Designing an IoT Framework for High Valued Crops Farming

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Keywords: Internet of Things, Sustainable Agriculture, IoT Framework, High Valued Crops.

Abstract: Agriculture plays a vital role in providing employment, revenue and domestic product of farmers. In the Philippines, agriculture has a large share of employment and likewise with the population who depends on it. The increase of agricultural product and income is necessary for the growth of the country's economic condition. Unfortunately, the insufficiency of technology and the use of traditional methods of farming along with the issues and challenges associated to crops farming greatly affects farmers which results to low yielding of crops. The integration of smart agriculture using the Internet of Things (IoT) is an absolute solution in modernizing the traditional methods of agriculture. This simplifies farming techniques and improves time efficiency, water and fertilizer management, crop monitoring, soil and security management. This paper proposes an IoT framework that address the current issues and challenges associated to high valued crops farming in Alfonso Lista, Ifugao. It integrates two main functions including environment data sensing by a wide variety of sensors and environment factors control with some mechanics driven by smart actuators. This sensors and actuators are used for real-time monitoring, analysis and collection of information about the farm conditions like weather, moisture, temperature, humidity, fertility of soil and level of water. Essential data were gather by means of observation and in-depth interview with Ifugao farmers and employees of Yao Jia Xi Corporation – Alfonso Lista, Ifugao. The developed framework provides holistic foundation in the development of IoT-driven system for high valued crops farming with low cost and easy implementation.

1 INTRODUCTION

The economic development of a country mostly depend on agricultural products as it is the main source of food and other raw materials. It provides employment opportunities, income and domestic product to the people. Of the 42.78 million persons in the Philippine labor force in 2017, the agriculture sector absorbed 10.26 million persons, representing 25.44 percent of the national employment (PSA, 2018). However, the use of traditional methods of farming greatly affects farmers which results in low yielding of crops. It is evident that the automation of manual processes of farming and the use of automatic machineries improved the yielding of crops (Gondchawar and Kawitkar, 2016). Improving farm productivity is essential in order to increase farm profitability and to provide the rapidly growing demand of food caused by rapid population growth all over the world. According to the United Nations' Food and Agriculture Organization, food production must increase by 50% to be able to feed the rapidly growing population that is expected to reach 10 billion by 2050. The urgent need in increasing the crop productivity is vital as it is the foundation of any solution for food shortage and farm profitability problems (FAO., 2019). The sustainability in agriculture plays an important role in addressing this challenges since it offers technological advancement that increase productivity and profitability while conserving resources, minimizing waste and enviromental impact, and promoting agroecosystem resilience (Velten et al., 2015). Hence there is a need to integrate smart farming and precision agriculture using Internet of Things (IoT) technology in order to achieve sustainable agriculture with increase production efficiency, profitability and the quality of agricultural products (Malavade and Akulwar,).

High value crops refer to new and expensive food crops such as vegetables, fruits, flowers, houseplants and foliage, condiments and spices. Most high value crops have higher production efficiency and income compared to usual cereal grains and export food crops. It is not usually a common food for local

Ngipol, D. and Palaoag, T.
Designing an IoT Framework for High Valued Crops Farming.
DOI: 10.5220/0009364503040310
In *Proceedings of the Second International Conference on Science, Engineering and Technology (ICoSET 2019)*, pages 304-310
ISBN: 978-989-758-463-3

people and are mainly grown for higher income in domestic and even abroad.

Over the past few years, IoT technology have been introduced in almost every area of the modern society. Among this areas are Smart Cities, Smart Health Care, Smart Industry, Autonomous Vehicle, Smart Agriculture, Precision Agriculture and others (Shang et al., 2015). IoT is significantly considered in the area of technology which gains appreciation and attention from known and reputable industries like Google, Apple, Samsung and Cisco (Vermesan and Friess, 2014). The IoT is referred to as the Internet of Objects that integrates several technologies such as computers, smart phones, internet, sensors, wireless communication technology and embedded systems to complete a system that is capable of data transmission without human intervention (Mohammed and Ahmed, 2017).

As an emerging paradigm, the IoT has great potential that can have a significant influence on the future of the world (Stoces et al., 2016). The application of the latest IoT technologies in agriculture practice allows traditional ways of farming to be changed fundamentally on every aspect, paving way to a new agriculture pattern of precision agriculture (Zhang et al.,). Iot devices such as wireless sensor, connected weather stations, cameras, and smart phones are capable of gathering huge amount of environmental and crop performance data which ranges from time series data from sensors, to four-dimensional data from cameras and to human interventions and observations. This data are analyzed to filter out invalid data and compute personalized crop recommendations for any specific farm (Veena et al., 2018).

