Mitigation Techniques for Agricultural Pollution by Precision Technologies with a Focus on the Internet of Things (IoTs): A Review

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ABSTRACT

The widespread of Information and Communication Technology (ICT) in the past decades brought numerous advantages to many individuals and most of the organizations everywhere in the world. In the 21st century, the most significant technology is the Internet of Things (IoTs) which has developed rapidly covering most of applications in the health, civil, military and agriculture sectors also. Precision Agriculture (PA), as the combination of information, communication and control technologies in agronomic practices, is emerging time by time. Also, precision agriculture is considered a smart farming system on the basis of modern technologies to regulate, examine and manage changes inside an agricultural field for cost-effectiveness, sustainability and optimal protection of environment. Meanwhile, agricultural practices are contributing to environmental pollution due to poor management which is further disturbing food security, health and climate. One of the best strategies to overcome this challenge can be introducing the deployment of precision technologies for the development of agricultural productivity while reducing the environmental degradation. Therefore, the key objective of this review was to discuss the mitigation techniques for agricultural pollution and enhance the agricultural production by smart technologies like IoTs. This paper summarizes the main categories of IoTs, Precision Agriculture, agricultural pollution and finally, mitigation practices on environmental degradation.

Key words: Agricultural pollution, E- agriculture, Information and communications technology, Internet of Things, Mitigation techniques, Precision agriculture.

Information and communication technologies (ICT) signify a vital approach that can be used in attaining adequate, harmless and healthful food security (Lashgarara, Mirdamadi and Hosseini, 2010). The ICTs comprises application of advanced methods to transmit information and knowledge in the community efficiently and effectively as per demand of the stakeholders (Kisan, Dadabhau and Singh, 2013). In recent years monitoring and control methods are achieved in agronomic systems by the use of new information and communication technologies. Nowadays, the awareness of the Internet of Things (IoT) is stated increasingly as the environment of interrelated human and machines among themselves. IoT provide advanced prospects for collected data which are used to feed machine learning languages to acquire information such as predictions and decision making for different types of stakeholders like proprietors, directors, policy makers and so on (Saville *et al*., 2015). IoT can be used at different areas in the agricultural production (Medela *et al*., 2013). It can use to monitor and control the field parameters such as status of soil, meteorological conditions (temperature, humidity), biodiversity of plants or animals and post-harvest practices such as transportation. (Pang *et al*., 2015). IoT has various enabling technologies and tools such as sensors, cloud computing, embedded systems, security protocols and architectures, web services, Internet, search engines and so on. Sensors and actuators offer highly precise values of the status of crops, manage irrigation, change meteorological factors, regulate the soil nutrients level and so on (Mulla, 2013).

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Previous and current agricultural practices have contributed to environmental pollution by poor agronomic practices which lead to affect the bio diversity. Yet, agriculture production cannot be reduced since, it has capable role of stopping malnutrition, decreasing poverty, increasing nutritional status and reaching food security in developing countries. Hence, there is a need for shift from 'unclean' practices to 'sustainable' practices. The influence of agricultural practices on the surroundings are of much interest because of the adverse consequence of nutrient run-offs of farmlands, which harbor several agricultural or livestock operations (Vallejo-Hernandez *et al*., 2019). Urban areas and industries are producing more pollutants, but recent study suggest that agriculture is the foremost source of water contamination in worldwide (Mateo Sagasta *et al*., 2018).

Based on these principles, the application of emerging trends in precision technologies may be applied to almost all the processes involved in Agriculture as well as related to it. Thus, this type of technologies will always be supportive in both the agricultural productivity and sustainability by means of reducing the resources, cost and time in the functionalities involved in Agriculture to mitigating the environmental pollution. One of the greatest approaches to overcome this challenge may be establishing the utilization of Information and Communication Technology for the improvement of agricultural productivity. Hence, there is a need to study the nature of the problem. Objectives of this review were to controlling the agricultural pollution by implementing the precision technologies in the faming systems and to increase agricultural productivity and decrease the poverty by introducing the new technologies to utilize the resources in optimum level. Therefore, this paper reviews the applications of precision technologies in agro-industrial and environmental that are using IoTs to control the environmental degradation.

