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Reduction Techniques for Consequences of Climate Change by Internet of Things (IoT) with an Emphasis on the Agricultural Production: A Review

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Abstract: Nowadays, Internet of Things (IoT) is one of the emerging technologies offers assistance in many important sectors. Agriculture is one of the important sectors globally which contributes to food security. The trends of IoT can be incorporated into various agricultural activities such as livestock monitoring and crop monitoring, etc. Various sensors and IoT gadgets are used in live monitoring, collection and processing of data. Processed data could be used to make predictions. Climate change is one of the critical environmental issue at the moment. We do not have our control over the occurrence of natural disasters, though the communication and forecasting offer a great support to us in protecting lives and to mend the ways towards a better future. Climate changes affect the land and water in many ways. The detrimental effect of continuous or unexpected flood, drought is some of the major concerns. The aim of this study was to introduce new technologies into agricultural production processes to improve those by reducing the impact of climate change over them. Therefore, this article discusses the applications of IoT in agriculture to mitigate the problems and consequences of climate change such as flood, drought, plant diseases, agricultural pollution and greenhouse gas emission with an emphasis on agricultural production.

Keywords: *Climate change; E-Agriculture; Information and Communications Technology; Internet of Things; Precision Agriculture*.

1. INTRODUCTION

Internet of Things (IoT) can be defined as a universal framework for people who adore information and permits progressive services by combining (physical and virtual) things based on current and developing inter-operable Information Communication Technologies (ICT) [1]. “The term “Internet of Things” was first used by Kevin Ashton in 1999” [2]. The application of emerging IoT trends can be applied to almost all processes in agriculture; such as animal monitoring, conservation monitoring, and plant and soil monitoring [3]. Therefore, it will be useful in increasing both product efficiency and process efficiency by reducing costs and time in agriculture. Internet of Things uses various sensors to collect data that are connected through Internet, and satellite integration [4]. After processing the collected data, IoT services offer forecasting services to farmers and producers so their decisions can be improved [5].

Environmental problems such as climate change have gained a lot of attention nowadays, and environmental monitoring, modeling and management allow us to acquire enlightenment of natural environmental processes. The impacts of climate variability and change in the agricultural sector are likely to translate directly into changes in land and water management, the main drivers of change (probably the main channels of change). Changes in the frequency and intensity of droughts, floods and storm damages are expected. Agriculture production can be influenced by climate change significantly, though, the results of climate change will vary considerably reliant on the region [6]. Agricultural productivity can be lost in vulnerable areas, mainly due to lower agricultural yields [7]. Since 2015, Indian farmers are under hardship from lack of inputs and drought [4]. Incidents of natural disasters have risen up dramatically over the years due, among other things, climate change, which costs us not only damage to assets / infrastructure, but also considerable losses. Although we cannot control the occurrence of natural disasters, modern technology can save lives more effectively. Communication systems during natural disasters can go a long way in saving lives in affected areas [8].

One of the best tactics could be to train and implement the use of information and communication technologies for the development of agricultural productivity [9]. Therefore, it is

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essential to understand the nature of the problem. The aim of this study was to increase agricultural productivity and reduce poverty by introducing new technologies to improve agricultural processes by reducing the impact of climate change into their production processes. This article describes the agro-industrial and environmental applications that use the Internet of Things to control the problems of climate change.

2. DISCUSSION

2.1 Internet of Things (IoT)

Internet of Things (IoT) has two terms; Internet and Things. “Things” refers to several IoT devices with special identities having the remote sensing, actuating and live monitoring abilities of particular type of data [10, 11]. Internet of Things can be defined as a universal framework for people who adore information and permits progressive services by combining (physical and virtual) things based on current and developing inter-operable information communication technologies [1]. IoT clearly ensures the utilization of specific devices to provide services to all types of applications and fulfillment of security and privacy requirements with the assistance of device identification, data capture, processing and communication ability. In a broader sense, the IoT can be visualized as an idea with technological and social significance [12]. IoT signifies the forthcoming state of computing communications and the development occurs faster. The technological revolt; IoT will impact the way of working, thinking and living of people [13]. The near explosive growth of cloud computing technologies, IoT and big data has strengthened effective flood monitoring. Industrial IoT is accountable for collecting real-time data. Big data analysis is used for the efficient analysis of real-time data. Fog computing decreases latency and cloud computing offers the necessary IT infrastructure, after the convergence between big data and High-Performance Computing (HPC) [14]. IoT connects the digital devices to work together in order to sense the environment, producing the results and transfer the results to people or other digital devices, as it unites services, technology and human [15, 16]. The development of IoT has been spreading through each industry such as production, city planning, finance, education, medical services and emergency services [17].