IoT technologies such as IoT devices provides a better way of collecting, gathering, exchanging, and transmitting data which absolutely delivers an innovative way in data processing and intelligent decision-making (Sreekantha and Kavya, 2017). The Internet of Things provides the fundamental network infrastructure to the physical and the digital worlds through which smart objects, ranging from micro sensors to heavy agricultural vehicles communicate to each other (Bhuvaneswari and Porkodi, 2014). It is capable of transforming the agricultural domain into more efficient and productive farming and improves the quality of life of farm workers by reducing heavy labor and tedious tasks (Elkhodr et al., 2016). At present, the internet protocol is mainly used in communicating and interconnecting numerous smart objects and various kinds of embedded devices and technologies. The increase in the application and distribution of smart objects and internet of things significantly impact the human life in the future generations (Rghioui, 2017).

Smart farming involves the use of the Internet of Things (IoT) to provide solutions via the electronic monitoring of crops, as well as related farm conditions (Mohanraj et al., 2016). Understanding and forecasting crop condition and performance under extensive diversity of environmental, irrigation, soil and fertilization is important to improve farm production efficiency (Jayaraman et al., 2016). Moreover, Iot-based smart farming allows farmers to have better control over the process of growing crops and making it more predictable and easy to manage (Prathibha et al., 2017).

Consequently, the absolute integration of IoT technologies into smart farming advanced the agriculture to a new level by which the whole agriculture industry is modernized with increased productivity and profit. In a broader perspective, the scope of smart agriculture which covers IoT improves or solves critical issues such as drought response, crop yield optimization, land and water management, and pest control (Rajakumar et al., 2018). In connection to this, the study aims to discuss the current issues and challenges associated to high valued crops farming in Alfonso Lista, Ifugao. It also covers the framework that shall be design to address the current issues and challenges associated to high valued crops farming in Alfonso Lista, Ifugao.

2 METHODOLOGY

This study was qualitative in nature which aimed to explore the current issues and challenges associated to high valued crops farming in Alfonso Lista, Ifugao and develop a framework that address each of the issues and challenges. The primary method of data collection was possibly made through in-depth interviews with the Ifugao farmers, the farm manager and farm workers of the Yao Jia Xi Corporation – Alfonso Lista with their various relevant functions which covers the scope of the study. The researcher used unstructured and informal interviews which positively allows a more flexible and responsive discussion for both the researcher and the respondents. Moreover, related articles were also reviewed to allow a wide-ranging knowledge on internet of things practices and applications. A framework development process was used as a guide during the development of the framework which involves the four main phases: design phase, implementation phase, instantiation phase and maintenance phase.

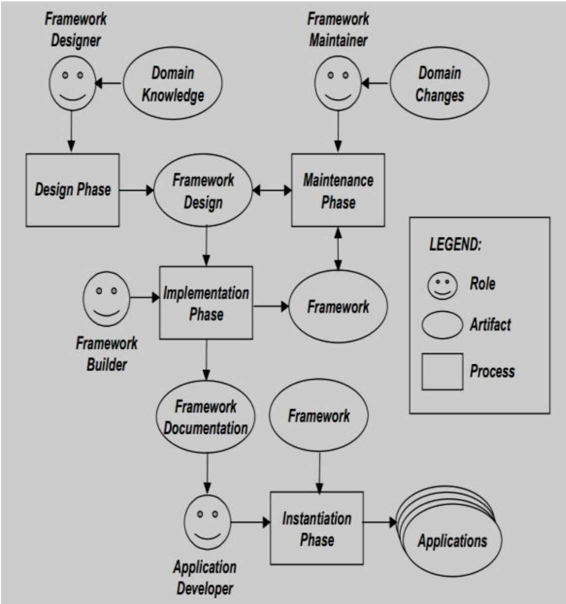

Figure 1: Framework Development Process.

Design phase: The framework structure in this phase is defined by the framework designer, which utilizes the information generated in the domain knowledge analysis and requirements phase. This requires an imaginative task and organized method to create the framework design from requirements level.

Implementation phase: In this phase, the framework builder generates the actual framework along with the framework documentation.