Internet of Things (IoT)

Internet of Things (IoT) has brought revolution to each and every sectors of communal human's life by creating everything smart and intelligent. The next generation of smart computing will be totally based on Internet of Things (IoT). IoT (Weber, 2010) is gaining an important place in research across the world especially in agricultural field. From the point of typical user, IoT has laid the foundation of improvement of various services and products like smart living, e-health services, automation, smart learning, business management, manufacturing, transportation and even agricultural sectors (Ashton, 2009).

Brief present status about application of IoT in agriculture

In order to rise the agricultural production, numerous IoT platforms have been designed for smart agronomic practices such as crop monitoring, disease expectation and irrigation management. Balamurugan *et al*, 2017 suggested an IoT application to regulate the changes in atmospheric temperature and soil moisture by temperature and moisture sensor system installed in the agricultural field using an IoT platform like Raspberry Pi to acquire, analysis and monitoring the data to get optimum agricultural yield and also Min-ShengLiao *et al.*, 2017 designed another IoT application for monitoring ecological parameters in greenhouses and agricultural field that incorporates an image processing system of orchid leaves allowing the follow-up and examine the leaf growth in actual time. Payero *et al.*, 2017 developed a low-cost precision application for checking moisture present in the soil in a wheat field. This system is based on a network of sensors and an IoT platform, the latter displays in real-time the values of soil moisture. IoT based agricultural convergence technology generates high value in terms of quality and quantity of production (Lee *et al*., 2013).

Precision Agriculture (PA)

In recent years, Agricultural sector is facing numerous challenges such as scarcity of water, climate changes issues, pest and diseases attacks to crops and so on. Precision technologies would be a perfect solution to overcome with above mentioned problems which can monitor diverse meteorological parameters, such as atmospheric temperature and relative humidity to maximize the production and minimize cost of production and pollution. PA delivers the possibility to do the correct thing, in the exact place, in the accurate time and in the precise way. Therefore Zhang *et al.*, 2002 stated that, PA identify and choose what is "right". Several features of PA have been developed with appropriate technologies to determine the environmental effects, economic outcomes. Many authors have discussed the environmental and economic benefits derived from IoT based precision technologies (Pierce and Elliott, 2008). The main principle of precision agriculture is becoming a smart idea for dealing with natural resources and realizing modern sustainable agricultural development (Maohua, 2001).

The basic objective of PA is to enhance the yield with least input and reduce the environmental pollution (Mondal and Basu, 2009). Hosseini *et al.*, 2010 discussed that, Precision agriculture will not only help cost saving but also has considerable environmental benefits. It makes it possible to decide the accurate quantity of the agro chemicals at the right moment which makes it possible to decrease the costs, the quantity of water required for the plants. In addition, this developed system permits farmers to virtually control their plants with a help of wireless network models (Shi, *et al*., 2015). According to Zhang *et al.*, 2002 people expected effects of using precision farming in profitability for producers and ecological and environmental benefits. Srinivasan, 2006 stated that implementing precision cultivation will affect job opportunities and agricultural structures, especially farms size distribution in rural areas and using chemical fertilizers, pesticides and other agronomic inputs efficiently will decline the environmental problems. Therefore, it will lead to improving productivity, profitability, sustainability, product quality, efficient product management, preserving soil, water and energy resources, preserving ground and surface water, increase the efficiency, diminishing environmental impacts and risks which is done with the purpose of maintains the sustainability in the environment (Salehi, 2007).

