AGRI. EXTENSION

IoT IN AGRICULTURE: CHALLENGES AND OPPORTUNITIES

Muhammad Shoaib Farooq *[1] and Sobia Akram [2]*

[1] Associate Professor,
[2] MS (SE) Student, School of Systems and Technology, University of Management and Technology, Lahore, Pakistan.

*Corresponding author's email: shoaib.farooq@umt.edu.pk

ABSTRACT

The consumption of food production demand for quality of food and the environmental impact of agriculture have led to utilize the information and communication technology in the agricultural sector. The Internet of Things (IoT) has become a contemporary technology, which is evolving quickly in recent years and brings many benefits with it to modernize the agriculture. The scientific groups and research institutes are working to deliver clarifications and solutions for the use of IoT to address various aspects of agriculture. The focal point of this research is to present an SLR (Systematic Literature Review) by collecting the valid and innovative research on IoT in agriculture which has been done during 2019 at School of System and Technology, University of Management and Technology, Lahore, Pakistan. This SLR has been conducted through research articles which were published in the prestigious venues from 2006 to 2019. In order to conduct this SLR concerned studies have been clustered into different classifications: type of the concerned research, empirical type, technological solutions for agriculture like monitoring, control, prediction, logistics and their sub-domains. Moreover, an IoT based framework of smart agriculture has been presented that indicate the current solutions of agricultural problems. The selected 80 research papers have been classified as per defined criteria. The findings of this research have been discussed in detail and summarize the practice of IoT in agriculture.

KEYWORDS: Internet of things (IoT); agricultural; empirical research; information; communication; Pakistan

INTRODUCTION

Agriculture has very significant role in the economic development of every country. We need to modernize our agricultural system because there are some basic problems which are creating hurdles in yielding of crops. The basic problem includes environmental conditions like rainy season, fluctuation in temperature, moisture in soil and humidity (Rajakumar *et al.,* 2018). Internet of Things (IoT) is providing advantages to everyday objects of our life which generate information and provide services in the actual time. Advances in communication have allowed the farmers to collect the information related to their fields. But our farmers still rely on traditional techniques to irrigate the field, fertilize the field and spray the pesticides without giving attention to the exact nature of the farm. All of these methods lead to insufficient and low growth of crops. Applying IoT techniques in agriculture can boost crop yields due to improved efficiency in agricultural methods (Mat *et al.,* 2018). The IoT brings advance innovations within the automation of ground as the collected data is used to develop expert system

strategies to generate forecasts. The deployment of IoT technology in agricultural field is very important because they occur in large space which requires constant monitoring (Rajakumar *et al.,* 2018). IoT helps the farmer to monitor field variables such as soil temperature, humidity, atmospheric condition, fertilization, crop productivity and livestock (Ashifuddin-Mondaly and Rehena, 2018). Farmers takes the advantage of IoT by utilizing it in a more innovative to increase the crop productivity. IoT can be integrated into the agricultural application to provide an efficient actual mapping of air, noise levels, temperature and dangerous radiations (Hachem *et al.,* 2015; Torres-Ruiz *et al.,* 2016). The IoT has used to gather and store up environmental information, ensure accuracy of climate change with domestic policies, initiate alert or send an advisory message to individuals (Minbo *et al.,* 2013).

The objective of this proposed research has to present the Systematic Literature Review (SLR) into the domain of IoT in agriculture. Various studies have been presented on this topic in recent years.

This SLR collects, analyzes and summarizes state of the art research. Depending on the feasibility of IoT applications in agricultural system, this SLR has been conducted to collect and map current applied research with technical viewpoints in which other practitioner and researcher can get guideline to promote IoT in agriculture.

In order to conduct a useful SLR, we dignified the basic search string to cover the existing solutions in these fields like technologies, architecture, publications and open challenges. We have been developed the assessment criteria to collect the best relevant studies and focus on various publications from well-known journals, conference and workshops. In terms of systematic review criteria, the duration of 2006-2019 has been covered and 80 research papers have been identified for further review out of 755 articles. The selected 80 research papers have been evaluated through different empirically and qualitative aspectsto present the existing literature of related domain.

The formation of this SLR is as following sections: section 2 presents the material and methods of SLR, section 3 presents the results which obtained from mapping the studies and discussion presents the principle finding, list of advices to farmers and outlines threats to validity. The section 4 presents the conclusion.

The contribution of this SLR and comparison with related survey articles: The research has been conducted on former reviews and related works of IoT in agriculture. In the selected literature, there is one SLR and three surveys that are related to IoT in agriculture as shown in Table 1.

The SLR (Talavera *et al.,* 2017) identified 72 main studies and examines agricultural industry and environmental applications which uses the IoT. It is encouraged by the requirement to categorize trends, architectures and areas of application related to domain. However we identified 80 studies and evaluated the technological solutions of agricultural problems.   In addition to this SLR, three surveys have been identified and all these surveys presented discussion on IoT in agricultural field. In (Mekala and Viswanathan, 2017)the authors evaluated 31 studies covering the time duration between 2010-2016 and presented some general discussion of IoT

in agriculture for monitoring the fields through wireless sensor networks and we presented the comprehensive discussion of IoT in agriculture. Our SLR can be used to recognize different understandings of smart agri-field and to improve the agricultural practices. In (Veena *et al.,* 2018) the authors presented the monitoring system to enable water, soil moisture and intruder's detection parameters by using IoT. However we presented the overall agricultural problems like plant monitoring, irrigation, pesticides, production estimation and crop growth. This overcomes the manual operations that require monitoring and retain the agricultural farms. In (Abbasi *et al.,* 2019) authors compare 80 studies and presented the concepts, challenges and IoT application in agriculture. However we present the updated and improved quality based SLR of recent published papers related to IoT in agriculture. Our article provides comprehensive discussion on the implementation of IoT based agriculture and designed a framework to present the automation of agricultural field.

The above discussion shows that a lot of efforts have been made out to identify and evaluate various practices of IoT in agriculture. In this research we concern on describing the complete evaluation criteria for proper automation of agriculture through IoT. The novelty of work is beyond the defining IoT in agriculture, the research types and empirically validation have been presented to justify the selected papers. Unlike current approaches our technique is very robust with the implementation of IoT in agriculture.

MATERIALS AND METHODS

Current study was conducted at School of System and Technology, University of Management and Technology, Lahore, Pakistan during 2019. According to (Petersen *et al.,* 2008) the major aspect of SLR is to find and analyze the meaningful research that is available in related domain. The main concern behind the conduction of this SLR is to recognize and categorize the research which is currently accessible in the field of IoT in agriculture, then evaluate them according to the proposed solution for the problems in agricultural activities. Fig. 1 shows the systematic review process to conduct SLR. The research methodology of this as follows: the first step of SLR is to define the research objectives that identify the goal to achieve the solution of the problem. The second

Table 1. Comparison with recent survey & SLR articles

Type of study	Study reference	Focus of study	Publication year	No of reviewed studies	Years covered
SLR	(Talavera *et al.,* 2017)	IoT in agriculture	2017	72	2006-2016
Survey	(Mekala and Viswanathan, 2017)	Smart agriculture	2017	31	2010-2016
	(Veena *et al.,* 2018)	IoT in agriculture	2018	45	2006-2013
	(Abbasi *et al.,* 2019)	Precision agriculture	2019	80	2003-2018

step is to define the research questions that address problems of agriculture. The third step is to conduct search of the relevant papers in the domain. The fourth step is to screening the research papers and select the more specific articles related to our research questions/domain. The fifth step after the exploration of all available current searches in related domain we select studies and extract the data by using keywords in abstracts that related to research questions. In step six by categorizing and mapping related studies, the review result provides scientific evidence.

Objectives

The research objectives have been presented here as following:

O1: To discover state of the art that defines research for IoT in agriculture.

O2: To finding the forum in which research types and justification are available to validate the study of IoT in agriculture.

O3: To describe the existing solutions in the problems of agriculture, identify the similarities and differences between them using the framework.

O4: To identify gaps in the implementation with respect to research challenges and approaches.

Research questions

To perform SLR, there has been important to design the initial Research Questions (RQ). Beyond the specific research questions, the process of review involves developing research approaches to identify and issue appropriate findings. The initial six research questions with major motivations have been shown in Table 2. Due to these research questions, the existing research of IoT in agriculture can be categorized and identified future research areas in the field.

Search strategy

The search strategy is very important for any SLR that guarantees the full range of selection of main important studies. Good results are generally based on the important studies that selected to conduct SLR. The selection of our study depends on the following three steps:

Selecting the source of repositories

Definition of the search keywords
Exclusion/inclusion criteria for studies selection related to RQ.

Selecting the source of repositories: Different digital libraries have been explored to identify published studies which are following: ACM, IEEE Digital Library, Scopus and Science Direct. The results have been collected from manual and automatic search to select the data to answer the RQ.