Instantiation phase: During this phase, applications are being generated by the application developer basing from the framework which utilizes the artifacts created in the implementation phase.

Maintenance phase: Lastly, the maintenance phase allows a harmonious communication between the framework design and especially to the whole framework which also supports the transformation of the design and implementation level.

3 FINDINGS

Alfonso Lista is a third class municipality of Ifugao with a vast land for agriculture. It has a progressing topography with an agricultural land area of 15,546 hectares, a pastureland of 17,808 hectares, a forest area of 7,305 hectares and a residential area of 394 hectares with a total land area of 41,051 hectares. It is politically subdivided into 20 barangays with a total of population of 32, 119 according to the 2015 census. A large percentage of its population depends on farming with corn, banana, cassava, legumes, tobacco, peanuts, gabi, and other high value vegetables as their main produce. Marketing of agricultural products in Alfonso Lista, Ifugao is quite easy because of the presence of traders within the municipality and even from neighboring provinces and cities. Figure 2 shows the satellite view of Alfonso Lista, Ifugao which obviously shows a large portion for agriculture.

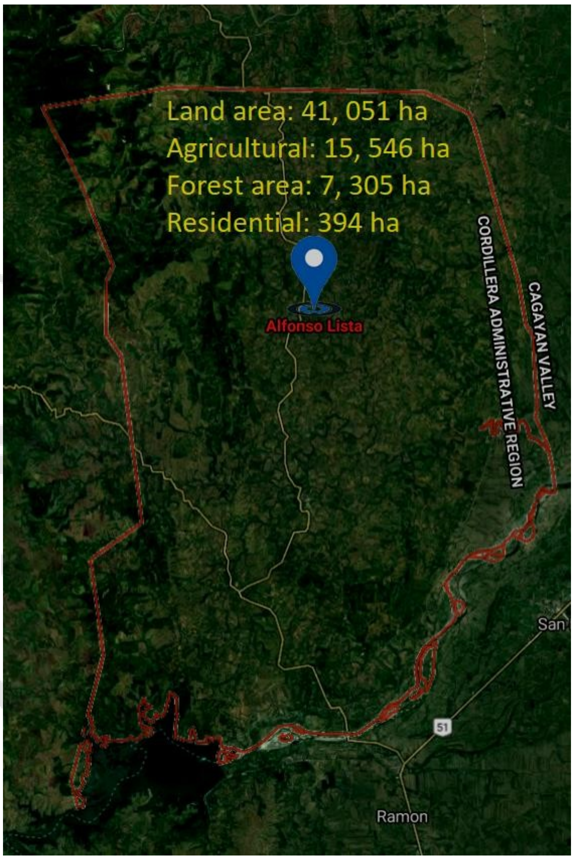

Figure 2: Satellite View of the Municipality of Alfonso Lista.

However, the insufficiency of technology and the use of traditional methods of farming along with the issues and challenges associated to crops farming greatly affects the productivity of the Ifugao farmers. Below are the current issues and challenges associated to high valued crops farming that were identified during the actual visit in the farm and were strongly signified by the majority of the respondent during the in-depth interview.

3.1 Current Issues and Challenges Associated to High Valued Crops Farming in Alfonso Lista Ifugao

Water demand and shortages: The Philippine Food and agriculture are the largest consumers of water which requires more than the use for personal needs. Figure 3 shows the total water withdrawal in 2009 that reached up 81, 555 million cubic meter, of which 82 percent was for irrigation and livestock that includes 754 million cubic meter for aquaculture, 10 percent for industry purposes and 8 percent for municipalities (FAO., 2019).

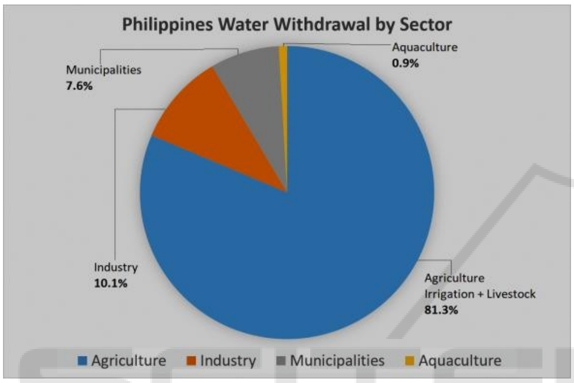

Figure 3: Philippines Water Withdrawal by Sector

On the other hand, agriculture production in the province of Ifugao especially in the municipality of Alfonso Lista is highly dependent on water and increasingly subject to water risks due to rapid population growth, changing climate, increasing demand for food and other individual needs. As a result, water scarcity is being encountered which adversely affect the yield of farmers since rainwater is not enough as the source for irrigation of their agricultural crops.