Agricultural Pollution

Agriculture is the world's greatest significant driver of environmental alteration (Godfray and Garnett, 2014) and is susceptible to the climate changes, which are often related to diverse emissions and run-offs of pollutants to land, waterand atmosphere. Agriculture, contributes to greenhouse effect by emission of greenhouse gases (Methane, Carbon di-oxide, Nitrous oxide and so on), eutrophication, degradation of air and soil, climate change and ozone depletion. Agriculture-based environmental pollution occurs where there is high manure production, usually due to high livestock population or intensification. Besides, the oversupply of inorganic fertilizers is a common cause of pollution in countries with fertilizer subsidies at higher rates (Sutton *et al*., 2013). Air pollution from automobile exhausts and presence of heavy metal as impurities in fertilizers and organo- chlorine compounds in agro-chemicals have contributed in soil pollution (Kumar and Sagwal, 2000). Exhaustion of the natural potential, destruction of the agrosphere and environmental pollution resulting from anthropogenic activities (Kumar, 2012).

Agricultural pollution mitigation by precision technologies

Innovative technologies can bring advantages to the majority of people. In the recent years, the Internet of Things (IoTs) has developed to play a key role in many activities and it has the ability to modify the environmental conditions around us. Particularly the agro-industrial and environmental fields apply IoTs in both diagnostics and regulation mechanism. In addition, it can offer information to the customers about the basis and properties of the product (Talavera *et al*., 2017).

Nayyar and Puri, 2016 discussed the benefits of IoT in Agricultural sectors as follow; low production cost to increase profitability and sustainability; efficiency level would be increased in terms of usage of Soil, Water, Fertilizers and Pesticides and various factors would also lead to the protection of environment. Smart agriculture (also known as the precision agriculture) allows farmers to increase their yields while reducing resources simultaneously. Resources saved include fertilizer, water and seeds (Schindler, 2014). Farmers can recognize their yields at a micro level by sensors networks and mapping fields, which lead to preserves resources and declines the undesirable impacts on the environment.

IoT techniques for reduction of water pollution due to excess irrigation

Precision agriculture is a smart crop management system that associate with modern technologies in agricultural field and industries to deliver actual amounts and type of inputs needs for cultivation in the various extent of farm (Malek-Saeidi and Rezaei-Moghaddam, 2008). Agriculture consume about 70% of total water in worldwide and is the major contributor of non-point-source pollution to water bodies such as lake, rivers, ponds and under groundwater (FAO. Org, 2019). The loss of water deeper into the soil profile is unavoidable during irrigation which lead to imperfect distribution of in the field. If excess water is applied in the field, particular amount of water in root zone will pass below the deeper soil layers and become inaccessible by plants. Due to excessive irrigation, leach down the agro chemicals like pesticides and fertilizers present in agricultural filed which lead to contaminate both groundwater and surface water. Therefore different scheduling methods and devices (tools) that can be practiced to examine and regulate the degree of over or under irrigation in the agricultural field.

One of the significant technologies is application of IoT in the crop field to minimize the environmental impacts by applying accurate quantity of water in efficient manner. IoT based precision applications are contributing in farming systems in many aspects (Sharma *et al*., 2016) and these technical solutions such as smart irrigation systems are utilizing optimum amount of irrigation water in the agricultural production. Environmental conditions like Soil moisture, temperature, precipitation, wind, solar radiation and evaporation are the crucial factors for developing a smart irrigation system. There are many researchers have been designed diverse types of models with the help of IoTs to control the water pollutions. Fourati *et al.*, 2014 designed an Internet-based decision support system for irrigation scheduling in olive fields with a set of wireless sensor network to measure relative humidity, sunshine radiation, atmospheric temperature and precipitation. Hashim *et al.*, 2015 reviewed that the Arduino device to monitor and regulate the temperature and soil moisture by using Android-based smartphone application. He recognized many benefits such as low cost, easy handling and many functionalities. Goap *et al.*, 2018 developed an open-source technology based smart system to forecast the crop water requirements of an agricultural field by using sensors to measure the soil factors like soil moisture, soil temperature and atmospheric parameters such as temperature, humidity and solar radiation along with the meteorological data from the website. This model has supply automatically the irrigation water by closed-loop control and also it will display the three weeks irrigation data based on the planned algorithm. Jaguey *et al.*, 2015 developed an irrigation water sensor to examine the soil moisture with a help of smart phone. Phone digital camera capture the wet and dry conditions in the area of soil by the process of RGB to gray. The proportion of wetness and dryness is communicated via access pathway to water motor controller device. A Mobile Application (APP) is developed to control sensor activity (like wakeup) and to set sensor in sleep mode.

