

REVIEW AND IMPLEMENTATION IOT IN AGRICULTURE AT HIGH ALTITUDE AREAS

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ABSTRACT :-Despite the perception people may have regarding the agricultural process, the reality is that today's agriculture industry is data-centered, precise, and smarter than ever. The rapid emergence of the Internet-of-Things (IOT) based technologies redesigned almost every industry including –smart agriculture|| which moved the industry from statistical to quantitative approaches. Such revolutionary changes are shaking the existing agriculture methods and creating new opportunities along a range of challenges. This article highlights the potential of wireless sensors and IOT in agriculture, as well as the challenges expected to be faced when integrating this technology with the traditional farming practices. IOT devices and communication techniques associated with wireless sensors encountered in agriculture applications are analyzed in detail. What sensors are available for specific agriculture application, like soil preparation, crop status, irrigation, insect and pest detection are listed. How this technology helping the growers throughout the crop stages, from sowing until harvesting, packing and transportation is explained. Finally, based on this thorough review, the automated irrigation and crop field monitoring system is used to optimize the use of water resource for agriculture. The system consists of sensor network for humidity, temperature, soil moisture, color and water level sensors. soil moisture, temperature, water level, colour sensor are placed in the root zone of the crops. The microcontroller of the controller unit is programmed with threshold values of the temperature and moisture content. The controller unit is used to control the irrigation motor thereby controlling the water flow to the field. In addition to that water level sensor is placed in this field, if it is excess water the motor gets automatically pumps the water into the outer area. Colour sensor provide the appropriate colour of leaf and the user give the pesticide before destroying plants. Field measure data about paddy plants. Raspberry pi is used in the controller mode. Internet of the things(IOT) is an ecosystem of connected physical objects that are accessible through the internet. Real time monitoring data can be utilized and the performance can be tracked. Hence high yield can be achieved. This project is mainly focused on improving the agricultural fields yield by providing a monitoring system with effective and efficient usage of water resource. Thus further development in this project will lead to a greater efficiency in the field of agriculture.

KEYWORDS:-INTERNET OF THINGS, WIRELESS SENSORS, AGRICULTURE, WATER SCARCITY

1. INTRODUCTION:

Internet of things IOT consists of two words Internet and Things. The term things in IOT refers to various IOT devices having unique identities and have capabilities to perform remote sensing, actuating and live monitoring of certain sort of data. IOT devices are also enable to have live exchange of data with other connected devices and application either directly or indirectly, or collected data from other devices and process the data and send the data to various servers. The other term internet is define as Global communication Network connecting Trillions of computers across the planets enabling sharing of information. Thus the IOT can be define as : "A dynamic Global Network Infrastructure with self-configuring capabilities based on standard and inter operable communication to protocol where physical and virtual things have identities, physical attributes, and virtual personalities and use intelligent interfaces and are seamlessly integrated into the information network, often communicate data associated with user and their environment."

An ideal IOT device consists of various interfaces for making connectivity to other devices which can either be wired or wireless.

Any IOT based device consists of following components:

- I/O interface for Sensors.
- Interface for connecting to Internet.
- Interface for Memory and Storage.
- Interface for Audio/Video.

2. Literature REVIEW

Improving farm productivity is important for increasing farm productivity and integration growing demand for food-fed food is a rapid increase in the world's population. Farm production can be increased by understanding and predicting crop performance in a variety of environmental conditions. Existing Internet of Things (IoT) technologies, such as IoT devices (e.g. wireless network sensors, network-connected weather channels, cameras, and smart phones) can be used to exchange large amounts of biological

and biological data, based on time data. from the sensors, location data from the cameras, to the visual cues collected and recorded via the mobile phone app. At least one of the proposed studies over the years has been discussed below

Prem Prakash Jayaraman 1, *, Ali Yavari 2,3, Dimitrios Georgiakopoulos 1, Ahsan Morshed 1 and Arkady Zaslavsky in 2016 launched the construction of the Smart Farm Net, an IoT-based platform that can collect environmental collections, soil, fertilizer, and irrigation details; automatically enter such information and filter out invalid data from a plant performance test; and forecasting crop specifications and recommendations made for any farm. Smart Farm Net can integrate almost any IoT device, including commercial sensors, cameras, weather stations, etc., and store its data in the cloud to analyze performance and recommendations. The Smart Farm Net stage test and our experience and lessons learned from building this program conclude the paper. Smart Farm Net is the world's first and largest program (in terms of the number of attached sensors, tested crops, and supporting users) that provides analysis and recommendations.

T. Zoranovic *, V. Erceg *, I. Berkovic ** in 2018 introduces a single solution for automatic irrigation of crop plants shown in this paper (tomatoes, but the solution also applies to the planting of all other crops, grass preparation, fruit irrigation, etc.) . The solution is available on the Raspberry Pi 3 Rev B connected platform temperature and humidity sensors DHT22, DS18B20 temperature sensor, ground moisture sensor and 8 transfer board. Irrigation management is supported Technical requirements for the production of the required amount of water for tomatoes, according to a table created for each day of plant growth in moderately moist soil. All data is recorded in the MySQL database for analysis and to enable the consideration of irrigation indicators. Based on the results of competitive experiments have shown that the external appearance, quality and yield of tomatoes go well, as the plants always have a lot of soil moisture. Plus, this is a cheap solution for a completely independent system. The system can be managed via Internet (SSH), as the current situation can be controlled via WWW. Only requests that the Apache server be pre-installed and the presence of a wireless connection to Raspberry.