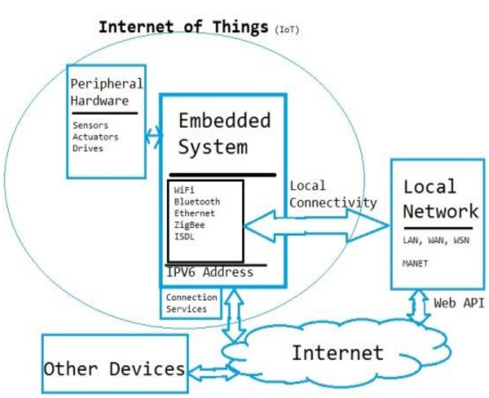

Figure 1: Internet of Things [3].

2.2 IOT in agriculture

Agriculture is one of the major field considered as the most important sector worldwide as it promises the continuous food availability and access to individuals, where IoT based experiments are being conducted and the unveiling of new products happens on a daily basis to increase the effectiveness and efficiency of the agricultural activities for a better yield. For example, Indian farmers are currently in great difficulty and disadvantaged in terms of farm size, technology, business, government policy, weather, etc. ICT-based technologies have undoubtedly worked out some problems, but they are not good enough for efficient and safe production. ICT has recently shifted into IoT, also recognized as "ubiquitous computing" [18]. Migration of IoT into various fields such as industry, private homes and cities, a great potential has been created to make everything smart and sensible. Nowadays the agriculture sector is also embraced the IoT technology, led to the evolution of "Agricultural Internet of Things" [11].

2.3 Precision Agriculture (PA)

According to Malek-Saeidi and Rezaei-Moghaddam (2008) (as cited in [19]) as an integrated crop management system precision agriculture coalesces information technology with agriculture sector and tries to supply inputs and their types according to the real needs of farming in small farms which are a part of bigger farms. In addition, precision agriculture is seen as an information technology-based agricultural management system that can be used to identify, analyze and manage changes within a farm to ensure for profit, sustainability and optimal conservation. This system helps to reduce the cost and also beneficial to the environment significantly [20]. This system can enhance the profitability of the manufacturer and reduce the risk of contamination of ground or surface water by agricultural chemicals by reducing overuse and underuse of inputs such as fertilizers and pesticide [21].

2.4 Global Climate Change on Agricultural Production

The change in climate which is directly or indirectly attributed to anthropogenic activities that change the composition of the atmosphere other than the natural climatic variations in comparable periods can be observed [22]. Responsiveness of crop cultivation to short and long-term climate change is very high. Temperature and rainfall, directly impacts the agricultural production [23, 24]. For example; increment of temperature diminishes the duration of most cereal crops by accelerating their phenological development [25] and in particular, the main crops of Sri Lankan agriculture such as rice are influenced by the increase in atmospheric Carbon dioxide (CO_2) concentrations, the rise in temperature and the development of precipitation, and the evapotranspiration regimes [26]. Short-term high temperature variability could affect flowering and crop yield formation significantly adverse, thus the effects of short-term climate fluctuation and severe weather occurrences should be considered with caution [27]. There are contradictions in the reports on whether the response of increased CO_2 emissions on crop harvest could balance the adverse results of rising temperatures [28].

2.5 Mitigation techniques by IoT

2.5.1 Flood

Flood impacts the agriculture productivity thus happens to be a cause for suffering in rural areas [29]. Geography and anthropogenic impacts could influence the floods, which are usually the consequences of extreme weather phenomena such as prolonged rainfall and snow-melt etc. [30]. When flooding happens in a significant duration of the crop calendar, the impact on farm land could be considerable [31].