Barkunan *et al.*, 2019 proposed an automated drip irrigation system with smartphone applications. System firstly takes soil image, computes its amount of moisture and send the data into the microcontroller over GSM module which decides the amount of water needed for irrigation and guides the conditions of the field to the Farmer's smart mobile. This developed model is verified for paddy field during three months periods. It is detected from the field trail, that it saves nearly 41.5% and 13% of water compared to the flood irrigation and drip irrigation system respectively. Detecting system practices for controlling the water flow by feedback control mechanism with control unit based on air temperature and soil moisture percentage. Control unit gathers data from temperature and soil moisture sensors for regulate the irrigation water (Nandurkar *et al*., 2014). Awati and Patil, 2014 elaborated the application of wireless sensor network for controlling and monitoring irrigation system. The crucial challenge which is faced in agricultural areas is the irrigation by fresh water resources. The high demand of freshwater is increased extremely, the optimal use of water bodies has been provided by automated precision technology and its devices such as solar power sensors, remote control and components needed for drip irrigation. This developed system was applied for drip irrigation of dwarf cherry trees on an area located in Central Anatolia for experiment (MahirDursun and SemihOzden, 2011).

Joseph Haule, 2014 proposed a research that explains the use of wireless sensor network used in irrigation automation. Wireless sensor network based irrigation control and programming are powerful solutions for optimal water management through automatic communication to know the soil moisture conditions when designing irrigation. The process used here is to determine the correct frequency and irrigation time that are important to ensure efficient water use, crop detection flow quality, flow rate and load. WSN uses low energy consumption, low data throughput and therefore energy saving technology. All devices and machines are controlled using the inputs received through sensors mixed in the ground. Nisha (2014) proposed an automated irrigation system based on wireless sensors to optimize the use of water for agricultural purposes. The system consists of a network of distributed wireless sensors of soil temperature and humidity sensors mounted in the crop field. The Zigbee protocol is used to manage sensor information and water quantity programming using an algorithm with sensor threshold values sent to a microcontroller of the irrigation system. So, farmers can irrigate precise amount of water to field to control the water pollution due to excess water which lead to pollute the surface water bodies and ground water by using above mentioned innovative concept like smart irrigation system.

IoT techniques for reduction of water, air and soil pollution due to excess agro chemical application

Excessive use of agrochemicals is a main source of water and soil contamination, especially in agricultural regions in low and middle income countries. Primary macronutrients such as nitrogen, phosphorus and potassium are added frequently to the field by famers as commercial fertilizers. Though, crop can absorb only limited quantity of nutrients from the chemical fertilizers like Urea, TSP and MOP. The excess fertilizer in the soil leaches into streams and ends up in distant locations, including reservoirs by traditional irrigation methods and rainfall. Ultimately, water bodies and soil became polluted. Therefore, the recommendations for fertilizer applications and their use should be accorded on precise crop-soil requirements. However, soil testing or soil information is not readily accessible in farming areas in most of developing countries. Consequently, farmers are using large quantities of fertilizer for their production, overuse of resources and polluting the environment. So, one of the reduction techniques is Internet of Things (IoT) based precision system for applying agro chemicals in actual quantities in the agricultural field.