Prashaunsa J. Nachankar1, Mayur G. Somani2, Deeksha M. Singh3, Professor Sunil N. Katkar4 in 2018 gifts This project was launched to demonstrate the use of Internet of Things (IoT) in the agricultural sector. In this project, sensors are used to measure various field parameters such as temperature, humidity, soil moisture. This data from the wild is compiled and stored on a server. From the available data, analysis was performed to calculate the plant's water requirement. The need for plant water is calculated by a system using the Penman Monteith algorithm. Based on the soil values of nitrogen, phosphorus and potassium (NPK), the system recommends fertilizer to achieve optimal crop production. The system also produces a plant irrigation system based on input parameters such as planting date, soil moisture by improving decision

Muhammad Ayaz1 (Senior Member, IEEE), Mohammad Ammad-uddin1 (Senior Member, IEEE), Zubair Sharif2, Ali Mansour3 (Senior Member, IEEE), and el-Hadi M. Aggoune1 2016 presents

One possible solution for automatic irrigation of plant crops is shown in this paper (for tomatoes, but the solution is also applicable for cultivation of all other plants, maintenance of lawns, irrigation of orchards, etc.). The solution is realised on Raspberry Pi 3 Rev B platform with connected sensors for temperature and humidity measurement DHT22, temperature sensor DS18B20, soil humidity sensor and 8 relay board. The irrigation management is based on requirements of the technological production of the quantity of the needed water for tomatoes, according to the formed table for each day of the plant's growth and based on the measured soil moisture. All data is recorded in the MySQL database in order to be analysed and to enable the correction of irrigation norms.

Swarup S. Mathurkar, Rahul B. Lanjewar, Nilesh R. Patel in 2014 presents monitoring agricultural environments for various factors such as temperature, moisture, humidity along with other factors can be of more significance. A traditional approach to measure these factors in an agricultural environment meant individuals manually taking measurements and checking them at various times. To avoid this, it is necessary to document the detail changes in environmental parameters by the use of technologies helping for both i.e. to improve the yield as well as to reduce the man efforts. The objective of this project was to develop a smart sensor based monitoring system for agricultural environment using field programmable gate array (FPGA) which comprised of wireless protocol, different types of sensors, microcontroller, serial protocol and the field programmable gate array with display element. Different types of sensors such as temperature, soil moisture and relative humidity senses the data in agricultural environment and provide it to microcontroller, interfaced with the wireless bluetooth module. A pair of transmitter and receiver wireless module helps in transmitting and receiving the data which is then fed to FPGA using a serial communication protocol UART. Data are displayed on LCD unit to monitor the system. Relays are interfaced with FPGA acting as a controlling element according to conditions provided to it.

Dr. D.R.P. Rajarathnam1*, Ms.C. Sumithra2*, Kanmani R3, Praveen Rajan S4, Gokulapriyan.S5 in 2019 present. This inspection strives to develop a robot capable of performing operations like automatic monitoring, inspecting water content according to seed varieties by use of IOT. It checks the level of humidity and inform the farmer. The operating system will be facile even for uneducated peoples.

Balaji Banu [1] designed a wireless sensor networks to observe the conditions of the farming and increasing the crop yield and quality. Sensors are used to monitor different conditions of environment like water level, humidity, temperature etc., The processors ATMEGA8535 and IC- S8817 BS, analog to digital conversion and wireless sensor nodes with wireless transceiver module are used in this designing system. Database and web applications are used to retrieve and store data. In this experiment the sensor node failure and energy efficiencies are managed.

Joseph Haule [2], carried out experiment on intelligent agriculture greenhouse monitoring system based on Arduino technology. The system performs data acquisition, processing, transmission and reception functions. The aim of their experiments is to realize greenhouse environment system, where the of system efficiency to manage the environment area and reduce the money and farming cost and also save energy.

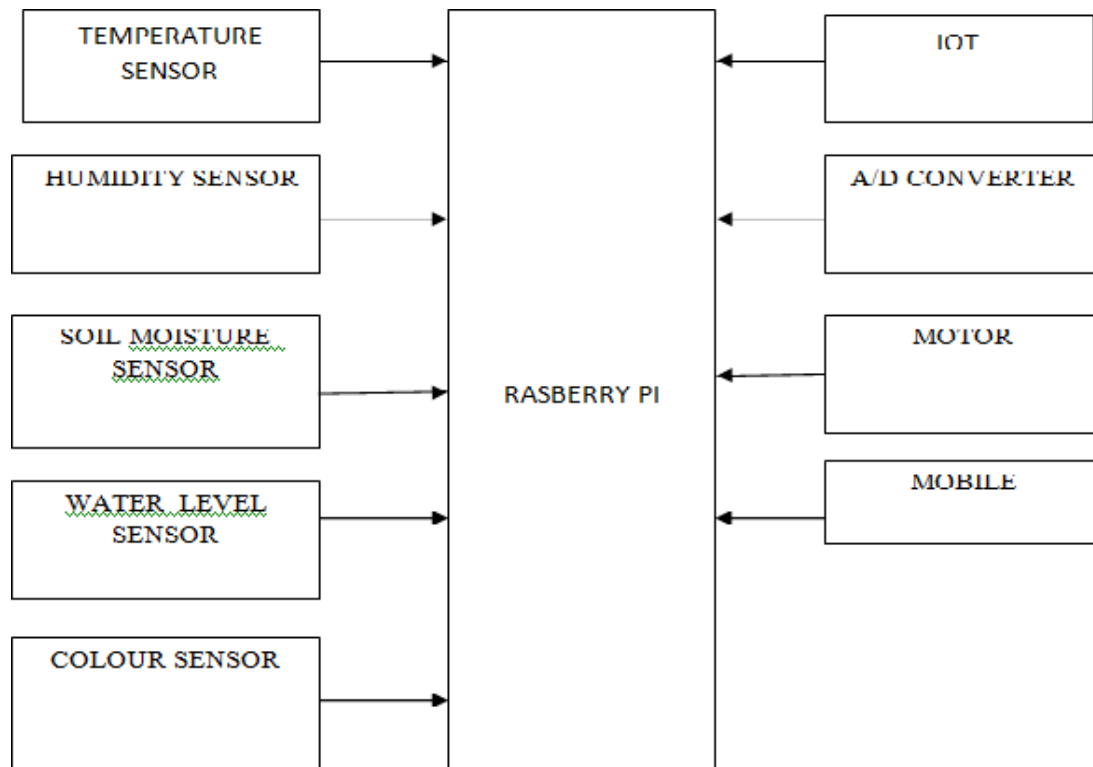
Patrick M. Grace [3], have proposed an experiment that explains the use of WSN used in automating irrigation. Irrigation control and rescheduling based on WSN are powerful solutions for optimum water management through automatic communication to know the soil moisture conditions of irrigation design. The process used here is to determine the proper frequency and time of watering are important to ensure the efficient use of water, high quality of crop detection delay throughput and load.