Fertilizer mismanagement: Fertilizer is one of the fundamental substance containing the chemical elements to improve growth and productiveness of agricultural crops. Therefore it is important to select the right source, the right place, the right timing, and the right rate of application for the greatest fertilizer nutrient use efficiency. Figure 4 shows the 4R principles of Nutrient Stewardship (Johnston and Bruulsema, 2014).

However, all farmers in the province of Ifugao are still using the traditional method of applying fertilizer which is subjected to fertilizer misuse. Ifugao farmers common assumption regarding fertilizer application is "the more, the merrier" which adversely affects the agricultural crop, soil and the environment due to salinity build up or to the toxicity of the chemical

Figure 4: 4R principles of Nutrient Stewardship

elements. Moreover, application of fertilizer with the correct rates is not a guarantee of a bountiful harvest but it's the application at the right rates at the right time since the nutrients uptake of crops is at different rates and ratios at the different phonological growth stages.

Unawareness on soil testing: Agricultural productivity mainly depend on soil which serves as a medium for plant growth and a sink for heat, water and chemicals. To achieve the soil full potential, soil testing must be done to determine the plant nutrient needs and for environmental assessments. However, almost all farmers in Ifugao are not aware on soil testing which results to misuse of fertilizers and other chemical elements which in turn causes soil quality degradation.

Lack of farm security: Safeguarding farm assets from burglars and destructive animals is very important to avoid unexpected loses. However, farmers usually overlooked which allows burglars and destructive animals robbed and destroy any valuable and available resources in the farm.

3.2 The Proposed IoT Framework for High Valued Crops Farming

Figure 5 shows the IoT framework for high valued crops farming which aims to address the identified issues and challenges associated to crop farming in Alfonso Lista, Ifugao. The IoT framework is a control model for irrigation, application and distribution of fertilizer. It is also a control model for farm security, real-time monitoring and collection of information about the farm conditions like weather, moisture, temperature, fertility of soil and level of water. The framework is composed of the Embedded IoT Platform and the three layers: the application layer, network layer and the perception layer.

Perception Layer: This layer composes the

Table 1: Hardware requirements part 1

Category	Item Name	Spesification	Function
Power Source	Solar Panel	The solar panel minimum dimension is 38 x 22 centimeter with 12 volts working power.	Its main purpose is to recharge the battery for continuous operation.
	Rechargeable Battery	The most recommended battery is a sealed lead acid battery with 12 volts power and 5 amp hour.	The battery serves as the main source of power.
IoT Sensing Devices	Soil Sensor	The soil sensor working voltage is ranging from 3.3 to 5 volts with an operating temperature of -40 degrees to +60 degrees.	It is mainly used to quantity the water content, salinity and nutrients of soil in the farm.
	Temperature Sensor	The temperature sensor measuring range is from 0 degrees to 50 degrees with a measurement error of +- 2 degrees. The operating voltage is from 3.3 to 5 volts.	It is used to collect data about temperature from the farm.
	Water Level Sensor	The water sensor operating voltage is ranging from 5 to 24 volts with a response time of 500 milliseconds and an operating temperature ranging from 0 degrees to 105 degrees.	It is used to detect the water level of the water tank.
	Water Flow Rate Sensor.	The water flow sensor working voltage is ranging from 5 to 18 volts with a maximum water pressure of 2 Mega Pascal.	The water flow sensor is used to quantity the volume of water passing through the water tank pipe and the amount of fertilizer for the crop needs.
	Real Time Clock	The real time clock operating voltage is ranging from 2.3 to 5.5 volts with a battery backup.	It is solely built for keeping time that basically counts hours, minute, seconds, months days and years. It is used to identify the schedule on when to apply fertilizer.
	PIR Motion Sensor	The working voltage of the PIR motion sensor is ranging from 5 to 20 volts with a delay time of .3 seconds to 18 seconds.	The primary purpose is to sense motion around the farm.
Microcontroller	ATMega2560 microcontroller	The microcontroller operating voltage is 5 volts with a recommended input voltage ranging from 7 to 12 volts.	It is used to process data and control every task for the whole system.

sensors and actuators which primarily aims to acquire and collect data from the physical world which is processed and serves as a basis for the actuators to operate. The process of perception is based on the IoT sensing devices such as the soil moisture / salinity sensor, temperature sensor, water level sensor, water flow sensor and the PIR motion sensor. Moreover, this layer is responsible in converting information to digital signals to allow convenient network transmission.