Lavanya *et al*, 2019 proposed a system to monitor and determine the nutrients present in the soil by colorimetric principle. IoT based system is designed by a novel Nitrogen-Phosphorus-Potassium (NPK) sensor, Light Dependent Resistor (LDR) and Light Emitting Diodes (LED). The data detected by the NPK sensor from the particular soil are sent to Google cloud database to support fast retrieval of data by famers. Dissanayake *et al*, 2017 developed an optical sensor to sense fluoride and pH level in order to investigate the water quality using colorimetric principle during agronomic practices like application of fertilizers and pesticides. Kale and Sonavane, 2018 suggested an IoT based smart farming decision support system with an improved genetic algorithm (IGA) based multilevel parameter optimized feature selection algorithm for ELM classifier (IGA-ELM) to apply the precise amount of pesticides during pest and disease management.

Rad *et al*, 2015 developed a CPS architecture model for monitoring potato crop vegetation status. CPS will perform a significant role in the field of precision agriculture. It is expected that the proposed architecture to: Protect the environment and to preserve the natural resources in a more efficient manner, optimizing the use of water bodies by careful observing the crop indices regarding optimizing the chemical inputs (fertilizer and pesticides) by knowing the right doses and moments when to be used and increase the sustainability of agricultural systems. Nisha, 2014 proposed an automated irrigation system with disease control decision system. The data inspection is done through a solar panel and a cellular Internet interface. A digital camera is installed in the field to control the disease area using an image processing technique.

Vijayakumar and Rosario, 2011 studied the work of the rural agricultural community that replaces some of the traditional techniques. The sensor nodes have several external sensors, namely leaf moisture, soil moisture sensor, soil pH and atmospheric pressure sensors connected to them. Based on the soil moisture sensor, the engine starts to emit the water during the water shortage period and turns off when the proper water is irrigated. This results in water conservation and the soil pH is sent to the base station, which in turn informs the interested party of the soil pH by SMS through a GSM model. This information helps farmers reduce the amount of fertilizer used. An expansion of rice crop monitoring is proposed using WSN to help farmers monitor and increase rice production in real time. Automated water spray control and the final provision of information are implemented using a wireless sensor network. Several investigators have been reported that assess the impacts of precision agriculture technologies can not only decrease costs, but can also increase yields. Furthermore, accurately applying chemicals and fertilizers only where needed reduces the impact for contaminations in ground and surface (Krishnan *et al*., 2006).

Therefore, this precision technological solution has the possibility to improve profitability for the producer and also to reduce the threat of soil, underground water or surface water contamination from agricultural chemicals by reducing excess application of inputs such as fertilizers and pesticides.

Conclusion

In this article, various experimental precision studies based on IoT in the agricultural sector have been discussed with the support of various researches conducted by different investigators. The smart technology of the Internet of Things has brought revolution to all areas of the human's life by making everything smart, precise and intelligent. However, many people claim to rethink agriculture by developing more environmentally friendly intensification practices that can guarantee food security and respect the environment and human security. These new practices should be based on the basic principles of sustainability, including minimizing the impacts of management systems on biodiversity, greenhouse gas emissions, water purity and the spread of pests and diseases. The development of IoT-based smart devices for agriculture is changing daily agricultural production not only by improving it, but also by making it profitable, reducing waste and minimizing environmental pollution. In this context, smart technologies can pave the way for precision agriculture based on a more sustainable and rational use of resources (water and land), as well as chemicals (fertilizers and pesticides), with the aim of improving crop yields in respect of ecosystems. Today, useful technologies as well as the conservation strategy of the environment, as well as the points of view that change from corrective strategies to preventive strategies in the use of such technologies, are at the center of attention. Therefore, education and training should aim to justify the perceived usefulness of these technologies by experts so that the teaching of precision agriculture in universities and rural areas is taken more into account. It is suggested to plan continuing education courses for experts, to build a network of experts, teachers and technicians, to develop and run expert internship programs. Finally, policy makers and governments can establish strategic planning based on the results of this study to disseminate these types of technologies.

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