3. EXPERIMENTAL AND COMPUTATIONAL

In an existing automated water management system, we cannot take decision at that instance by taking different attribute of agriculture soil. Current automated irrigation system only works on one parameter at one time. Soil have different attribute like soil moisture and temperature, humidity etc. Soil moisture is below threshold value then water valve is open for water supply and after proper water supply if it goes above threshold value water valve is get close. Existing system does not concern about available water in reservoir and requirement of water to particular crop. So system does not have decision power. It only works on one condition at one time. In the system send the information about the growth of paddy plant and sugarcane in the field. The data are send details about every stage in the plant growth in the field.

4. PROPOSED SYSTEM

In this work, the automated irrigation system based on low power microcontroller was developed and deployed. To overcome the drawbacks of existing system like high cost, difficult in maintenance and wired connection, we introduce a new system which will have wireless connection between server and nodes. We introduce a new design of embedded web server making use of raspberry pi technology and internet of things. The automated irrigation system consists of distributed sensor network built using soil moisture sensor, temperature sensor, humidity sensor and water level sensor and colour sensor. Water level sensor senses the excess water in the field and the motor automatically pumps the water to the outer area. Irrigation system uses valves to turn irrigation ON and OFF. The colour sensor is is placed in the field is used to know the perfect colour of leaf and provide the pesticide before destroying the plants. Earlier, farmer faced the problem of sending SMS and making calls, overcoming which we are designing an Desired application which does the work by button clicks, here the hardware works in three modes of operation viz.

BLOCK DIAGRAM**Fig-1.1 Block Diagram****5. HARDWARE SECTION****5.1 RASPBERRY PI**

The Raspberry Pi-3 is used in my model. Raspberry Pi is a single board computer with Linux or other small operating systems. It was developed by Raspberry Pi foundation in UK for the use of computer science education. The second version of the Raspberry Pi is used in my project. This part describes models of Raspberry Pi is available. This report will not attempt to provide full specifications but an overview in order to help in making decision as to which device it is required to accomplish the objectives in question. Currently, five Raspberry Pi model do exist. They are: Model B+, Model A+, Model B, Model A and the Compute Module (currently only available as part of the Compute Module development kit). All these models use the same SOC (System on Chip combined CPU & GPU), the BCM2835, but other hardware features differ.

The raspberry pi board is consists of HDMI port is connected to monitor.usb1 is connected to keyboard and other usb2 is connected to mouse. The board that has power supply port and insert memory card.

5.2 SENSORS

The distributed sensor network that consists of soil moisture sensor, temperature sensor, humidity sensor, color sensor and water level sensor. There are different types of soil sensor technologies and measurement techniques that have been developed for the measurement of soil moisture content. The commonly used soil sensors are based on frequency domain reflectometry (FDR), which uses capacitance probes to measure the dielectric permittivity of the soil.

In this work however, we used a resistive soil sensor, which was developed using two probes to pass electrical currents into the soil and reads the response or resistance to get the moisture content of the soil. The resistive sensor works on the principle that the more moisture we have in the soil makes the soil to conduct electricity easily due to lower resistance while dry soil conditions makes the soil conducts electricity poorly due to higher resistance. Water level sensors detect the level of water. The colour sensor is used to measure the perfect colour of the leaf.

5.3 AUTOMATIC MOTOR CONTROLLER

This module is used to control the pump automatically. The maximum soil moisture state reaches it automatically goes minimum soil moisture state. The watering is on when the soil get dry, when the watering will be stop when the soil is wet. The pump will be turned on automatically every day at a particular time for a certain soil, immediately the pump will turns off. led is acts as motor.

The turning on and off of the pump will work regardless of the moisture rate around the field area. This automatic mode can be set by sending a data to monitor and mobile.

SOFTWARE REQUIREMENTS

THE ARDUINO IDE

When working with the InduinoR3 Board, select the board as Arduino UNO from the Tools->

Boards List and Select the Appropriate Com Port.

6. SIMULATION MODEL

The simulation work on the project has been done in PROTEUS PROFESSIONAL software. The following image shows the monitoring and the displaying process in LCD.