Definition of search keywords: This systematic approach has been used to design search keywords
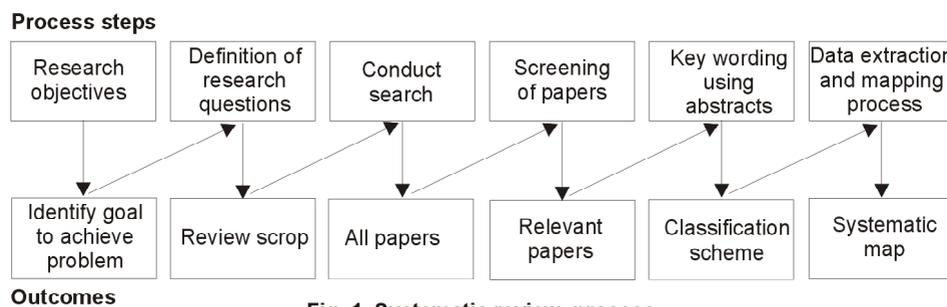

Fig. 1. Systematic review process

Table 2. Research questions and major motivations

No	Research questions	Major motivations
RQ1	Which research publications channels are focused for IoT in agriculture?	The motivate is to find the area where IoT in agriculture research found and also find the great source of the publications for future studies
RQ2	How IoT in agriculture frequency changed over time?	To identify the research publication trends over time for IoT in agriculture
RQ3	Which research types are main targets for IoT in agriculture?	To explore research types which have been reported in the literature of related domain
RQ4	Are IoT in agriculture studies empirically validated?	To discover that whether IoT in agriculture studies has been empirically validated.
RQ5	Which technological solutions are the main concerns for IoT in agriculture?	To identify, studies are classified into related solutions and their sub-domains.
RQ6	How does the usage of IoT evolve in agriculture?	To explore in selected studies that what is the purpose of IoT in agriculture.

for the following search steps:

Highlight keywords related to research questions.

Categorize some words and their synonyms for main keywords.

Expand the search method by combining these Keywords with the Boolean operator "AND" and alternate words with Boolean operator "OR".

To automatically search in digital libraries the following search string has been used as shown in Table 3.

Table 3. Search string for digital libraries

Digital libraries	Number of results
IEEE	250
ACM	330
Science Direct	102
Scopus	73
Total	**755**

Exclusion/inclusion criteria for studies selection related to RQ:

The main objective of study selection process was to recognize the most related studies which were the main targets for this systematic literature review. The article has been reviewed only once if it appears in more than one source. Every paper is returned with an evaluation to make a decision that if it should be involved or not by considering the title, abstract or keywords. In order to guarantee the majority of related studies, the study period has been considered from 2006 to 2019. To guarantee the validity of documentation, only those papers that go beyond the following IC (Inclusion Criteria) have been included for the review process.

IC1Papers published must be in English
IC2Include the research studies that are clearly addressed the research questions.
IC3Include only those papers which concentrate on IoT in agriculture.

Selection and screening process: To acquire the assessments, the selection process of three steps has been conducted which is shown in following Fig. 2. The research method provided 755 initial papers which have been selected from the major sources as shown in Table 4. From these papers, 170 papers selected and then 80 papers have been finalized as primary studies.

The description of the above diagram selection process has been shown in the following Table 5.

If the main topic is not empirical or it is outside the domain of this SLR, it has been deleted. A selection criterion has been used to decrease the number of citations found in the search of studies. This criterion has been made by using the Inclusion criteria (IC) and Quality Assessment (QA) that are well-defined in a four-step process.

Search by title: In this phase, the duplicate and irrelevant papers based on titles were removed. After this stage, the numbers of papers were 170.
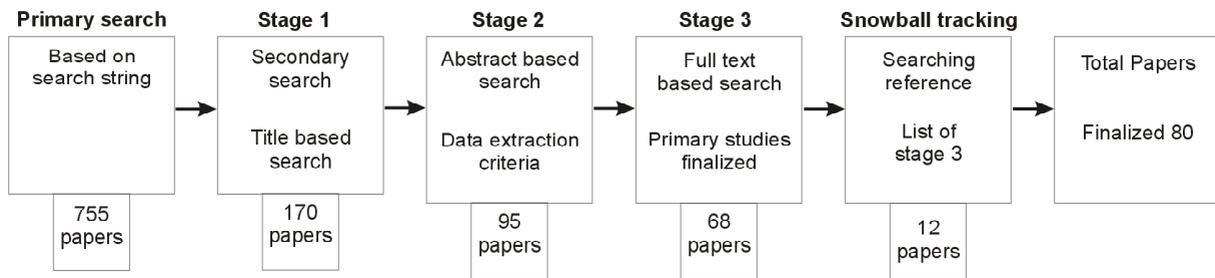

Fig. 2. Selection process

Table 4. Search results from digital libraries

Data base	Search string
ACM digital library	((Internet of Things OR IoT) AND ("Agriculture" OR "Cultivation" OR "Horticulture" OR "Agronomy" OR "Agri-business" OR "Farming" OR "Agricultural application" OR "Irrigation" OR "Smart farming" OR "Environment monitoring" OR "Livestock" OR "Product traceability" OR "Agri-food logistics "))
IEEE Xplore	(("Internet of Things" OR "IoT") AND ("Agriculture" OR "Cultivation" OR "Horticulture" OR "Agronomy" OR "Agri-business" OR "Farming" OR "Agricultural application" OR "Irrigation" OR "Smart farming" OR "Environment monitoring" OR "Livestock" OR "Product traceability" OR "Agri-food logistics "))
Science Direct	Title, abstract, keywords: Internet of Things OR IoT ("Agriculture" OR "Cultivation" OR "Horticulture" OR "Agronomy" OR "Agri-business" OR "Farming" OR "Agricultural application" OR "Irrigation" OR "Smart farming" OR "Environment monitoring" OR "Livestock" OR "Product traceability" OR "Agri-food logistics ")
Scopus	TITLE-ABS-KEY ("Internet of Things" OR "IoT" AND ("Agriculture" OR "Cultivation" OR "Horticulture" OR "Agronomy" OR "Agri-business" OR "Farming" OR "Agricultural application" OR "Irrigation" OR "Smart farming" OR "Environment monitoring" OR "Livestock" OR "Product traceability" OR "Agri-food logistics "))

Search by abstract: In this phase, papers were kept for further processing that includes little information related to IoT in agriculture. After this phase, 95 papers were in list.

Search by full text: In this phase, papers that did not satisfy the research questions were removed. The papers were completely evaluated to know whether they are empirically validated or not. After this phase, 68 papers were finalized.

Snow ball tracking: By using all above phases, the snow ball tracking has been applied in the references section of selected articles. The numbers of identified papers were 12. The finalized result of 80 papers has been presented in Table 7.

Table 5. Description of selection process

Stages	Criteria of Selection	Explanation
Pre-phase	Primary search	String based search from appropriate conferences, journals and workshops.
Phase 1	Search by title	Selection of main important articles.
Phase 2	Search by abstract	Extraction of main articles.
Phase 3	Search by full text	Evaluate the studies critically.

Table 6. Conference and journal ranking

	Type	Weight
Conference	A*	1.5
	A	0.95
	B	0.60
	C	0.40
	No core ranking	0
	Type	**Weight**
Journal	Q1	2
	Q2	1.5
	Q3 & Q4	1
	Others	0

Quality assessment

Mostly quality assessment is implemented as an important part of the SLR. That's why the questionnaire was intended to evaluate quality assessment of the selected papers. The quality assessment is classified by scoring the following questions:

(a) The study contribution that how IoT in agriculture can be intended. The number of answers were Yes = 1, No = 0.

(b) The study grants clear solution related to IoT in agricultural problems. Yes = 1, Partially = 0.5 and No = 0

(c) The results of study presents whether they are empirically validated or not. Yes = 1, No = 0

(d) The studies were available in a familiar channel. This question has been rated by the score of the Core ranking conferences list and (JCR) are shown in Table 6.

The synthesis method and data extraction strategy: The procedure of data extraction was categorized to provide the answers of research questions.

1: To accomplish this research question, the publication channel and source should be identified for each article.

2: As per publication year, the articles should be categorized to design the publication trend.

3: The research type can be categorized into:

Evaluation research: The evaluation of approaches has been accompanied that contains the problem identification related to the domain.

Solution proposal: The solution for agricultural problem has been proposed. The advantages of the proposed solution have been shown with examples.

Experience paper: These papers indicate the personal experience of authors in related field and describe how it was realized during practices.

Other: Theoretical papers, reviews and opinion papers, etc.

4: The empirical validation can be categorized into:

Survey: A process to collect quantitative information that relate to IoT based agricultural system, for example a questionnaire.

Case Study: A validated inquiry that observes the fact of IoT based agriculture system within a real life context.

Experiment: An empirical process applied to observe the effects of IoT in agriculture.

5: To recognize the major IoT solutions and their sub domains in the agricultural fields, the studies have been clustered into four technical disciplines, applicable to:

Monitoring: The process and activities of IoT that need to be distinguished and maintained the quality of green environment. The following sub domains were recognized: soil monitoring, air monitoring, plant monitoring, water monitoring and others which consist of aquaculture and animal monitoring.

Control: A controlled method forthe production of food and the purpose of this solution is to give protection and maintained finest condition of crop growth. The sub domains which were considered are following: access control, irrigation, fertilization and pesticides.

Prediction: This IoT-based platform provides tools and knowledge to farmers for making the decision.

The perspectives of the variables are listed as follows: environmental condition, crop growth and production estimation.

Logistics: The logistics in the development of agriculture states to the stream of physical objects and associated information from the manufacturer to the user to meet his or her needs. Primary studies have been further divided into strategies: production, commerce and transport.