There is currently no effective and efficient generic system for predicting the severity of the socio-economic outcomes of the floods. Effectively modeling, managing and monitoring floods is a vital task for scientists and researchers [17]. Different approaches for flood management system or water management system were developed by some researchers. [32] presented a Big Data-HPC-convergent industrial IoT service for flood management and demonstration of potential and efficiency of industrial IoT, including full walk-through of architecture, algorithms, and experimental steps, outcomes, and study. Presented flood management service can assist the convergence of IoT, big data and HPC and provide more authentic flood prediction and analysis, for example using the business intelligence approach [32] as well as modern prediction and data visualization techniques [33]. It is very important to keep all outcomes and data secured against unauthorized access, somehow the management and security aspects become more difficult due to high quantity data collection [34]. The ability of data recovery and continuation of services without interruption becomes crucial at the times of damage causing natural disasters [35]. Analysis of hydro-meteorological techniques for sensory data was at risk because ubiquitous access, storage, and analysis of such a large set of sensory data is a complex and resource-intensive process. Watersheds or areas such as ponds, rivers and lakes where water collects from any source such as precipitation or drainage have certain similarities. Therefore, a ubiquitous system for worldwide flood monitoring can be produced, since watersheds with similar characteristics will behave with same flood generation responses, so that most research and analysis can be reused [17]. Further, an automated water management system was developed to control the moisture content of the field. When the moisture content becomes lower than the required amount the motor connected to the soil moisture sensor will be activated to irrigate the field. If there is a heavy flooding in the field another motor connected to the soil moisture sensor will remove the excess moisture from the field to a well or water bed. An Arduino micro-controller is used for the automation of this water management system [36].

Real time detection of flood and rescue services offers a more advantageous approach to save many lives. IoT based rescue services enables the communication ways for survivors and victims of natural disasters to share their present status and information on protection among themselves and relatives. This strategy can be applied to industrial IoT services connected with alarming and forecasting effects of natural disasters like floods. Anyhow, an application based on real-time flood forecasts is sensitive to latency if the current location and spread of floods are to be predicted. Latency may occur in cloud computing based IoT due to the push and pull of data between the cloud and the gadgets. The researchers have made their greatest efforts in the area of spatial proximity, for example in the Geographic Information System (GIS), which only enables real-time detection of the flood. Imagery models like Synthetic Aperture and Radar (SAR), Digital Elevation Model (DEM) are crucial, but not as far as the early warning system [17].

2.5.2 Drought

Drought is a common and repeated phenomenon of climate change. Agricultural drought occurs when the availability of soil moisture to vegetation has decreased beyond a required limit that it affects crop yields and thus agricultural production [37]. According to Wang et al., (2002) (as cited in [38]) agricultural drought is one of the most common disaster, affects the population significantly and a considerable amount of yield is lost due to drought in rain-fed and irrigated farming, thus the crop yield requirement for increasing population becomes questionable [24]. As Hailong et al., (2007) (as cited in [38]) reported, agricultural drought leads to economic losses, the environmental degradation and pollution.

More rain, which is evenly distributed during the growing season, is beneficial to the harvest. Low precipitation (below-average precipitation) could be a cause for droughts [37, 39], which impacts the crop yield and decreases the water availability which impacts the irrigation and water supply of farm animals. The continuity of severe droughts hinders the plenteous precipitation and reduces the well distribution during the growing season [39].

Hence, it signifies the development of a comprehensive drought monitoring system for drought prevention [38] and IoT helps the farmers to overcome scarcity and droughts [4]. Internet of things can help improve the accuracy of plans and practices, and improve understanding of watershed sustainability and groundwater drought management. IoT can lead to better climate change mitigation and efficient use and protection of groundwater [40]. [38] produced a synthetic system that allows monitoring and forecasting of drought and prediction of irrigation volume in a platform based on Internet of Things technology, hybrid programming and parallel computing. This system is implemented in most of the northern provinces of China and offers a potential for an integrated service to monitor and predict droughts and to predict irrigation volumes.

Further an Automatic Smart Irrigation Decision Support System (SIDSS for short) was developed to manage and irrigate the farm lands effectively to conserve the available water. Weekly irrigation estimation is done with determination of soil properties, weather conditions and weather forecasts. Different types of sensors are used to implement this new system. Soil sensor is used to notice different crops and conditions, and a Global System for Mobile Communications (GSM) / General Packet Radio Service (GPRS) modem is used to collect information at different points. Environmental variables such as precipitation, humidity, required water depth, etc. are the inputs for the system [4].