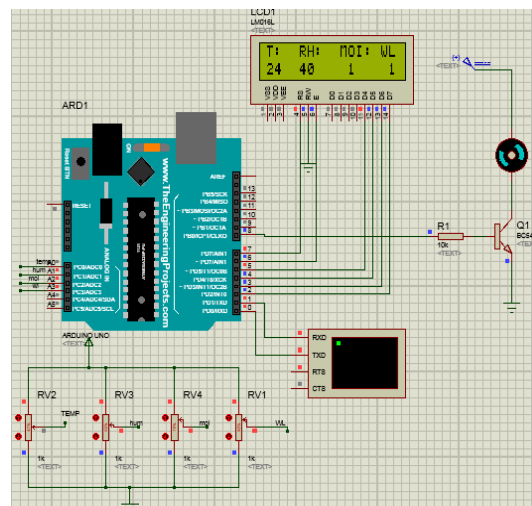


Fig6.1:-schematic diagram

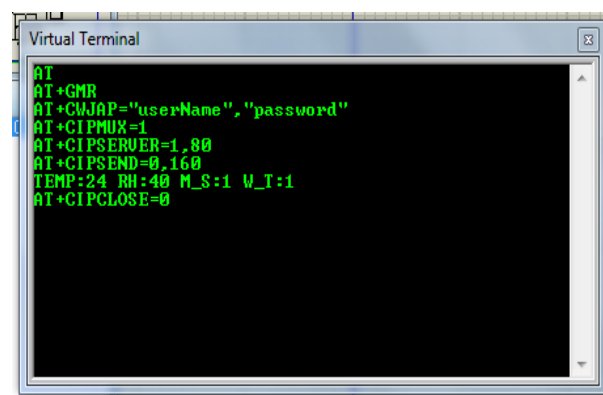


Fig 6.2- Simulation Output

Shows the monitoring condition simulated in Proteus Professional software version 8. The virtual terminal represents the functional status of the sensors connectivity.

7. RESULTS AND DISCUSSION

After performing the experiment on the hardware the following results have been extracted as an output

7.1 HARDWARE OUTPUT

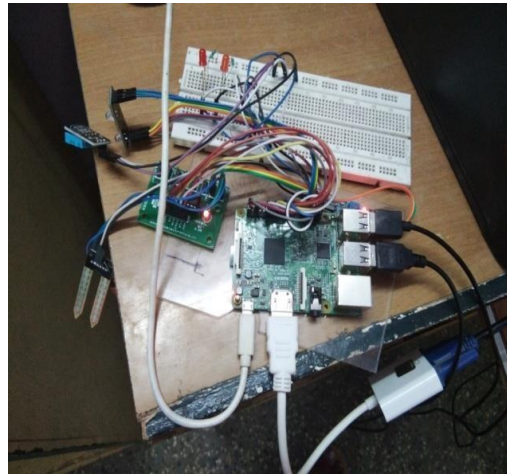


Fig7.1 Hardware Module

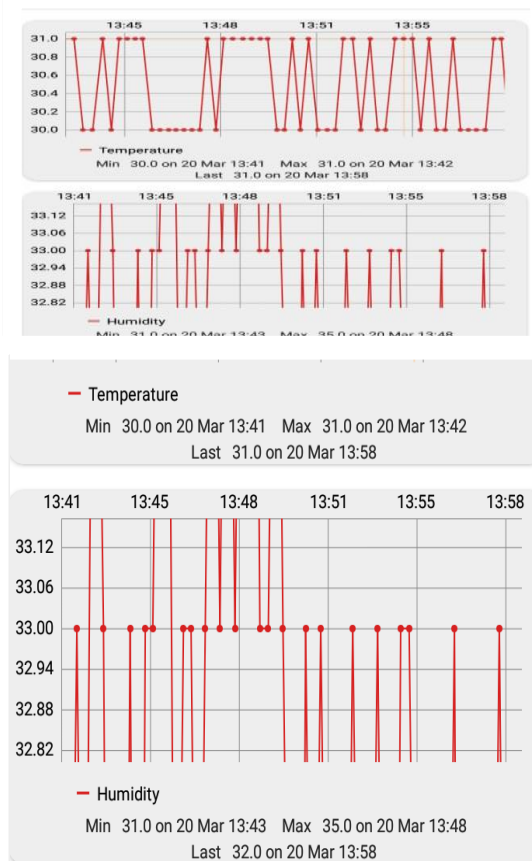


Fig 7.2 Output Chart



```
pi@raspberrypi ~  
File Edit Tabs Help  
-----  
temperature = 30.0 °C Humidity = 32.0 %  
Water Level = 90 Soil Humidity = 0.0 %  
6025.64643294 Hz PLANT COLOR IS NOT GOOD! ->  
WATERING THE PLANT  
-----  
temperature = 31.0 °C Humidity = 33.0 %  
Water Level = 102 Soil Humidity = 0.0 %  
2179.65102144 Hz PLANT COLOR IS GOOD !!!  
-----  
temperature = 30.0 °C Humidity = 32.0 %  
Water Level = 103 Soil Humidity = 0.0 %  
323.57901247 Hz PLANT COLOR IS NOT GOOD! ->  
WATERING THE PLANT  
-----  
temperature = 30.0 °C Humidity = 32.0 %  
Water Level = 109 Soil Humidity = 0.0 %  
876.27028972 Hz PLANT COLOR IS NOT GOOD! ->  
WATERING THE PLANT
```

Fig7.2 Software Output

8. CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

According to a plan announced in 2015 under "The 2030 Agenda for Sustainable Development", the UN and international community set a target to end hunger by 2030. However, recent figures released by WHO (World Health Organization) do not look encouraging enough to support the agenda, as more than 800 million people worldwide are facing the food shortage—one out of every nine people [125]. Although these figures are quite alarming on their own, what is more shocking is the quality of food. Other than availability, the quality of food is becoming another serious issue and even more critical.

In response to all this, overall crop production needs to increase not only for food but cash-crops are also required to grow in order to fulfill the demands of industry, like cotton and rubber, and, most importantly, increasing demands for bioenergy like ethanol.