6: To answer this research question, each selected study should be explored to identify the purpose of IoT in agriculture.

RESULTS AND DISCUSSION

This section presents the results with classification and quality assurance detail based on the research questions described in Table 2. To show examples of each RQ's answer, different type of studies have been selected. We analyze that these studies have importance and huge influence to IoT in agriculture.

Selection results

After deep investigation of 170 articles, 90 papers out of them were rejected and there were only 80 papers that were finally selected. The 80 papers have been identified and investigated to respond to the information related to IoT in agriculture. In Table 7 the list of nominated papers presented with classification results and quality assurance details.

1. What are the major publication channels are focused for IoT in agriculture?

The Table 8 shows the list of different channels and sources of publication. The selected papers have been taken from four publication channels: conferences, workshops, journals, and symposia. About 56% of the selected papers have been presented at conferences, 34% of the selected studies have been published in Journals and 8% appeared in symposia respectively.

2. How IoT in agriculture frequency changed over time?

Fig. 3 shows the publication of articles from 2006 to 2019. There is only one prominent outlier who has conducted a number of conferences in 2013, 2014 and 2015. The reason for this statement is that some articles have been published in conferences as per shown in Fig. 3. Mostly the selected articles were published between 2012 and 2019. The readers notice that few numbers of articles have been published from 2006 to 2011 which means that the interest of researchers has increased after the publication year of 2012. The publication frequency rate increased from

2013 to 2019 whereas rate is average from 2006 to 2012.

3. Which research types are main targets for IoT in agro-industry?

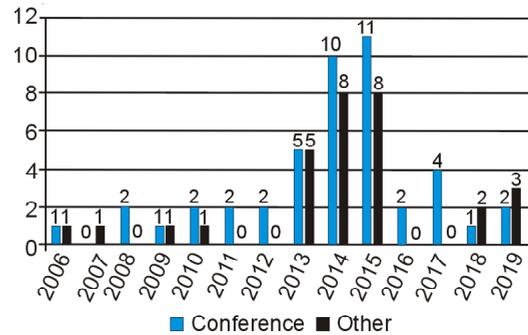The four types of research have been recognized in this systematic literature review as shown in Fig. 4.

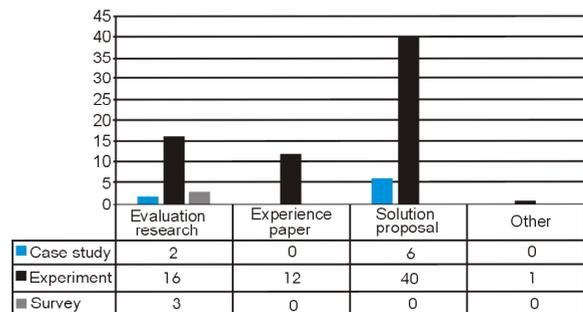**Fig. 3. Year wise comparison of publication (per annum)**

Fig. 4. Distribution of papers according to research type and empirical type

Solution proposal (46 articles), experience paper (12 articles), evaluation (21 articles) and review (1 article). About 83% (solution proposal and evaluation paper) selected papers presented the solutions to IoT in agriculture, 15% shows the experience of authors and 1 review has found in the literature of IoT in agriculture. The authors described the experience with deploying wireless sensor network on large scale for precision agriculture. The experiment involves protection of potato crops against disease of fungal. For monitoring of these factors, the authors used wireless network in the potato field. This improved time-saving efficiency, lowers the cost more than traditional farming methods (Langendoen *et al.,* 2006). The agricultural information evaluated because people cannot do scientific work in the current agricultural production system, consumers have difficulty expressing their views on agriculture and farmers do not have any resource to improve plant productivity. So the authors introduce an agricultural platform design based on the IoT. The system provides conveniences to the farmers through planting process,

agricultural techniques and feedback to query system. Agricultural service systems have been introduced to understand agriculture transportation, production and after-sales services for intelligent control and data management (Fang *et al.,* 2014; Mathurkar *et al.,* 2014).

4. Are IoT in agriculture studies empirically validated?

The results of this research question exposed that all selected papers were empirically validated because they have evidence of conception. There are about 86% empirical studies identified in which different experiments were managed to estimate the efficiency of IoT in agriculture. The result of survey is 4% and 10% of case studies. A review has also selected which provides the comparison of related domain application. Around half of the experience papers and solution proposals have been empirically validated through experiments as per shown in Fig. 4. It also shows that for the evaluation of existing method, authors conduct the experiments. A case study of fox house implementation has been presented where sensing application was implemented to monitor the agriculture parameters like temperature, humidity and air (Hakala *et al.,* 2008). Another case study which was beside to the erection of a WSN that included low cost infrastructure and parameters for improved irrigation system (Postolache *et al.,* 2013). Authors surveyed some smart farming applications that can control cost, reliability and performance of monitoring. Through the agricultural equality approach, farmers can monitor crop yield using smart phones and computers (Mekala and Viswanathan, 2017; Veena *et al.,* 2018). The experiments has been presented in which the authors describe the implementation of the sensor technology at ZigBee's low cost to improve the production of crops and vegetables (Khandani and Kalantari, 2009; Ruan *et al.,* 2019).

5. Which technological solutions are the main concerns for IoT in agriculture?

To analyze the major technological solutions of IoT in agriculture, selected articles have been classified into four technical domains which resultant to monitoring, control, prediction and logistic. The results have been précised in Table 7 and shown in Fig. 5. The Fig. 5 shows the result of selected articles such as monitoring (52%), control (25%), logistic (8%) and prediction (4%). The number of articles which was not presenting the technological domain have been also classified in this SLR, but these papers show the contribution in IoT and agricultural field. The percentage of these papers was (11%).

Monitoring: Selected studies describes that the domain of monitoring dealt by quick identification of environmental and physical factors collected in natural conditions like crops and fields using WSN. The major purpose of this area has to retrieve data without an operator and transmit it to the data center for control or vision.
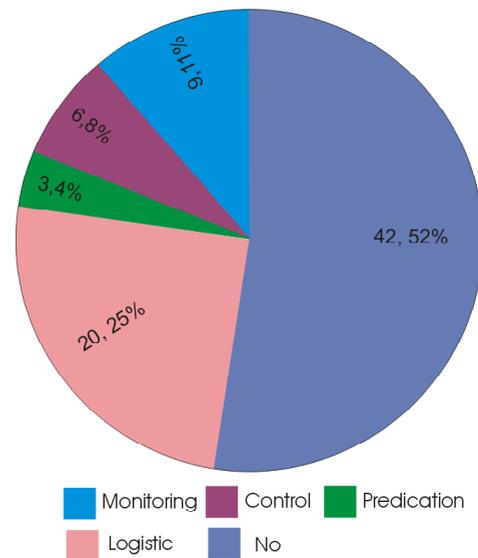

Fig. 5. Distribution of selected papers as per technological domain

Consolidated tools of monitoring ensure the communication with deployed WSN and being able to store data over internet. Therefore, IoT based smart agriculture increases efficiency for farmers by facilitating them to gather appropriate information from farms and crops using sensors.In (Jha *et al.,* 2017) an IoT based field monitoring system has been developed that provide the real time information of humidity, temperature and live soil moisture for farmers to make decision. The monitoring and alerting system was introduced in (Soontranon *et al.,* 2014) to obtain flood image data by wireless sensor nodes that integrate with the CMOS camera to transmit data collected through the ZigBee sensor network. An agricultural monitoring system was developed (Pokric *et al.,* 2014) for Thailand. Different types of plants were observed from fields consisting of agricultural products such as sugar cane, rice, rubber and others. In (Kuroda *et al.,* 2015) a system is developed and implemented that can collect data, transfer the data and provide a remote control through mobile phone. It consists of temperature, humidity sensor, server and mobile client to manage the green house. In (Minbo *et al.,* 2013) a monitoring based agriculture system was developed which used IoT protocols to increase the production. This system also provides the resources due to which

