., Shouqi, Y., Junping, L., Haofang, Y., & Xingye, Z. (2017). Overview of advances in improving uniformity and water use efficiency of sprinkler irrigation. *International Journal of Agricultural and Biological Engineering*, *10*(2), 1–15. https://doi.org/10.3965/j.ijabe.20171002.1817

De la Concepcion, A.R.; Stefanelli, R.; Trinchero, D. A wireless sensor network platform optimized for assisted sustainable agriculture. In Proceedings of the IEEE Global Humanitarian Technology Conference (GHTC), San Jose, CA, USA, 10–13 October 2014; pp. 159–165.

Delfin & Bagtasa Trogo, Rhia & Ebardaloza, Jed & Sabido, Delfin & Bagtasa, Gerry & Tongson, Edgardo & Balderama, Orlando. (2015). SMS-based Smarter Agriculture decision support system for yellow corn farmers in Isabela. 1-4. 10.1109/IHTC.2015.7238049.

Dukes, M.D., Simonne, E.H., Davis, W.E., Studstill, D.W and Hochmuth, R (2003). Effect of sensor-based high frequency irrigation on bell cucumber yield and water use. Proceedings of 2nd International Conference on Irrigation and Drainage, May 12-15. Phoenix, AZ. pp. 665-674

Eastwood, B. 2020. The 10 Most Popular Programming Languages to Learn in 2020. https://www.northeastern.edu/graduate/blog/most-popular-programming-languages/

Food and Agricultural Organization. Irrigation Water Management: Irrigation Methods. Via delle Terme di Caracalla, 00100 Rome, Italy.

Agricultural Engineering (Vol. 1, Issue 2). www.researchjournal.co.in/online/subdetail.html

Kour V.P., Arora S. 2020. Recent Developments of the Internet of Things in Agriculture: A Survey.IEEE Access, 8, 129924–129957.

Lakhiar, Imran & Jianmin, Gao & Syed, Tabinda & Chandio, Farman Ali & Buttar, Noman & Qureshi, Waqar. (2018). Monitoring and Control Systems in Agriculture Using Intelligent Sensor Techniques: A Review of the Aeroponic System. Journal of Sensors. 2018. 18. 10.1155/2018/8672769.

Lambe, T. How dry is a soil?. Soil Mechanics, Massachusetts Institute of Technology.

Liebig H.P., (1981). Physiological and economical aspects of cucumber crop density. Acta Horticulturae, The Hague 118: 149–164

López-Córdoba, A., & Goyanes, S. (2017). Food Powder Properties. Reference Module in Food Science. doi:10.1016/b978-0-08-100596-5.21198-0

Macias-Bobadilla, I., Vargas-Hernandez, M., Guevara-Gonzalez, R. G., Rico-Garcia, E., Ocampo-Velazquez, R. v., & Torres-Pacheco, I. (2020). Differential response to water deficit in cucumber cucumber (Capsicum annuum l.) growing in two types of soil under different irrigation regimes. *Agriculture (Switzerland)*, *10*(9), 1–15. https://doi.org/10.3390/agriculture10090381

Mohammed, H.E., Ahmed, M.K., 2006. Effect of Irrigation Levels on Cucumber (Cucumis sativus L.) Yield Under Cooled Plastic Tunnels. 36th proceedings of the Meetings of the National Crop Husbandry Committee – NCHC.

Munoth, P., Tiwari, K., Goyal, R., & Scholar, P. D. (2016). *Sensor based Irrigation System : A Review Integrated Water Resource Management View project Calibration of VH400 Soil Moisture Sensors View project Sensor based Irrigation System : A Review*. https://www.researchgate.net/publication/303842913

Nijamudeen, M.S. & Dahrmasena, P.B. (2004). PERFORMANCE OF CHILLI UNDER DRIP-IRRIGATION WITH MULCH. Field Crops Research and Development Institute, Maha Illuppallama

Nijamudeen. (2002). *PERFORMANCE OF CHILLI UNDER DRIP-IRRIGATION WITH MULCH Poverty reduction through agricultural development View project Sustainable Land Management View project Sustainable Agriculture Research and Development Centre Sri Lanka Punchi Bandage Dharmasena Improving System Efficiencies and Water Productivity Project.* https://www.researchgate.net/publication/303945879

Odhiambo, Judith & Aguyoh, Joseph. (2022). Soil moisture levels affect growth, flower production and yield of cucumber. Agricultura Tropica et Subtropica. 55. 1-8. 10.2478/ats-2022-0001.

Padmanabhan P., Cheema A., Paliyath G. Solanaceous fruits including tomato, eggplant, and cucumbers. In: Caballero B., Finglas P.M., Toldrá F., editors. Encyclopedia of Food and Health. Academic Press; Oxford, UK: 2016. pp. 24–32.

Palmer-Jones RW. 2001. Irrigation service markets in Bangladesh: private provision of local public goods and community regulation. Presented at Symp. Managing Common Resources: What is the Solution? Lund Univ., Sweden. Sept. 10–11. http://www.sasnet.lu.se/palmer jones.pdf

Panda, R. K., Behera, S. K., & Kashyap, P. S. (2004). Effective management of irrigation water for maize under stressed conditions. *Agricultural Water Management*, *66*(3), 181–203. https://doi.org/10.1016/j.agwat.2003.12.001

Prodhan, A, Rahman, M.L. and Haque M.A., 2001. Effect of Water Stresses on Growth Attributes in Cucumber I. Plant Height. Pakistan Journal of Biological Sciences, 4: 128-135.