Figure 1 presents a snapshot of major challenges that future agriculture expected to face in 2050. This diagram, basically presents three major issues: how to feed around 10 billion people; without using more land and; by reducing the emission of greenhouse gases by more than 60%. However, when we look closely then these three challenges lead to many new, including smaller rural labor, continuously shrinking arable land, water scarcity, harsh weather conditions, and many more. As the world moves toward urbanization, the rural populations are not only shrinking but are rapidly aging; hence, fewer and younger growers need to step up to take the responsibility. Such population imbalance and generation shift can create serious implications, not only for the remaining workforce

REFERENCES

1. Accessed: Apr. 18, 2019. [Online]. Available: <https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.html>
2. Accessed: Apr. 13, 2019. [Online]. <https://ourworldindata.org/world-population-growth>
3. Accessed: Mar. 15, 2019. [Online]. <https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html>
4. Accessed: Apr. 5, 2019. [Online]. <https://www.un.org/press/en/2009/gaef3242.doc.htm>
5. Zhang, X., Davidson, E. A, "Improving Nitrogen and Water Management in Crop Production on a National Scale", American Geophysical Union, December, 2018
6. How to Feed the World in 2050 by FAO, available at www.fao.org/wsfs/forum2050/wsfs-forum/en/
7. Abhishek D. et al, "Estimates for World Population and Global Food Availability for Global Health", Book chapter, The Role of Functional Food Security in Global Health, 2019, Pages 3-24
8. Elder M., Hayashi S., "A Regional Perspective on Biofuels in Asia", in Biofuels and Sustainability, Science for Sustainable Societies, Springer, 2018
10. Accessed: Apr. 15, 2019. [Online]. World agriculture: towards 2015/2030 by FAO, Available at www.fao.org/3/a-y4252e.pdf
11. Zhang, L., Dabipi, I. K. and Brown, W. L, "Internet of Things Applications for Agriculture". In, Internet of Things A to Z: Technologies and Applications, Q. Hassan (Ed.), 2018
13. S. Navulur, A.S.C.S. Sastry, M. N. Giri Prasad, "Agricultural Management through Wireless Sensors and Internet of Things" International Journal of Electrical and Computer Engineering (IJECE), 2017; 7(6) :3492-3499.
14. E. Sisinni, A. Saifullah, S. Han, U. Jennehag and M. Gidlund, "Industrial Internet of Things: Challenges, Opportunities, and Directions," in IEEE Transactions on Industrial Informatics, vol. 14, no. 11, pp. 4724-4734, Nov. 2018.
15. M. Ayaz, M. Ammad-uddin, I. Baig and e. M. Aggoune, "Wireless Sensor's Civil Applications, Prototypes, and Future Integration Possibilities: A Review," in IEEE Sensors Journal, vol. 18, no. 1, pp. 4-30, 1 Jan.1, 2018.
16. J. Lin, W. Yu, N. Zhang, X. Yang, H. Zhang and W. Zhao, "A Survey on Internet of Things: Architecture, Enabling Technologies, Security and Privacy, and Applications," in IEEE Internet of Things Journal, vol. 4, no. 5, pp. 1125-1142, Oct. 2017
17. hi, X.; An, X.; Zhao, Q.; Liu, H.; Xia, L.; Sun, X.; Guo, Y., "State- of-the-Art Internet of Things in Protected Agriculture", Sensors 2019, 19, 1833.
18. [16]. O. Elijah, T. A. Rahman, I. Orikumhi, C. Y. Leow and M. N. Hindia, "An Overview of Internet of Things (IOT) and Data Analytics in Agriculture: Benefits and Challenges," in IEEE Internet of Things Journal, vol. 5, no. 5, pp. 3758-3773, Oct. 2018.
19. Accessed: Apr. 25, 2019. [Online]. <https://www.globenewswire.com/news-release/2018/08/02/1546021/0/en/Global-Smart-Farming-Market-to-Reach-23-14-Billion-by-2022.html>
20. to-Reach-23-14-Billion-by-2022.html
21. Kong, Q.; Chen, H.; Mo, Y.L.; Song, G., "Real-time monitoring of water content in sandy soil using shear mode piezoceramic transducers and active sensing—A feasibility study", Sensors, 2017, 17, 2395.
22. N. Srivastava, G. Chopra, P. Jain, B. Khatter, " Pest Monitor and Control System Using Wireless Sensor Network (With Special Reference to Acoustic Device Wireless Sensor)", International Conference on Electrical and Electronics Engineering 27th Jan 2013, Goa, ISBN: 978-93-82208-58-7.
23. Gasso-Tortajada, V., Ward, A.J., Mansur, H., Brøchner, T., Sørensen, C.A.G., Green, O. A novel acoustic sensor approach to classify seeds based on sound absorption spectra. Sensors, 2010.
24. Millan-Almaraz, J.R.; Romero-Troncoso, R.J.; Guevara-Gonzalez, R.G.; Contreras-Medina, L.M.; Carrillo-Serrano,