Table 7. Classification of selected papers

Classification							Assessment of quality				
References	Channel of publication	Year of publication	Type of empirical	Type of research	Application domain	Sub domain	a	b	c	d	Score
(Patil *et al.,* 2006	Conference	2006	Experiment	Solution Proposal	Monitoring	Air Monitoring	1	1	1	0	3
(Langendoen et al., 2006)	Symposium	2006	Experiment	Experience Paper	Monitoring	Plant Monitoring	1	1	1	0.95	3.6
(Yoo et al., 2007)	Symposium	2007	Experiment	Evaluation Research	Control	Fertilizer & Pesticides	1	1	1	0	3
(Jain *et al.,* 2008)	Conference	2008	Experiment	Solution Proposal	Monitoring	Others	1	1	1	0	3.6
(Hakala *et al.,* 2008)	Conference	2008	Case study	Solution Proposal	Monitoring	Others	1	0.5	1	0	2.5
(Watthanawisuth *et al.,* 2009)	Journal	2009	Experiment	Solution Proposal	Monitoring	Air Monitoring	1	1	1	2	5
(Khandani *et al.,* 2009)	Conference	2009	Experiment	Experience Paper	Prediction	Production estimation	1	1	1	0.4	3.4
(Marino *et al.,* 2010)	Journal	2010	Experiment	Solution Proposal	Logistic	Production	1	1	1	2	5
(Salas *et al.,* 2014)	Conference	2010	Experiment	Experience Paper	Monitoring	Plant Monitoring	1	1	1	0	3
(Zhao *et al.,* 2010)	Conference	2010	Case study	Solution Proposal	No	No	1	1	1	0	3
(Jiber *et al.,* 2011)	Conference	2011	Experiment	Evaluation Research	Control	Irrigation	1	1	1	0.6	3.6
(Charoenpanyasak *et al.,* 2011)	Conference	2011	Experiment	Experience Paper	Logistic	Production	1	1	1	0	3
(Ehsan *et al.,* 2012)	Journal	2012	Experiment	Evaluation Research	Monitoring	Others	1	1	1	1.5	4.5
(Lee *et al.,* 2012)	Conference	2012	Experiment	Evaluation Research	Prediction	Crop Growth	1	1	1	0	3
(Mittal *et al.,* 2012)	Conference	2012	Experiment	Experience Paper	Monitoring	Plant Monitoring	1	0.5	1	0	2.5
(Ma *et al.,* 2012)	Journal	2012	Experiment	Solution Proposal	Monitoring	Water Monitoring	1	1	1	2	5
(Liping, 2012)	Journal	2012	Case study	Evaluation Research	Logistic	Commerce	1	1	0	1.5	3.5
(Feng *et al.,* 2012)	Journal	2012	Experiment	Solution Proposal	Monitoring	Plant Monitoring	1	1	1	1	4
(Sun *et al.,* 2012)	Journal	2012	Experiment	Solution Proposal	Monitoring	Water Monitoring	1	1	1	2	5
(Ye *et al.,* 2013)	Conference	2013	Experiment	Solution Proposal	No	No	1	1	1	0	3.4
(Pahuja *et al.,* 2013)	Journal	2013	Experiment	Solution Proposal	Control	Irrigation	1	1	1	2	5
(Smarsly, 2013)	Conference	2013	Experiment	Solution Proposal	Control	Irrigation	1	0.5	1	0	2.5
(Lee *et al.,* 2013)	Conference	2013	Experiment	Solution Proposal	Monitoring	Soil Monitoring	1	1	1	0	3
(Minbo et al., 2013)	Journal	2013	Experiment	Solution Proposal	No	No	1	1	1	1.5	4.5
(Liu *et al.,* 2013)	Conference	2013	Experiment	Experience Paper	Monitoring	Water Monitoring	1	1	1	0	3.4
(Jiang and Zhang, 2013)	Symposium	2013	Experiment	Evaluation Research	Logistic	Transport	1	1	1	0	3
(Postolache *et al.,* 2013)	Symposium	2013	Case study	Solution Proposal	Monitoring	Water Monitoring	1	0.5	1	0	2.5
(Mafuta *et al.,* 2013)	Journal	2013	Experiment	Solution Proposal	No	No	1	1	1	1.5	4.5
(Vo *et al.,* 2013)	Conference	2013	Experiment	Solution Proposal	Monitoring	Air Monitoring	1	1	0	0	3.6
(Chavez-Burbano *et al.,* 2014)	Conference	2014	case study	Evaluation Research	Control	Irrigation	1	1	1	0	3
(Soontranon *et al.,* 2014)	Symposium	2014	Experiment	Solution Proposal	Monitoring	Plant Monitoring	1	0.5	1	0	2.5
(Fang *et al.,* 2014)	Journal	2014	Case study	Solution Proposal	Monitoring	Air Monitoring	1	1	1	2	5
(Gutiérrez *et al.,* 2013)	Journal	2014	Experiment	Solution Proposal	No	No	1	1	1	2	5
(Jiao *et al.,* 2014)	Journal	2014	Experiment	Evaluation Research	Control	Fertilizer & Pesticides	1	1	1	1.5	4.5
(Chen *et al.,* 2014)	Conference	2014	Experiment	Solution Proposal	Monitoring	Soil Monitoring	1	1	1	0	3.95
(Fourati *et al.,* 2014)	Conference	2014	Experiment	Solution Proposal	Monitoring	Water Monitoring	1	0.5	1	0	2.9
(Pokric *et al.,* 2014)	Conference	2014	Experiment	Solution Proposal	Monitoring	Air Monitoring	1	1	1	0	3.4

Classification							Assessment of quality				
References	Channel of publication	Year of publication	Type of empirical	Type of research	Application domain	Sub domain	a	b	c	d	Score
(Islam *et al.*, 2014)	Conference	2014	Experiment	Solution Proposal	Monitoring	Water Monitoring	1	1	1	0	3
(Sawant *et al.*, 2014)	Symposium	2014	Experiment	Evaluation Research	No	No	1	1	0	0.4	2.4
(Khriji *et al.*, 2014)	Journal	2014	Experiment	Solution Proposal	No	No	1	1	1	1.5	4.5
(Valenzuela *et al.*, 2018)	Conference	2014	Experiment	Evaluation Research	Monitoring	Soil Monitoring	1	1	1	0	3.4
(Tao *et al.*, 2013)	Conference	2014	Experiment	Experience Paper	Control	Access Control	1	1	1	0	3
(Kaewmard and Saiyod, 2014)	Conference	2014	Experiment	Experience Paper	Control	Irrigation	1	1	1	0	3
(Li, *et al.*, 2014)	Conference	2014	Experiment	Solution Proposal	Control	Access Control	1	1	1	0.6	3.6
(Mathurkar *et al.*, 2014)	Conference	2014	Experiment	Solution Proposal	Monitoring	Soil Monitoring	1	1	1	0	3
(Eom *et al.*, 2014)	Journal	2014	Experiment	Evaluation Research	Monitoring	Others	1	1	1	2	5
(Postolache *et al.*, 2014)	Journal	2014	case study	Solution Proposal	Monitoring	Air Monitoring	1	1	1	1.5	4.5
(Kar and Kar, 2015)	Conference	2015	Experiment	Evaluation Research	Monitoring	Water Monitoring	1	1	1	0	3.4
(Chen *et al.*, 2015)	Journal	2015	Experiment	Solution Proposal	Monitoring	Plant Monitoring	1	1	1	2	5
(Kuroda *et al.*, 2015)	Conference	2015	Experiment	Evaluation Research	Monitoring	Plant Monitoring	1	1	1	0.6	3.6
(Roy *et al.*, 2015)	Conference	2015	Experiment	Solution Proposal	Control	Access Control	1	1	1	0	3.6
(Zheng *et al.*, 2016)	Journal	2015	Case study	Solution Proposal	No	No	1	1	1	2	5
(Luan *et al.*, 2015)	Conference	2015	Experiment	Solution Proposal	Prediction	Environmental Condition	1	1	1	0	3
(Ryu *et al.*, 2015)	Journal	2015	Experiment	Solution Proposal	Control	Fertilizer &Pesticides	1	1	1	2	5
(Jayaraman *et al.*, 2015)	Conference	2015	Experiment	Evaluation Research	Monitoring	Plant Monitoring	1	1	1	0	3.6
(Marjanović *et al.*, 2016)	Journal	2016	Experiment	Evaluation Research	Control	Access Control	1	1	1	1.5	4.5
(Saville *et al.*, 2015)	Journal	2015	Experiment	Experience Paper	Monitoring	Others	1	1	1	1.5	4.5
(Tanumihardja and Gunawan, 2015)	Conference	2015	Experiment	Experience Paper	Monitoring	Water Monitoring	0	1	1	0	2
(Nguyen *et al.*, 2015)	Conference	2015	Experiment	Solution Proposal	Monitoring	Air Monitoring	1	1	1	0	3.6
(Culibrina and Dadios, 2015)	Conference	2015	Experiment	Solution Proposal	Control	Irrigation	1	1	1	0	3
(Shuwen and Changli, 2015)	Conference	2015	Experiment	Experience Paper	Control	Irrigation	1	1	1	0.95	3.95
(Zhao and Zhu, 2015)	Conference	2015	Experiment	Evaluation Research	Monitoring	Soil Monitoring	0	1	1	0.4	2.4
(Pang *et al.*, 2015)	Journal	2015	Experiment	Solution Proposal	Logistic	Commerce	1	1	1	2	5
(Sales *et al.*, 2015)	Journal	2015	Experiment	Solution Proposal	Control	Irrigation	1	1	1	2	5
(Nguyen *et al.*, 2015)	Symposium	2015	Experiment	Evaluation Research	Monitoring	Air Monitoring	1	1	1	0	3
(Xu *et al.*, 2015)	Conference	2015	Experiment	Solution Proposal	Control	Fertilizer &Pesticides	1	1	1	0.6	3.6
(Patil and Kale, 2016)	Conference	2016	Experiment	Others	No	No	1	1	1	0	3
(Capello *et al.*, 2016)	Conference	2016	Experiment	Solution Proposal	Logistic	Transport	1	1	1	0	3.4
(Rajeswari *et al.*, 2017)	Conference	2017	Experiment	Solution Proposal	Control	Access Control	1	1	1	0	3.4
(Uddin *et al.*, 2017)	Conference	2017	Experiment	Solution Proposal	Monitoring	Plant Monitoring	1	1	1	0	3.6
(Jha *et al.*, 2017)	Conference	2017	Experiment	Solution Proposal	Monitoring	Plant Monitoring	1	1	1	0	3.4
(Mekala and Viswanathan, 2017)	Conference	2017	Survey	Evaluation Research	Monitoring	Plant Monitoring	1	1	1	0	3.4
(Heble *et al.*, 2018)	Journal	2018	Experiment	Experience Paper	Monitoring	Soil Monitoring	1	1	1	2	5