2.5.3 Plant disease

Plant diseases and nutrient deficiency cause considerable harm and economic loss to agriculture. Plant disease development and crop growth can be influenced by temperature, light and water, likewise these parameters could influence type and condition of host plant [41-43]. High CO_2 concentrations and temperatures in the atmosphere, altered rainfall patterns and the frequency of extreme weather events have a profound impact on plant development and production. Therefore, the diseases occurrence varies according to these different conditions [44]. Climate change will also alter the physiology and resistance of crops, and modify the development stages and growth rates of pathogens [6]. The methods of plant disease management could influence the agriculture productivity significantly [45].

Integrated Pest Management is one of the management activities to which Agricultural IoT may provide the assistance to increase the productivity of crops [46]. With the assistance of devices like sensors, robots and drones which are used in IoT, the farmers could apply the chemicals precisely on the threat spots which have been identified. Advanced approaches for example; field sensors, Unmanned aerial vehicles (UAVs) or remote sensing satellites are used in the entire growing area to capture raw images to detect plat disease and pests based on image processing [47].

[48] put forward an IoT-based agricultural greenhouse environmental monitoring system in which environmental information about the greenhouse is remotely monitored in real time. Additionally, Wireless Sensor Network (WSN) can be used to monitor and control factors that affect plant growth and performance. Optimal harvesting time, plant diseases, control machinery etc. can be found out with this system [49]. Use of decision support system (DSS) to control the potato late blight disease was a success. DSS allows for efficiency, reduces costs and environmental impact by estimating the exact amount of fungicide required. This prediction uses a weather model to predict late blight. With the advent of IoT, however, a large number of inexpensive, low-power sensor nodes on cultivation lands could be used without any problem in recording accurate weather data. A newly budding service such as Cloud-IoT permits an open access web service with which remote sensors can be connected and used. In addition, the collected data can be transferred to the Cloud IoT Framework via an internet connection. DSS for late blight, which uses location-specific climate data to determine disease predictions and a mechanistic model for the disease to deliver real-time (in-season) assistance for blight control [50].

[51] and [52] concentrated on irrigation systems that use WSN to collect environmental data and a smartphone was used to control the irrigation system. A portable measurement technique was developed as a long-term sustainable solution for agriculture automation for plant data or for environmental measures by [51]. The system contains a soil moisture sensor, an air humidity sensor, and air temperature sensors. [53] proposed a multi-layer measuring system to measure soil temperature and water content of cultivation land with WSN to enhance water use and gather baseline data to study soil water infiltration fluctuations and intelligent precision irrigation. [4] developed a system to support smart irrigation, smart pest management by inspecting the health of crop and apply smart spray of pesticides according to the monitoring. The system was applied on a grape vineyard and a drone is used to identify the infected portion. Relative humidity, temperature, ultra violet radiation data were collected at every 15 min. Remote sensing technologies and IoT, Cloud servers, intelligent systems [illegible] of the system.

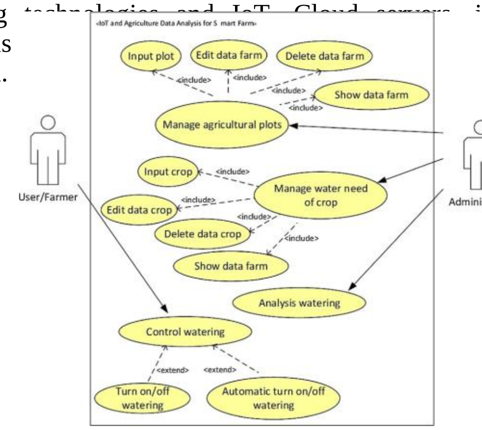

Figure 2: Use case diagram to present the process of web based and mobile application [54].

2.5.3 Agricultural Pollution Mitigation by IoT

Environmental pollution is the change occurs in the biosphere and the atmosphere around it due to different pollutants (chemicals and energy). Pollution mainly affects the climate. To ensure the protection of the nature, the pollution should be tracked. The pollution level should be within the safe limits [55]. Urban air quality has been a major concern around the globe in recent years. Therefore, the urban air quality index needs to be continually monitored to ensure the viability of the cities [56].