- R.V.; Osornio- Rios, R.A.; Duarte-Galvan, C.; Rios-Alcaraz, M.A.; Torres- Pacheco, I. "FPGA-based fused smart sensor for real-time plant- transpiration dynamic estimation", *Sensors* 2010, 10, 8316–8331.
25. M. I. Husni, M. K. Hussein, M. S. Bin Zainal, A Hamzah, D Md Nor, H Poad, "Soil Moisture Monitoring Using Field Programmable Gate Array" *Indonesian Journal of Electrical Engineering and Computer Science*, Vol.11, No.1, July 2018, pp. 169~174.
26. de la Piedra A, Braeken A, Touhafi A, "Sensor systems based on FPGAs and their applications: a survey". *Sensors*, 2012,12(9):12235-12264.
27. Seth C. Murray, "Optical Sensors Advancing Precision In Agricultural Production" *Photonics Spectra*, June 2018.
28. Povh F, de Paula G, Anjos W, "Optical sensors applied in agricultural crops". *Optical Sensors - New Development Practical Applications*, 2014.
29. Pajares, G. *Advances in sensors applied to agriculture and forestry*. *Sensors* 2011, 11, 8930–8932.
30. Molina I, Morillo C, García-Meléndez E, Guadalupe R, Roman MI. Characterizing olive grove canopies by means of ground-based hemispherical photography and spaceborne RADAR data. *Sensors (Basel)*. 2011;11(8):7476–7501.
31. Dvorak, J. S., Stone, M. L., & Self, K. P., "Object Detection for Agricultural and Construction Environments Using an Ultrasonic Sensor", *Journal of Agricultural Safety and Health*, 2016, 107-119.
32. Gómez Álvarez-Arenas T, Gil-Pelegrin E, Ealo Cuello J, et al. "Ultrasonic Sensing of Plant Water Needs for Agriculture". *Sensors (Basel)*. 2016;16(7):1089. Jul. 2016.
33. Pajares G, Peruzzi A, Gonzalez-de-Santos P., "Sensors in agriculture and forestry". *Sensors (Basel)*. 2013;13(9):12132– 12139, Sep 2013.
34. Andújar D, Ribeiro Á, Fernández-Quintanilla C, Dorado J, "Accuracy and feasibility of optoelectronic sensors for weed mapping in wide row crops", *Sensors*, 2011, 11:2304–2318.
35. D. Andújar, A Ribeiro, C F. Quintanilla, J. Dorado, J Dorado, "Assessment of a ground-based weed mapping system in maize" *Book Precision Agriculture '09* Chapter: Assessment of a ground- based weed mapping, 2009.
36. T. K. Yew, Y. Yusoff, L. K. Sieng, H. C. Lah, H. Majid and N. Shelida, "An electrochemical sensor ASIC for agriculture applications," 2014 37th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, 2014, pp. 85-90.
37. Cocovi- Solberg, D. J., Rosende, M., & Miro, M., Automatic kinetic bio accessibility assay of lead in soil environments using flow- through micro dialysis as a front end to electro thermal atomic absorption spectrometry. *Environmental Science & Technology*, 2014, 48, 6282–6290.
38. <http://blog.agrivi.com/post/smart-sensors-for-accurate-soil- measurements>
39. M. A. M. Yunus and S. C. Mukhopadhyay, "Novel Planar Electromagnetic Sensors for Detection of Nitrates and Contamination in Natural Water Sources," in *IEEE Sensors Journal*, vol. 11, no. 6, pp. 1440-1447, June 2011.
40. A. Hemmat, A.R. Binandeh, J. Ghaisari, A. Khorsandi, "Development and field testing of an integrated sensor for on-the-go measurement of soil mechanical resistance", *Sensors and Actuators A: Physical*, Vol 198, 2013, Pages 61-68,
41. J. N. Schuster, M. J. Darr, R. P. McNaull, "Performance benchmark of yield monitors for mechanical and environmental influences " *Agricultural and Biosystems Engineering Conference Proceedings and Presentations*, IOWA State University, July, 2017
42. *Managing Calibration Curves under John Deere Tractors in Yield Monitor Systems*, report prepared at IOWA State University
43. Moureaux C, Ceschia E, Arriga N, Béziat P, Eugster W, Kutsch WL, Pattey E, "Eddy covariance measurements over crops". In: Aubinet M, Vesala T, Papale D (eds) *Eddy covariance: a practical guide to measurement and data analysis*. Springer, Dordrecht, 2012.
44. Kumar A, Bhatia A, Fagodiya RK, et al. "Eddy covariance flux tower: a promising technique for greenhouse gases measurement". *Advances in Plants & Agriculture Research*. 2017; 7 (4):337–340.
45. Crabit, A.; Colin, F.; Bailly, J.S.; Ayroles, H.; Garnier, F. Soft water level sensors for characterizing the hydrological behaviour of agricultural catchments. *Sensors* 2011, 11, 4656–4673.