Classification							Assessment of quality				
References	Channel of publication	Year of publication	Type of empirical	Type of research	Application domain	Sub domain	a	b	c	d	Score
(Yoon *et al.*, 2018)	Conference	2018	Experiment	Solution Proposal	Control	Access Control	1	1	1	0.6	3.6
(Veena *et al.*, 2018)	Journal	2018	Survey	Evaluation Research	Monitoring	Soil Monitoring	1	1	1	1.5	4.5
(Ruan *et al.*, 2019)	Journal	2019	Experiment	Evaluation Research	Control	Fertilizer &Pesticides	1	1	1	2	5
(Muangprathub *et al.*, 2019)	Journal	2019	Experiment	Solution Proposal	Control	Fertilizer &Pesticides	1	1	1	2	5
(Grimblatt *et al.*, 2019)	Symposium	2019	Experiment	Solution Proposal	Monitoring	Plant Monitoring	1	1	1	0.4	3.4
(Araby *et al.*, 2019)	Conference	2019	Experiment	Solution Proposal	Monitoring	Plant Monitoring	1	1	1	0	3.4
(Abbasi *et al.*, 2019)	Conference	2019	Survey	Evaluation Research	Monitoring	Plant Monitoring	1	1	1	0	3.4

the system is very useful to monitor the crop. The IoT devices like sensors, RFID and GSM/GPS has used for sensing and monitoring the different agricultural parameters.

The following sub-domains have been recognized: air monitoring (20%), soil monitoring (17%) water monitoring (20%), plant monitoring (30%) and others (13%) have shown in Fig. 6. It is important to point out that many of the selected components recovered in this SLR can be distinguished from more than one sub domain.

Soil Monitoring: The selected study introduces a system for monitoring thesoil moisture and temperature from the field using a wireless sensor network. These soil monitoring systems have been protected by technologies of communications like ZigBee, GPRS, and Internet, in which the transactions between the farmer and the web application can be controlled (Chen *et al.,* 2014; Mafuta *et al.,* 2013).

Air Monitoring: The purpose of air monitoring has to provide continuous measurement, evaluating and defining environmental factors (forecast) to avoid from negative effects. In (Watthanawisuth, 2009) an IoT solution has been proposed for agriculture that can be distinguished for air monitoring. In this selected article, the actual micro-climate monitoring system has been developed that monitors the climate by using WSN. The solution consists of humidity and temperature sensors which have been powered with solar panels and maintained through ZigBee.

Water monitoring:In this sub domain, selected studies shows the monitoring of quality and pollution of water through sensing the chemicals, temperature and pH that can change natural condition of water. A (Postolache *et al.,* 2013) solution for assessment the quality of water has been developed from measurement and conductivity based on WSN architecture that integrate the sensing devices and monitoring quality of water in urban areas.

Plant monitoring: The system for plant monitoring has been presented in Patil *et al. (*2006), this experiment aimed to protect the crops of potato by monitoring the humidity and temperature by using wireless sensor network. The system has been designed with sensors which has capability to protect the crops from fungal disease.

Control: The selected articles under the domain of control have been used actuator devices (pumps, valves, humidifier and alarm) where data handled by using two way integration which means that communication is added and sensing commands can be forwarded to the field. This domain aims to improve the use of water, pesticides and fertilizer by collecting the sensing information of the weather forecasting and WSN-site(Culibrina and Dadios, 2015; Yoo *et al.,* 2007). The automated system of agriculture was developed that used IoT technology and mobile network to control and monitor agriculture system remotely. A management system for information was also developed to collect the data for monitoring agricultural parameter. This structure has facilitated the automatic control on greenhouse parameter like temperature, moisture issues (Zhao *et al.,* 2010). Overall, this solution with automated system can save money for the farmer and provide valuable insights on water use, pesticides and fertilizers.The following sub domains have been included in this SLR such as fertilization and pesticides (30%), irrigation (40%) and access control (30%) shown in Fig. 6.

Fertilizer and pesticide control: This IoT based solution has been categorized that uses maintenance activities to improve food production, crop quality and economy recovery. In (Zhang *et al.,* 2014) the authors propose a systematic approach to control disease and

pests. The system uses the amount of huge data which has been collected by sensors to build a platform of data for controlling and warning alert against pest or disease. Farmers can monitor what's happening in their wheat fields by using a PC or mobile device.
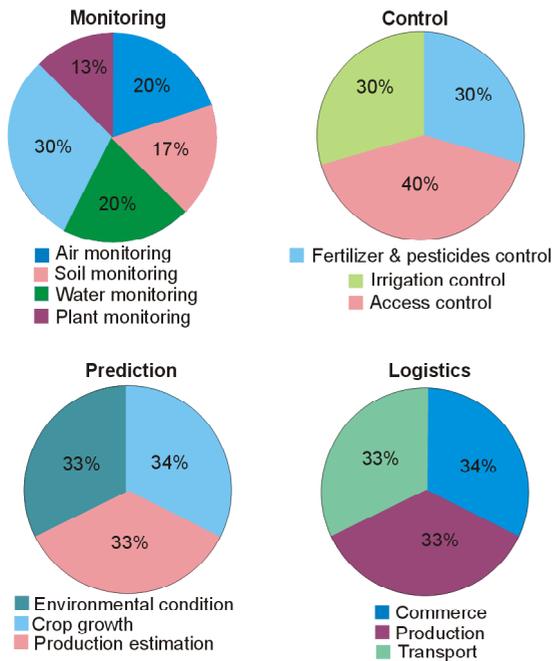

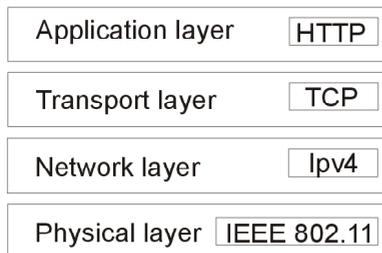**Fig. 6. Distribution of papers as per application sub domain**

Fig. 7. Communication layers and protocol

Irrigation control: In this sub domain, IoT based monitoring and management system has been developed for agriculture. This system included an eco-system which has been divided into layers such as sensing, transmission and application. The wireless sensor network has proposed to identify information related to environment of actual time inside a greenhouse and send the collected data to remote sensor for the control of irrigation (Jiao *et al.,* 2014). An irrigation control system has been proposed by using ZigBee. This system was solar powered which monitored and controlled the humidity and temperature (Shuwen and Changli, 2015).

Access control: A detection system for agricultural interruption was proposed by (Roy *et al.,* 2015), this system generated an alarm in the green house and

send a SMS to mobile phone of farmers when an intruder entered into the agricultural field.

Prediction: The selected articles have been classified into the domain of prediction which providing the tools and information to the farmers for making decision. A sensor network based on field data presented in (Lee *et al.,* 2012) which capture the soil moisture data through sensor nodes, analysis the information and send to farmers for further measurements. The soil moisture can be controlled through measured result and farmer can predict the production of crop. An IoT based system has been developed that combines drought monitoring and forecasting to improve the efficiency of protecting agricultural deficiency and resolve all kinds of problems (Luan *et al.,* 2015). The following sub domains have been categorized like production estimation (33%), crop growth (33%) and environmental conditions (33%) as shown in Fig 6.

Production estimation: The authors in (Lee *et al.,* 2013) proposed IoT solution to estimate production of agriculture. They achieved this target by sensing the factors of environment and developed prediction system for crops. In (Saville *et al.,* 2015) an estimation system has been developed for fixed-net fishery by using WSN to improve the weakness of existing approach.

Crop growth: Extensive exploration of farms using sensor has introduced in which intended to set up grain management plans for growth of grapes (Lee *et al.,* 2012). Smart agriculture system was developed which uses sensor and wireless network for monitoring the real condition of environment. This system gathers the actual-time data of agricultural production that gives the approach for agriculture facilitate like alerts by Short Messaging Service (SMS) and suggestions for weather sample and crops (Patil and Kale, 2016).

Environmental conditions: In this sub domain, the prediction of environmental condition has been proposed by(Luan *et al.,* 2015) and environmental prediction conditions has been described the process that involves monitoring and forecasting by using IoT.