A system of IoT was developed to determine the pollution by measuring the parameters such as temperature, air pressure, Ultra-violet (UV) radiation, air quality, Nitrogen Dioxide and Carbon Monoxide in air, noise level and smoke etc. in the surrounding with the help of various sensors. For example; UVI-01 sensor was used to produce an output according to the amount of UV rays detected, the 2 in 1 Temperature and PH sensor was responsible to monitor water quality. The collected data will be transferred to the cloud. Collected data will be analyzed and a report will be produced. According to the results of the report pollution controlling actions will be implemented [55]. Another air quality monitor system was developed with the incorporation of IoT for smart cities. Parameters in the atmosphere such as temperature, Smoke, Humidity, Carbon Monoxide level, Liquid Petroleum Gas (LPG) and particulate matters like PM2.5 and PM10 levels which causes health hazards could be measured. The real-time data about the quality of the air will be accessed through an android application globally [56].

Increasing environmental pollution is a global concern. This pollution leads into the increment of acidity in ocean and thus hinders the marine organisms. A project was developed to control the pollution and improve the agriculture by observing the environmental factors. Sea temperature, air, humidity and oxygen levels in various points of the field have been tested regularly. Accurate digital images were taken with drones and the images were uploaded to the cloud server and can be called up from the cloud at any time by the agricultural adept. The adept has the right to access the images from the cloud using the smartphone or tablet application [4]. Further, An IoT sensor was presented to monitor air pollution. The sensor was named as CleanSpace. Here, machine learning creates hyperlocal population data so that users can understand air quality in real time. The sensor recovers radio frequency energy from its surroundings to charge the battery. It only measures Carbon monoxide (CO) currently, but assertion is there to be a generic marker for other contaminants (including transport) [57].

2.5.4 Reduction techniques for Greenhouse gas emission

Significant amount of greenhouse gases was released into atmosphere due to agricultural sector [58] and contributed to global warming and climate change to a considerable amount in recent times [58, 59]. In a normal scenario, greenhouse gas emissions in Asia, Africa and Latin America are expected to increase by 37%, 32% and 21% respectively by 2050, most of which are the developing countries [60]. In addition to the economic benefits and environmental benefits the reduction of greenhouse gas emissions and contamination caused by fertilizers and pesticides should also be taken into account [61]. Nitrification and denitrification of the soil are the major agricultural contributors of greenhouse gases, resulting nitrous oxide (N2O) emissions. Decomposition of manure resulting in methane and nitrous oxide emissions. Results of contemporary studies show that increment of greenhouse gas emissions are the important source of climate changes, such as risen temperatures, reduced and irregular precipitation in some places, increased flooding and hurricane spread in some other places, and increased occurrences of tornadoes [58].

Precision farming (PA) supports in managing the greenhouse gases emission, which aims to coordinate the agricultural processes, thus optimum productivity. It needs speedy, reliable, and widespread measures to give a more detailed approach to farmers to enable a view of the current circumstances in growing area and / or setup automated machines to optimize energy consumption, water consumption and the use of pesticides and fertilizers. At top level, after collecting information from many heterogeneous systems, well-evaluated scientific knowledge can be organized in the form of intelligent algorithms to allow a better understanding of current processes, justify the present circumstances, and determine forecasts based on heterogeneous data, warn possible threats to varieties at an early stage and enhanced automated control signals, in relation to crop reactions [62].

IoT was used in a study to determine the CO_2 emission from vehicles, forest fires and industries. MG811 sensor was used to sense the CO_2 levels and a Raspberry pi was used as a controlled module. The system senses the amount of CO_2 emission and the place where the pollution occurred the most. The system could be used as an early detection system of wild fires. Thus, many lives can be saved. A notification will be sent to mobile phone if high amount of CO_2 emitted in a particular area via Simple Notification Service (SNS) [59].

CONCLUSION

In this paper we have presented the results of the reduction techniques for consequences of climate change by internet of things (IoT) with an emphasis on the agricultural production. In this paper we have presented the results of the reduction techniques for consequences of climate change by internet of things (IoT) with an emphasis on the agricultural production. No matter what the agricultural production has to be increased with increasing population. The production efficiency can be hindered by the increasing concerns of climate change such as flood, drought, pollution and greenhouse gas emission. The impact of climate change on the agricultural production has to be reduced. We could understand from the review that new trends of IoT in different phases of agriculture helps to bring down the impacts on agricultural production.

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