46. S Navulur, A. S. C. S. Sastry, M. N. G Prasad, "Agricultural Management through Wireless Sensors and Internet of Things", *International Journal of Electrical and Computer Engineering*, Vol. 7, No. 6, December 2017, pp. 3492~3499 ISSN: 2088-8708
47. Bob Howard, "LIDAR and its use in agriculture", in *Agricultural Innovation*, September, 2015
48. Weiss, U., and Biber, P., "Plant detection and mapping for agricultural robots using a 3D-LIDAR sensor", *Robotics and Autonomous Systems* 59, 265-273, 2011.
49. Biber, P., Weiss, U., Dorna, M. and Albert, A., "Navigation System of the Autonomous Agricultural Robot --BoniRob||", 2012 <http://www.cs.cmu.edu/~mbergerm/agrobotics2012/01Biber.pdf>.
50. del-Moral-Martínez I, Rosell-Polo JR, Company J, et al., "Mapping Vineyard Leaf Area Using Mobile Terrestrial Laser Scanners: Should Rows be Scanned On-the-Go or Discontinuously Sampled?", *Sensors (Basel)*. 2016; 16(1):119. Published Jan. 2016
51. Montagnoli A. et al., -Estimating forest aboveground biomass by low density lidar data in mixed broad-leaved forests in the Italian Pre-Alps,|| *Forest Ecosystems*, 2:10, 2015.
52. Mark, Tyler B., and Terry Griffin, -Defining the Barriers to Telematics for Precision Agriculture: Connectivity Supply and Demand,|| presented at SAEA Annual Meeting 2016, Texas.
53. A. K. E. Mohamed, "Analysis of Telematics Systems in Agriculture", theses Master of Science, Department of Machinery, Utilization, CULS, Prague, 2013.
54. Digital Farming: what does it really mean? And what is the vision of Europe's farm machinery industry for Digital Farming? in *European Agricultural Machinery*, Prepared by CEMA,. 2017.
55. Jaafar H H and Woertz E, "Agriculture as a funding source of ISIS: a GIS and remote sensing analysis", *Food Policy* 64, 2016.
56. Yalew SG, van Griensven A, Mul ML, van der Zaag P, "Land suitability analysis for agriculture in the Abbay basin using remote sensing, GIS and AHP techniques",. *Model Earth Syst Environ* 2:10, 2016.
57. Hegazy, I.R.; Kaloop, M.R. "Monitoring urban growth and land use change detection with GIS and remote sensing techniques in Daqahlia governorate Egypt", *Int. J. Sustain. Built Environ.* 2015, 4.
58. Rose, I., Welsh, M.: Mapping the urban wireless landscape with Argos. In: *Proceedings of the 8th ACM Conference on Embedded Networked Sensor Systems, SenSys '10*, ACM, New York, 2010.
59. PATMASARI, Raditiana et al. "Design and Realization of Automatic Packet Reporting System (APRS) for Sending Telemetry Data in Nano Satellite Communication System", *Journal of Measurements, Electronics, Communications, and Systems*, v. 4, n. 1, p. 1-7, June 2018. ISSN 2477-7986.
60. Beecham Research. An Introduction to LPWA Public Service Categories: Matching Services to IOT Applications, 2016, <http://www.beechamresearch.com/download.aspx?id=1049>
61. C. Zulkifli, N. Noor, "Wireless sensor network and Internet of Things (IOT) solution in agriculture", *Pertanika J. Sci. Technol.*, vol. 25, no. 1, pp. 91-100, 2017.
62. Gu-Zhah Hong, Ching-Lu Hsieh, "Application of Integrated Control Strategy and Bluetooth for Irrigating Romaine Lettuce in Greenhouse", *IFAC-PapersOnLine*, Volume 49, Issue 16, 2016
63. Jonathan B., Evaluation of Bluetooth Low Energy in Agriculture Environments: An empirical analysis of BLE in precision agriculture,
64. Student Thesis, Malmö Högskola Univeristy, Sweden, 2016
65. Taskin, D., Taskin, C., Yazar, S., "Developing a bluetooth low energy sensor node for greenhouse in precision agriculture as internet of things application", *Adv. Sci.Technol. Res. J.* 12 (4), 88-96, 2018
66. G. R. Mendez, M. A. Md Yunus and S. C. Mukhopadhyay, "A WiFi based smart wireless sensor network for an agricultural environment", *Fifth Int'l Conf. on Sensing Technology*, Palmerston North, 2011
67. J. Petäjajarvi, K. Mikhaylov, M. Hämäläinen and J. Iinatti, "Evaluation of LoRa LPWAN technology for remote health and wellbeing monitoring," 2016 10th International Symposium on Medical Information and Communication Technology (ISMICT), Worcester, MA, 2016, pp. 1-5.

68. R. Jedermann, M. Borysov, N. Hartgenbusch, S. Jaeger, M. Sellwig,
69. W. Lang, "Testing Lora for food applications - Example application for airflow measurements inside cooled warehouses with apples", *Procedia Manufacturing*, Vol 24, 2018, Pages 284-289,
70. N. Zhu, Y. Xia, Y. Liu, C. Zang, H. Deng, and Z. Ma, " Temperature and Humidity Monitoring System for Bulk Grain Container Based on LoRa Wireless Technology", in *ICCCS 2018*
71. A. Lavric, A. I. Petrariu and V. Popa, "Long Range SigFox Communication Protocol Scalability Analysis Under Large-Scale, High-Density Conditions," in *IEEE Access*, vol. 7, 2019.
72. Metcalfe H, *Mobile for Development Impact Products and Services Landscape Annual Review*. GSM Association: London, 2015
73. Alfian, G.; Syafrudin, M.; Rhee, J. Real-Time Monitoring System Using Smartphone-Based Sensors and NoSQL Database for Perishable Supply Chain. *Sustainability* 2017, 9, 2073.
74. Pongnumkul, S., Chaovalit, P., & Surasvadi, N, Applications of smartphone-based sensors in agriculture: a systematic review of research. *Journal of Sensors*, 2015, Open Access Article ID195308.
75. e-agriculture 10 year Review Report, Implementation of the World Summit on Information Society (WSIS), Action Line C7. ICT Applications: e-agriculture in by FAO, 2015.
76. Wyche S, and Steinfield C: Why Don't Farmers Use Cell Phones to Access Market Prices? *Technology Affordances and Barriers to Market Information Services Adoption in Rural Kenya*, *Information Technology for Development*, 22, 320-333.
77. Heike Baumüller, "Agricultural Innovation and Service Delivery through Mobile Phones Analyses in Kenya" Doctoral Dissertation Center for Development Research The Faculty of Agriculture, University of Bonn, 2015.
78. Hidrobo, M. and Gilligan, D., Using quantitative methods to evaluate mobile phone technology based nutrition and agriculture advisory services in Ghana, *Evaluation Methodology Brief 1*,
79. Brighton, 2017
80. Barnett, I.; Faith, B.; Gordon, J. and Sefa-Nyarko, C., External evaluation of mobile phone technology-based nutrition and agriculture advisory services in Africa and South Asia: Mobile phones, agriculture, and nutrition in Ghana: Qualitative midline study report Brighton, 2019
81. Adio, E. O., Abu, Y., YUsuf, S. K., & Nansoh, S., Use of Agricultural Information Sources and Services by Farmers for Improve Productivity in Kwara State. *Library Philosophy and Practice (e-journal)*, 2016
82. Koyenikan, M.J. ; Ighoro, A., Farmers' use of mobile phone-based services for accessing agriculture and rural development information in northern zone of Edo State, Nigeria, *Nigerian Journal of Rural Sociology*, 16, 2, 2015
83. G.V. Nakato, F. Beed, H. Bouwmeester, I. Ramathani, S. Mpiira, J. Kubiriba, S. Nanavati, "Building agricultural networks of farmers and scientists via mobile phones: case study of banana disease surveillance in Uganda" *Can. J. Plant Pathol.*, 38, 2016, pp. 307-316
84. Masuka, B., Matenda, T., Chipomho, J., Mapope, N., Mupeti, S., Tatsvarei, S., "Mobile phone use by small-scale farmers: A potential to transform production and marketing in Zimbabwe", *South African J. of Agri Extension (SAJAE)*, 2016, 44(2), 121-135.
85. S. Musungwini, Mobile Phone Use by Zimbabwean Smallholder Farmers: A Baseline Study. *AJIC*, 2018, vol.22, pp.29-52.
86. Minkoua Nzie JR, Bidogeza JC, and Ngum NA, Mobile phone use, transaction costs, and price: evidence from rural vegetable farmers in Cameroon. *J Afr Bus* 1-20. 2017
87. J. Qian, X. Yang, X. Wu, B. Xing, B. Wu, and M. Li, -Farm and environment information bidirectional acquisition system with individual tree identification using smartphones for orchard precision management,|| *Computers and Electronics in Agriculture*, pp. 101-108, 2015.
88. Yu, Q.Y.; Shi, Y.; Tang, H.J.; Yang, P.; Xie, A.K.; Liu, B.; Wu,
89. W.B. eFarm: A tool for better observing agricultural land systems. *Sensors* 2017, 17.
90. M. F. Işık, Y. Sönmez, C. Yılmaz, V. Özdemir, and E. N. Yılmaz,