Logistics: *Ag*ricultural production refers to the process of moving things and information that varies from manufacturer to consumer for need of customer satisfaction. It includes: agricultural production, purchases, shipping, storage, inventory and placement, packaging, distribution, and related activities. In (Liping, 2012) authors presented that the development of logistics not only provide transparent and efficient
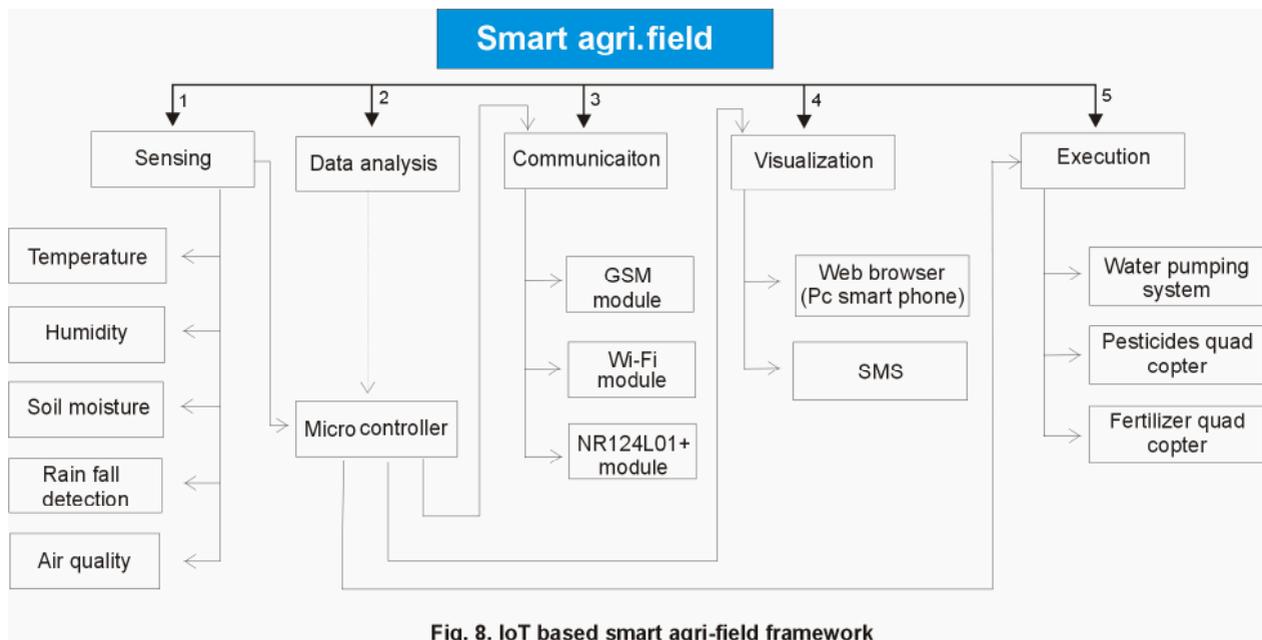
Fig. 8. IoT based smart agri-field framework

information to the business sector but also trim down the cost of agricultural products, protect farmers' needs and increase agricultural productivity. The following sub domains were categorized: production (33%), commerce (34%), transport (33%) as shown in Fig. 6.

Production: The cognitive system has been developed for monitoring an orchard of apple to support decision making. The system has been intended to reduce the apple processing costs improving apple value, efficient electronic delivery and guidelines for the planting services and tracking the quality of apples production. The system includes wireless sensor network using GPRS and ZigBee which provide complete data of apple growth to maintained the supply chain of farmers (Feng *et al.,* 2012).

Commerce: In this sub domain, an IoT based information system has been proposed for tracing and tracking all agricultural production activities. Likewise, the process of identifying information has been applied to capture, adapt, manage, locate and analyzes the data from agriculture. The system allows farmers to ask for information about farming the products to ensure their reliability and efficiency (Minbo *et al.,* 2013).

Transport: The IoT based architecture has been developed for the supply chain of food production which deals with logistics related to transportation of melon from Brazil to Sweden. The sensor nodes measure the atmosphere combination of carbon dioxide, oxygen, ethylene, temperature, mechanical stress to improve the quality of food (Pang *et al.,* 2015).

RQ6. How does the usage of IoT evolve in agriculture?

The results of selected 80 studies have been shown as a summary in Table 7. The studies have been explored one by one to identify the purpose of IoT in agriculture. The aim of this research question is to know that how IoT integrated in agriculture to provide better crop production by monitoring the fields.

Framework of IoT based smart agriculture

The framework of IoT based smart agriculture has been presented in Fig. 8.

Components

Arduino mega 2560 Rev 3: The Arduino Mega 2560 is ATmega2560 based microcontroller board which consists of 54 digital pins of input and output, 16 pins for analog, USB port for connectivity, crystal oscillator of 16 MHZ, power barrel jack, ICSP header and reset push button (Adel *et al.,* 2018).

ESP8266 module: The module ESP8266 is self-sufficient system on chip (SOC) integrated through TCP and IP (Protocol Layers) which has ability to permit the microcontroller to access the Wi-Fi network. ESP8266 has the ability to facilitate application or turn off all functionalities of Wi-Fi network from other processor of application (Rosli *et al.,* 2018).

The wireless transceiver module nRF24L01: The modulen Rf24L01 is 2.4 GHz wireless single chip which have baseband of protocol engine. The range of this transceiver module is 1100m and operates in the ISM (Industrial, Scientific and Medical) frequency band
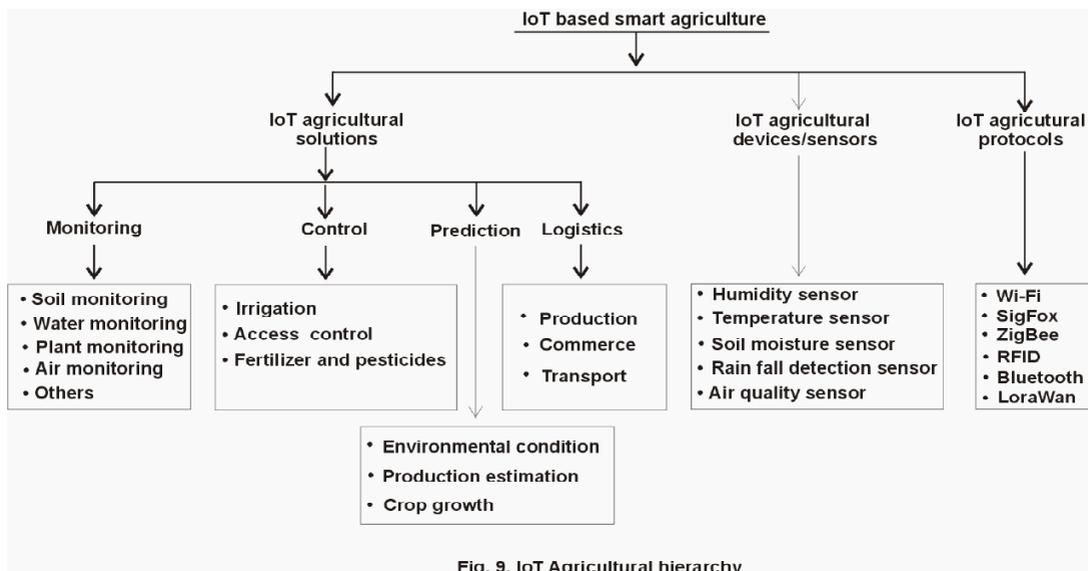
Fig. 9. IoT Agricultural hierarchy

is required for smart farming and it is responsible for transferring the data of agriculture to the layer of application. To support the technical capabilities like connectivity of network layer, the IP is a great deal which has two versions of IPv4 / IPv6. The IPv6 was designed because of increasing the numbers of addressing devices. In this case, the Wi-Fi module ESP8266 relies on the IPv4 for the communication of network layer(Wan *et al.,* 2019).

onthe frequency of 2.400-2.4835 GHz. This wireless transceiver module was developed to be adapted and controlled by serial peripheral interface (SPI) (Wang *et al.,* 2018).

Humidity and temperature sensor: This sensor has sensing capability to provide the digital output of humidity and temperature. The microcontroller is required to pair with this sensor for operation. The sensor consists of resistive element and devices of Negative Temperature Coefficient (NTC) for measuring the temperature. The NTC is an electronic device which is responsive, flexible and highly efficient.

MQ-135 Gas sensor: This sensor is utilized in control devices for air quality and detecting the NH3, Alcohol, smoke, benzene. The module MF-135 accompany with digital pins without microcontroller that enables this gas sensor to operate (Dorcea *et al.,* 2018).

Rainfall detection sensor: The sensor of rainfall is performed due to detector plate of water with a comparator who controlled the insight. This sensor detects the water when the water drops make the tape of interconnected printed circuits which is called short circuit. The sensor acts as an intermediate transformer: when the sensor cools then the resistivity level

increase and when sensor is dry then the resistivity level decrease. The comparator has two components related to sensor of rain or water detection, digital output and analog output (Yun *et al.,* 2017).

Sensor of soil moisture: This sensor is great module and perfect device to estimate the materials and soil moisture. The two major non-detector functions act as a probe for the sensor and acting as a transformer (Farooqui and Kishk, 2018).

Communication protocols and networks: IoT agricultural networks are based on a variety of high speed and short ranges networks for the communication. Many IoT based networks helps to design monitoring sensor and devices for agriculture. The protocols of communication are the strength of IoT based agricultural applications and networks which have been used for exchanging all sensing information of agricultural parameters on a network. Fig. 7 shows the protocols and communication layers.

Application Layer: The protocols (HTTP, MQTT, AMQP and Coap) which are used on application layerdue to high energy consumption and high computational complexity of IoT devices. The consumption of listed protocols could be increased or decreased as per their need. The module of Wi-Fi ESP8266 use HTTP as a default into application layer. The HTTP is popular protocol of web messaging based on system request and response which runs on TCP (Botta *et al.,* 2016).