Network Layer: The network layer serves as gateway and provides data routing and addressing paths for network communication. It allows data transfer in the form of packets through logical network paths in an ordered format. The network layer processes the received data from the Perception Layer and transfer it to the Application Layer using various network technologies like wireless networks which includes WiFi, Bluetooth and 3G network. This layer is basically used as a mode of communication between the application layer and the perception layer.

Application Layer: This layer composes the Mobile Application and the Monitor. It constitute the front end of the whole IoT framework which provides personalized based services according to user relevant needs. It allows the user to receive text messages or notifications from the system and provide real time data monitoring through graphical representations regarding the farm condition which the user can understand. Real time data from the monitor serves as a basis for user decision making or

Table 2: Hardware requirements part 2

Actuators	Liquid Crystal Display (LCD).	The LCD uses Liquid Crystal Monitor (LCM) that operates with 5 volts Direct Current with 80mm x 36mm x 12mm dimension.	The LCD serves as a monitor for all environment data that is provided by the IoT sensing devices.
	Relay Switch Module	The relay switch operates with 5 volts with output maximum contact of AC110V, AC250V 10A and DC30V 10A.	It is responsible in controlling the solenoid valve which is switch on or off whenever the soil moisture reached the threshold value.
	Solenoid Valve	The solenoid valve operating voltage is 12 volts direct current with recommended water pressure of .02 to .08Mpa.	It operates with an electromagnetic solenoid coil which change the state of the water valve from closed to open whenever the relay switch is turned on, or vice-versa.
	Water Pump	The water pump operating voltage is 12 volts that is powered by 2 pieces of 100 watts solar panel.	It is used to refill the water tank whenever the water level sensor reached the threshold value.
	GSM Shield	The GSM shield module operating voltage is ranging from 5 to 26 volts that allows communication using the GSM cell phone network which includes SMS, MMS, GPRS and audio.	The GSM shield module sends text messages to users whenever the water tank is running out of water and also whenever there are intruders or animals around the farm.
	Buzzer	It operates with 5 volts with controllable sound frequencies and has 16 ohm resistance.	The buzzer is triggered whenever there are intruders or animals around the farm.
Communication Network	3G	It is the third generation of wireless technology for mobile phones.	It is used as mode of communication between the system and the users.
	Bluetooth	Bluetooth allows to transmit data wirelessly over a short distance using short-range wireless technology devices such as smart phones and computers.	It is used as mode of communication between the system and the mobile phone.
	WiFi	The minimum WiFi specification is the 802.11 WLAN which offers higher speed transmission and longer transmission range.	It is used to provide wireless high-speed Internet and network connections.
User Interface	Mobile phone	Smart phone is the most recommended mobile device for the application since the system provides graphical data and text messages.	The mobile phone allows the users to receive text messages from the system. It is also used to monitor the farm condition and can perform system override.
	Display Monitor	The display monitor can be LCD screen with a minimum size of 98mm x 60mm x 20mm or tablet that supports wireless communication such as Bluetooth and WiFi.	The display monitor allows the user to view data in visual form.

further actions.

Embedded IoT Platform: The embedded IoT platform composes the microcontroller and the power source. Its primary function is to process and interpret data from all the layers and control every task for the whole operation of the system. The microcontroller is powered by rechargeable battery which is being recharge through solar panel.

3.3 Technology Required

The technology required in this research is listed in Table 1 and Table 2.