Peters, R. T. (n.d.). *PRACTICAL USE OF SOIL MOISTURE SENSORS AND THEIR DATA FOR IRRIGATION SCHEDULING.*

Philippine Statistics Authority. (2022). Technical Notes on Production Costs and Returns of Selected Agricultural Commodities. https://psa.gov.ph/statistics/technical-notes/node/167182

Pramanik, M., Khanna, M., Singh, M., Singh, D. K., Sudhishri, S., Bhatia, A., & Ranjan, R. (2022). Automation of soil moisture sensor-based basin irrigation system. *Smart Agricultural Technology*, *2*, 100032. https://doi.org/10.1016/j.atech.2021.100032

Priandana, K., & Wahyu, R. A. F. (2020, February 1). Development of Automatic Plant Irrigation System using Soil Moisture Sensors for Precision Agriculture of Cucumber. *Proceeding - ICoSTA 2020: 2020 International Conference on Smart Technology and Applications: Empowering Industrial IoT by Implementing Green Technology for Sustainable Development.* https://doi.org/10.1109/ICoSTA48221.2020.1570615896

Ray, P.P. (2018) A Survey on Internet of Things Architectures. Journal of King Saud University—Computer and Information Sciences, 30, 291-319. https://doi.org/10.1016/j.jksuci.2016.10.003

Sahin, U. & Kuslu, Yasemin & Kiziloglu, Fatih. (2015). Response of cucumbers to different irrigation regimes applied through drip-irrigation system. Journal of Animal and Plant Sciences. 25. 198-205.

Sahu, A. P., Panigrahi, B., & Mohapatra, J. (2020). Estimation of crop coefficient of green chilli grown under rooftop greenhouse Academic excellence View project. In *Article in Journal of Pharmacognosy and Phytochemistry*. www.phytojournal.com

Sharma, V. (2019). Integration of Soil Moisture Sensor Based Automated Drip Irrigation System for Okra Crop. *International Journal of Pure & Applied Bioscience*, *7*(4), 277–282. https://doi.org/10.18782/2320-7051.7642

Shock, C. C., & Wang, F. (2011). Soil Water Tension, a Powerful Measurement for Productivity and Stewardship, HortScience horts, 46(2), 178-185. Retrieved Mar 23, 2023, from https://doi.org/10.21273/HORTSCI.46.2.178

Sui, R. (2017). Irrigation Scheduling Using Soil Moisture Sensors. *Journal of Agricultural Science*, *10*(1), 1. https://doi.org/10.5539/jas.v10n1p1

Tabatabaei, Sayyed-Hassan & Moslehi, Sh & Najafi, Payam & Raiesi, Tahereh. (2011). Management of water content of soil in cultivation of greenhouse cucumber (Cucumis sativus L, Nasim variety) in Isfahan- Iran. African Journal of Biotechnology. 10. 11157-11164. 10.5897/AJB11.226.

Tam, S. 2006. Irrigation scheduling with tensiometers. Ministry of Agriculture and Lands. Water Conservation Factsheet. [Online]. Available from: http://www.al.gov.bc.ca/resmgmt/publist/500series/577100-2.pdf

Trogo, R., Ebardaloza, J. B., Sabido, D. J., Bagtasa, G., Tongson, E., and Balderama, O. (2015), "SMS-based smarter agriculture decision support system for yellow corn farmers in Isabela," in 2015 IEEE Canada International Humanitarian Technology Conference (IHTC2015). IEEE. 1–4.

Trogo, Rhia & Ebardaloza, Jed & Sabido, Delfin & Bagtasa, Gerry & Tongson, Edgardo & Balderama, Orlando. (2015). SMS-based Smarter Agriculture decision support system for yellow corn farmers in Isabela. 1-4. 10.1109/IHTC.2015.7238049.

United States Department of Agriculture (USDA) CUCUMBER PRODUCTION MANUAL.https://www.ams.usda.gov/sites/default/files/media/CucumberInspectionInstructions.pdf

Visconti, F.; de Paz, J.M.; Martínez, D.; Molina, M.J. Laboratory and field assessment of the capacitance sensors Decagon 10HS and 5TE for estimating the water content of irrigated soils. *Agric. Water Manag.* 2014, *132*, 111–119.

Wanasuria, S., De Datta, S.K. & Mengel, K. Rice yield in relation to electroultrafiltration extractable soil potassium. *Plant Soil* 59, 23–31 (1981). https://doi.org/10.1007/BF02183589

Yaghi, T., Arslan, A., & Naoum, F. (2013). Cucumber (Cucumis sativus, L.) water use efficiency (WUE) under plastic mulch and drip irrigation. Agricultural Water Management, 128, 149–157. doi:10.1016/j.agwat.2013.06.002

Y, L. L. (2013). Cucumber (Capsicum annuum L.) in southern Benin: production constraints, varietal diversity, preference criteria and participatory evaluation. In *International Research Journal of Agricultural Science and Soil Science* (Vol. 3, Issue 4). http://www.interesjournals.org/IRJAS

Yang, H., Liu, H., Zheng, J., & Huang, Q. (2018). Effects of regulated deficit irrigation on yield and water productivity of cucumber cucumber (Capsicum annuum L.) in the arid environment of Northwest China. *Irrigation Science*, *36*(1), 61–74. https://doi.org/10.1007/s00271-017-0566-4

Zazueta SF, Xin J (1994) Soil moisture sensors. Bulletin 292, Florida Cooperative Extension

Zellman, P. (2016). Drip Irrigation System Evaluations:How to Measure & Use Distrib ution Uniformity Tests. https://www.sustainablewinegrowing.org/docs/DUArticle.pdf\

Zhu, X., Chikangaise, P., Shi, W., Chen, W. H., & Yuan, S. (2018). Review of intelligent sprinkler irrigation technologies for remote autonomous system. *International Journal of Agricultural and Biological Engineering*, *11*(1), 23–30. https://doi.org/10.25165/j.ijabe.20181101.3557