Transport layer: This layer is referred to as the host to host and transmitted the data from IP to the IoT domain. The main purpose of transport layer has to collect and consolidated the data of agriculture that

Table 8. Source of Publication

Publication Source	Channel	No	%
SENSORS	Journal	2	2.50
ACM international wireless communications and mobile computing conference	Conference	2	2.50
International conference on geoinformatics	Conference	2	2.50
IEEE conference on wireless sensors	Conference	2	2.50
IEEE internet of things journal	Journal	2	2.50
IET science, measurement & technology	Journal	2	2.50
International Workshop on Database and Expert Systems Applications	Conference	1	1.25
IEEE international parallel & distributed processing symposium	Symposium	1	1.25
IEEE international symposium on consumer electronics	Symposium	1	1.25
international conference on intelligent sensors, sensor networks and information processing	Conference	1	1.25
international conference on sensor technologies and applications	Conference	1	1.25
Annual conference on information sciences and systems	Conference	1	1.25
ieee transactions on instrumentation and measurement	Journal	1	1.25
IEEE international conference on progress in informatics and computing	Conference	1	1.25
International conference on computer science and information technology	Conference	1	1.25
Joint IFIP wireless and mobile networking conference	Conference	1	1.25
IEEE transactions on wireless communications	Journal	1	1.25
International conference on ict convergence	Conference	1	1.25
International conference on sensing technology	Conference	1	1.25
Intelligent automation & soft computing	Journal	1	1.25
Software engineering and knowledge engineering	Journal	1	1.25
Advanced materials research	Journal	1	1.25
Safety science	Journal	1	1.25
IEEE pervasive computing	Journal	1	1.25
International conference on agro-geoinformatics	Conference	1	1.25
IEEE international conference on computational science and engineering	Conference	1	1.25
automatika	Journal	1	1.25
international conference on intelligent control and information processing	Conference	1	1.25
International symposium on distributed computing and applications to business, engineering & science	Symposium	1	1.25
Symposium on environmental instrumentation and measurements	Symposium	1	1.25
International journal of distributed sensor networks	Journal	1	1.25
International conference on advanced technologies for communications	Conference	1	1.25
IEEE international work-conference on bioinspired intelligence	Conference	1	1.25
International symposium on communications and information technologies	Symposium	1	1.25
IEEE transactions on industrial informatics	Journal	1	1.25
IEEE transactions on instrumentation and measurement,	Journal	1	1.25
Advance journal of food science and technology	Journal	1	1.25
International conference on wireless communication and sensor network	Conference	1	1.25
IEEE international conference in information science and technology	Conference	1	1.25
International conference on innovative mobile and internet services in ubiquitous computing	Conference	1	1.25
International conference on informatics, electronics & vision	Conference	1	1.25
IEEE geoscience and remote sensing symposium	Symposium	1	1.25
International conference on intelligent systems design and engineering applications	Conference	1	1.25
International conference on computer and computing technologies in agriculture	Conference	1	1.25
International wireless communications and mobile computing conference	Conference	1	1.25
International conference on circuits, power and computing technologies	Conference	1	1.25
International journal of distributed sensor networks	Journal	1	1.25
International conference on computer, communication, control and information technology	Conference	1	1.25
International conference on information networking	Conference	1	1.25
IEEE international conference on communications	Conference	1	1.25
International journal of sustainable development & world ecology	Journal	1	1.25
IEEE sensors	Journal	1	1.25
IEEE international conference on intelligent sensors, sensor networks and information processing	Conference	1	1.25
Journal of network and computer applications	Journal	1	1.25
OCEANS	Journal	1	1.25
IEEE international conference on computing & communication technologies	Conference	1	1.25
International conference on humanoid, nanotechnology, information technology, communication and control, environment and management	Conference	1	1.25
International conference on computational sciences	Conference	1	1.25
IEEE international conference on information and automation	Conference	1	1.25
Information systems frontiers	Journal	1	1.25
IEEE international microwave symposium	Symposium	1	1.25
International conference on cyberworlds	Conference	1	1.25
International conference on global trends in signal processing, information computing and communication	Conference	1	1.25
International conference on information systems, logistics and supply chain	Conference	1	1.25
International conference on intelligent computing and control	Conference	1	1.25
International telecommunication networks and applications conference	Conference	1	1.25
International conference on intelligent computing, instrumentation and control technologies	Conference	1	1.25
International conference on advanced computing and communications	Conference	1	1.25
International journal of innovative research in engineering & management	Journal	1	1.25
IEEE communications magazine	Journal	1	1.25
Computers and electronics in agriculture	Journal	1	1.25
International symposium on circuits and systems	Symposium	1	1.25
International conference on modern circuits and systems technologies	Conference	1	1.25
International conference on internet of things and applications	Conference	1	1.25
International conference on microelectronic devices, circuits and systems	Conference	1	1.25

Table 9. Focus of IoT in agriculture

References	Major focus	References	Major focus
(Patil *et al.,* 2006)	The WSN architecture was used to design two monitoring principles in agricultural practice: continuous monitoring (CM) and query-based monitoring (QM).	(Langendoen *et al.,* 2006)	The experiment was setup with sensors nodes to monitor the humidity and temperature into the potato field.
(Yoo *et al.,* 2007)	This paper describes the results of deployment for an improved automation system that incorporates WSN to monitor and manage the farm.	(Jain *et al.,* 2008)	This paper presents a workflow approach for monitoring micro-climate using WSN.
(Hakala *et al.,* 2008)	WSN is widely used in monitoring of agriculture. CiNet network, sensing application and node architecture is introduced.	(Watthanawisuth *et al.,* 2009)	This paper developed the design and implementation of system which monitored the actual micro-climate by using ZigBee.
(Khandani and Kalantari, 2009)	To design a sensor network for soil moisture measurements, soil moisture extraction data known as SMEX03 which used to evaluate the moisture of the soil.	(Marino *et al.,* 2010)	The sensor based wireless distributed network is designed to provide real-time measurements for the validity of different biological models using viticulture.
(Salas *et al.,* 2014)	This study presents the GPRS-based environmental management system (GEMS) which collected meteorological data to influence the production of apple.	(Zhao *et al.,* 2010)	Remote monitoring system with internet and wireless networks are used to control the actual condition of agricultural production.
(Jiber *et al.,* 2011)	Introduced a framework that is easy to use and expand agricultural monitoring services to improve yield through better water management.	(Charoenpanyasak *et al.,* 2011)	The network of wireless sensors and ZigBee has been deployed to monitor and control the temperature.
(Ehsan *et al.,* 2012)	To monitor animals, this article has been concerned with analysis and design of delay-tolerant networks (DTNs).	(Lee *et al.,* 2012)	The dynamic field analysis system was designed using a mobile sensor node. Analysis of a field like trend, interaction becomes more efficient.
(Mittal *et al.,* 2012)	Introduces the platform of sensor network and designed a sensor network of low cost for smart agriculture.	(Ma *et al.,* 2012)	The IoT model of the aquaculture information system was developed with wireless sensors and mobile internet to remote real-time data prediction.
(Liping, 2012)	Analyzed the problems and status of agricultural logistics development with guiding principles.	(Feng *et al.,* 2012)	To lower the cost of information management and monitor the apple plantations, wireless sensor technology applications are being implemented using Zigbee, GPRS and IoT.
(Sun *et al.,* 2012)	An tailing dam monitoring and pre alarm system (TDMPAS) was developed which based on IoT and integrates cloud computing with actual monitoring for level of water.	(Ye *et al.,* 2013)	This system depends on the Internet of Things (IoT) and Web GIS to monitor the production of precision agriculture.
(Pahuja *et al.,* 2013)	Introduce a system which monitor the microclimate of greenhouse and analyzed the humidity of crops using Zigbee.	(Smarsly, 2013)	The initial results introduced the implementation of a low cost wireless monitoring system for ecosystem of agriculture.
(Lee *et al.,* 2013)	The IoT monitoring system has been developed to analyze the conditions of crop and a way to improve the effectiveness by using the nodes of sensor.	(Minbo *et al.,* 2013)	The distributed architecture and information system has been presented which depends upon IoT for monitoring the production of field.
(Liu *et al.,* 2013)	Developed an IoT integrated warning and monitoring system for lakes which based on the WSN, ZigBee, mobile internet, web services, predictive analytics and expert advice.	(Jiang and Zhang, 2013)	Design a scheme for information service platform of agriculture which based on the IoT to provide the guidelines for better crop production.
(Postolache *et al.,* 2013)	Design the architecture of WSN that combines the low-cost wireless sensor nodes and a wide range of sensing parameters for efficient monitoring the quality of water.	(Mafuta *et al.,* 2013)	Demonstrate how the irrigation management system (IMS) could be implemented by installing WSN.
(Vo *et al.,* 2013)	It provides a framework of WSN to monitor the impact of climate change on the fields. This system includes two support stations and some nodes of sensor which operating with the solar cell.	(Chavez *et al.,* 2014)	Implementation of an affordable low cost irrigation system has been presented which uses wireless sensor networks to provide technical equipment to farmers for reliable crop production.
(Soontranon *et al.,* 2014)	It presents monitoring system for agriculture in Thailand. Many types of plants have been observed directly from green fields.	(Fang *et al.,* 2014)	It presents an IIS report that combines the IoT, cloud computing, Geo-informatics and e-Science to monitor environmental issues using web services and sensor nodes.
(Gutiérrez *et al.,* 2013)	Developed an irrigation system which has been automated to improve use of water for crops. This system has wireless network of temperature sensor and soil-moisture sensor that have placed in plants.	(Jiao *et al.,* 2014)	The IoT based monitoring system has been presented in which software and hardware was designed for routers / coordinators.
(Chen *et al.,* 2014)	The system was developed for monitoring the soil temperature and humidity which based on the wireless sensor network by using core ship CC2530. The system consists of gateway node, 3 monitoring sensor nodes and a system platform.	(Fourati *et al.,* 2014)	The principles currently being presented to implement a web based decision support system which communicate with the WSN for planning of irrigation.
(Pokric *et al.,* 2014)	Presents the ekoNET solution for actual monitoring of air pollution and weatherparameters like temperature, humidity and air pressure which depends upon low cost energy and climate sensors.	(Islam *et al.,* 2014)	This research combines the implementation &design of a water monitoring system which provides the solutions to monitor levels of water, warning alerts, send notifications to farmer's phone when the water reached at critical level.
(Sawant *et al.,* 2014)	An attempt was made to upgrade KrishiSense. A web-based approach was developed that enables rapid understanding of the wireless sensing system for application of smart agriculture by multiple protocols and distributed web formats.	(Khriji *et al.,* 2014)	Improved irrigation solution was presented to the farmer which based on WSN. The system consists of differentsensing nodes. Every sensing node consists of telosB mote and tolerable actuator.
(Valenzuela *et al.,* 2018)	The field monitoring approach has been introduced in the application process model based on the systematic framework and ZigBee for crop production.	(Tao *et al.,* 2013)	An intelligent granary management system (IGMS) has been designed and succeeded for agriculture which depends upon the IoT, the IOT gateway.
(Kaewmard and Saiyod, 2014)	Develop advanced measurement sensing technology including sensors of ground moisture, air sensors and the air humidity sensors. Likewise, the irrigation system has installed these sensors by using a WSN.	(Li *et al.,* 2014)	Presented the design and implementation of a monitoring system which has been collected the actual data, transfer data automatically and give control capabilities for monitoring temperature, humidity.