4 CONCLUSIONS

The developed IoT framework for high valued crops farming in Alfonso Lista, Ifugao is a

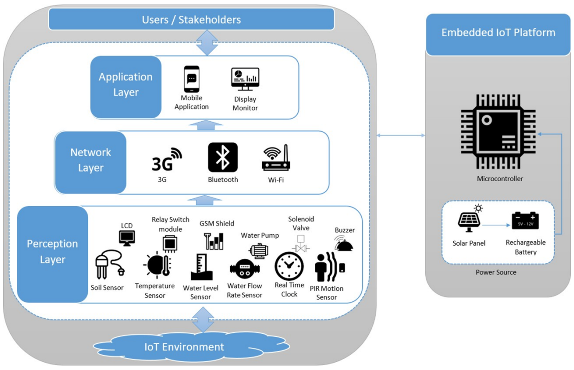

Figure 5: IoT Framework for High Valued Crops Farming

holistic solution for the identified current issues and challenges associated to high valued crops farming. It is a control model of irrigation, fertilizer, soil monitoring and security management which is composed of several sensors to provide environmental data and microcontroller to manage operations on how and when the actuators should perform basing from environment data. The actual implementation promotes sustainable agriculture and improves agricultural production with affordable and easy implementation for small scale farmers.

ACKNOWLEDGMENTS

This study was supported by the Research Development and Extension Training Service Unit and funded under the Research Development and Special Trust Fund of the Ifugao State University.

REFERENCES

Bhuvaneswari, V. and Porkodi, R. (2014). The internet of things (IoT) applications and communication enabling technology standards: An overview. *International Conference on Intelligent Computing Applications. DOI*, 10.

Elkhodr, M., Shahrestani, S., and Cheung, H. (2016). Internet of things applications: Current and future development. *Information Science Reference (an imprint of IGI Global). DOI:*, 10.(4018/978-1-5225-).

FAO. (2019). (2017) the future of food and agriculture: Trends and challenges. *Available at: http://www.fao.org/3/a- i6583e. pdf. (Accessed:*, 14.

Gondchawar, N. and Kawitkar, R. S. (2016). Iot based Smart Agriculture. *International Journal of Advanced Research in Computer and Communication Engineering. DOI*, 10.

Jayaraman, P. P., Yavari, A., Georgakopoulos, D., Morshed, A., and Zaslavsky, A. (2016). Internet of things platform for smart farming: Experiences and lessons learnt. *MDPI. DOI:*, 10.

Johnston, A. M. and Bruulsema, T. (2014). (2014) 4r nutrient stewardship for improved nutrient use efficiency. *Procedia Engineering. 83*, 83.(10.).

Malavade, V. N. and Akulwar, P. K. *Role of IoT in Agriculture*. National Conference on.

Mohammed, Z. K. A. and Ahmed, E. S. A. (2017). *Internet of Things Applications, Challenges and Related Future Technologies*. World Scientific News 67(2).

Mohanraj, I., Ashokumar, K., and Naren, J. (2016). Field monitoring and automation using iot in agriculture domain. *Procedia Computer Science*, 93:931–939.

Prathibha, S. R., Hongal, A., and Jyothi, M. P. (2017). Iot based monitoring system in smart agriculture. *International Conference on Recent Advances in Electronics and Communication Technology. DOI*, 10.

Rajakumar, G., Sankari, S., Shunmugapriya, D., and Maheswari, S. P. U. (2018). Iot based smart agricultural monitoring system. *Asian Journal of Applied Science and Technology (AJAST)*, 2.

Rghioui, A. (2017). an oumnad. *A. (2017) Internet of Things: Visions, Technologies, and Areas of Application. Automation, Control and Intelligent Systems. Vol. 5, No*, 5(6):83–91.

Shang, X., Zhang, R., Hu, X., and Zhou, Q. (2015). Design theory, modelling and the application for the Internet of Things service. *Enterprise Information Systems. Vol. 10, No*, 10(3):249–267.

Sreekantha, D. K. and Kavya, A. M. (2017). *Agricultural Crop Monitoring using IOT- A Study*. 11th International Conference on Intelligent Systems and Control (ISCO).

Stoces, M., Vaněk, J., Masner, J., and Pavlik, J. (2016). Internet of things (iot) in agriculture-selected aspects. *Agris on-line Papers in Economics and Informatics*, 8(665-2016-45107):83–88.

Veena, S., Mahesh, K., Rajesh, M., and Salmon, S. (2018). The survey on smart agriculture using iot.

Velten, S., Leventon, J., Jager, N., and Newig, J. (2015). What is sustainable agriculture? a systematic review. *Sustainability*, 7(6):7833–7865.

Vermesan, O. and Friess, P. (2014). Internet 0f things – from research and innovation to market deployment. *River Publishers Series in Communication. ISBN:*, pages 978–8793102–95–8.

Zhang, L., Dabipi, I., and Brown, L. J. *(2018) Internet of Things Application for Agriculture*. The Institute of Electrical and Electronics Engineers, Inc.