91. -Precision Irrigation System (PIS) Using Sensor Network Technology Integrated with IOS/Android Application,|| Applied Sciences, vol. 7, no. 9, pp. 891, 2017.
92. Guler, E.; Sengel, T.Y.; Gumus, Z.P.; Arslan, M.; Coskunol, H.; Timur, S.; Yagci, Y. Mobile phone sensing of Cocaine in a lateral flow assay combined with a biomimetic material. *Anal. Chem.* 2017, 89, 9629–9632.
93. Fu, X., & Akter, S. The impact of mobile phone technology on agricultural extension services delivery: Evidence from India. *The Journal of Development Studies*, 52(11), 2016, 1561–1576.
94. Das, Ashutosh, Debabrata Basu, and Rupak Goswami. "Accessing Agricultural Information through Mobile Phone: Lessons of IKSL Services in West Bengal." 2012
95. . Baumüller H, The little we know: an exploratory literature review on the utility of mobile phone-enabled services for smallholder farmers. *J Int Dev* 30(1), 2018, 134–154.
96. F. Orlando, E. Movedi, D. Coduto, S. Parisi, L. Brancadoro, V. Pagani, T. Guarneri, and R. Confalonieri, -Estimating Leaf Area Index (LAI) in Vineyards Using the PocketLAI Smart-App,|| *Sensors (Basel)*., vol. 16, no. 12, pp. 1–12, 2016.
97. A. Camacho and H. Arguello, -Smartphone-based application for agricultural remote technical assistance and estimation of visible vegetation index to farmer in Colombia: AgroTIC,|| in *Remote Sensing for Agriculture, Ecosystems, and Hydrology*, 2018.
98. A. L. H. Andriamandroso, F. Lebeau, Y. Beckers, E. Froidmont, I. Dufrasne, B. Heinesch, P. Dumortier, G. Blanchy, Y. Blaise, and J. Bindelle, -Development of an open-source algorithm based on inertial measurement units (IMU) of a smartphone to detect cattle grass intake and ruminating behaviors,|| *Comput. Electron. Agric.*, vol. 139, pp. 126–137, 2017.
99. M. F. M. Azam, S. H. Rosman, M. Mustaffa, S. M. S. Mullisi, H. Wahy, M. H. Jusoh, and M. I. M. Ali, -Hybrid water pump system for hilly agricultural site,|| 2016 7th IEEE Control Syst. Grad. Res. Colloquium, ICSGRC 2016 - Proceeding, no. August, 2017.
100. J. E. Herrick, et al, -The land-potential knowledge system (landpks): mobile apps and collaboration for optimizing climate change investments,|| *Ecosyst. Heal. Sustain.*, vol. 2, no. 3, 2016.
101. W. Palomino, G. Morales, S. Huaman, and J. Telles, -PETEFA: Geographic Information System for Precision Agriculture,|| *Proc. 2018 IEEE 25th Int. Conf. Electron. Electr. Eng. Comput. INTERCON 2018*, pp. 1–4, 2018.
102. A. Sopegno, A. Calvo, R. Berruto, P. Busato, and D. Bocthis, -A web mobile application for agricultural machinery cost analysis,|| *Comput. Electron. Agric.*, vol. 130, pp. 158–168, 2016.
103. M. V. Bueno-Delgado, J. M. Molina-Martínez, R. Correoso- Campillo, and P. Pavón-Mariño, -Ecofert: An Android application for the optimization of fertilizer cost in fertigation,|| *Comput. Electron. Agric.*, vol. 121, pp. 32–42, 2016.
104. R. Jordan, G. Eudoxie, K. Maharaj, R. Belfon, and M. Bernard,
105. -AgriMaps: Improving site-specific land management through mobile maps,|| *Comput. Electron. Agric.*, vol. 123, 2016.