References	Major focus	References	Major focus
(Mathurkar *et al.,* 2014)	Upgrade the system of monitoring for agriculture through Field Programmable Gate Array (FPGA) that includes wireless protocols, microcontroller, types of sensors serial protocol and programmable gate array with display equipment.	(Eom *et al.,* 2014)	Introduced monitoring system for meat and use-by date based on RFID. The system includes RFID tag, sensor of humidity, sensor of gas, sensor of temperature, reader and server.
(Postolache *et al.,* 2014)	It introduces architecture of wireless sensor network that combines sensing nodes of low cost for efficient monitoring of water quality parameters.	(Kar and Kar, 2015)	A novel concept has been presented about a combined spectrometric sensor platform. The design and functionality of the tools and software for this system has been discussed and its potential applications are explored for better agricultural cultivation.
(Chen *et al.,* 2015)	IoT has seen significant development, the routing protocol IPv6 for low power and lossy networks that offers a robust and flexible system which could be used in agricultural applications.	(Kuroda *et al.,* 2015)	Launched a high-speed sensor network to greenhouse, utilizing a 400MHz band and high-frequency power station.
(Roy *et al.,* 2015)	The hardware prototype was introduced by using the wireless sensor network (WSN) to detect intruders into the crop field.	(Zheng *et al.,* 2016)	Describe the EIoT Environmental IoT monitoring system for canal construction that monitors and control the water resources.
(Luan *et al.,* 2015)	Developed an integrated approach that incorporates first-hand monitoring, forecasting and irrigation calculations to the platform based on Internet of Things technology.	(Ryu *et al.,* 2015)	It introduces a farm connected to the IoT system, which aims to provide an efficient farming system to end users.
(Jayaraman *et al.,* 2015)	Discusses a new IoT platform that demonstrates its efficacy and quality in many use cases, including the use case of digital architecture (Phenonet) for monitoring agricultural parameters.	(Marjanović *et al.,* 2016)	It presents a frame function for Green Mobile Crowd Sensing (G-MCS) that uses advanced sensor management to continue selecting sensors for optical sensing.
(Saville *et al.,* 2015)	ICT applications of actual monitoring systems have been introduced to quantify the catch amount within set-nett. To support the fishermen for avoiding difficulties real-time monitoring systems have been introduced based on the ICT.	(Tanumihardja and Gunawan, 2015)	The need to monitor water levels of troughs is increasing. Combined with WSN and IoT, cattlemen can track disturbed areas using their electronic devices.
(Nguyen *et al.,* 2015)	Provides a framework for WSN which designed to monitor the impact of climate change on fields. The life cycle includes two base stations and some sensors that operate through the solar system.	(Culibrina and Dadios, 2015)	Introduce the WSN network to collect environmental data and send control instructions to turn on / off irrigation systems and control divisions.
(Shuwen and Changli, 2015)	This paper is best suited to ZigBee and configuration technologies for designing remote irrigation systems. The designed system is powered by solar energy.	(Zhao and Zhu, 2015)	The system provides a type of digital wireless remote sensing monitoring platform for agricultural cultivation by using radio transmitting, Bluetooth wireless technology, and GPRS.
(Pang *et al.,* 2015)	Offer a collaborative business model using digital technology. According to this model, the cost of income associated with improved agricultural productivity and lower guaranteed costs has been identified.	(Sales *et al.,* 2015)	This paper proposes and evaluates the cloud based actual operation of the Wireless Sensor and the wireless sensor and actuator network (WSAN). This solution monitors and controls the sensors and operators, respectively, to determine the requirement of aquatic plants.
Nguyen *et al.,* 2015)	WSN nodes has been reported for agriculture. Each node includes an efficient harvesting of hardware, a System-on-Chip (SoC) integrated smart transceiver like bluetooth, and a wide range of sensors to monitor environmental factors.	(Xu *et al.,* 2015)	Combined with sensor networks, cellular networks and remote sensing technologies, a monitoring platform is being developed and maintained which can monitor environmental parameters like soil moisture, temperature, humidity.
(Patil and Kale, 2016)	Sensor and IoT wireless networks are studied and the actual nature of agricultural systems is reviewed. An integrated approach with internet and wireless communication, Reliability Monitoring System (RMS) is introduced.	(Capello *et al.,* 2016)	The solution is accepting the Industrial Internet of Things (IIoT) technology, which allows full control over all food chain processes.
(Rajeswari *et al.,* 2017)	Cloud based analysis has been used to search for data of fertilizer, exploration of crops. The data is then analyzed based on technique of data mining, then information reached to the farmer's phone.	(Uddin *et al.,* 2017)	The Unmanned Aerial Vehicle (UAV) has been used to detect and enable ground IoT devices to create them in convergence and set up a secure network connection to transmit data.
(Jha *et al.,* 2017)	The Arduino Microcontroller panel is used with ground, temperature and high humidity to collect data from the field. The information received is analyzed and discussed.	(Mekala and Viswanathan, 2017)	Some applications of the IoT sensor monitoring network technologies have been explored. This study has been used to recognize different technologies and to build better agricultural practices. The IoT smart model has addressed the smart agriculture.
(Heble *et al.,* 2018)	In this paper, authors present a robust, cheaper IoT network for smart agriculture. To monitor moisture in soil, sensors have been used for analysis and measurement.	(Yoon *et al.,* 2018)	Smart and automated farm system was developed in existing farm by using Low Power Wide Area Network (LPWAN) and Bluetooth.
(Veena *et al.,* 2018)	The system offers improved monitoring system for soil moisture intruder detection parameters by using IoT. This allows for efficient soil moisture control and mechanical operation.	(Ruan *et al.,* 2019)	Address that technological advances provide sensors and efficient networks which have advance future applications, but it must quickly address the challenges that are relevant to the development agricultural environment.
(Muangprathub *et al.,* 2019)	Developed a proper and efficient irrigation system for crops by using WSN. This project aims to design and optimize control systems using sensors in the crop and data management through mobile phones or web applications.	(Grimblatt *et al.,* 2019)	This system can gives the solutions for agricultural parameters to grow the plant by a set of sensors and make possible to fix some of these parameters by actuators as per required.
(Araby *et al.,* 2019)	A sensing network has deployed to collect field data from certain crops (Potatoes, Tomatoes, etc.), then feed these data to a machine learning algorithm to get the warning message, then showing both the warning message and data through a Graphical User Interface (GUI).	(Abbasi *et al.,* 2019)	The nature of research, predictions, IoT challenges and applications of IoT in agriculture have been analyzed.

Table 10. Quality assessment

References	Score	Total
(Watthanawisuth *et al.,* 2009; Marino *et al.,* 2010; Ma *et al.,* 2012; Sun *et al.,* 2012; Pahuja *et al.,* 2013; Fang *et al.,* 2014; Gutiérrez *et al.,* 2013; Eom *et al.,* 2014; Chen *et al.,* 2015; Zheng *et al.,* 2016; Ryu *et al.,* 2015; Pang *et al.,* 2015; Sales *et al.,* 2015; Heble *et al.,* 2018; Veena *et al.,* 2018; Ruan *et al.,* 2019).	5	16
(Ehsan *et al.,* 2012; Minbo *et al.,* 2013; Mafuta *et al.,* 2013; Jiao *et al.,* 2014; Khriji *et al.,* 2014; Postolache, Pereira and Girão, 2014; Marjanović *et al.,* 2016; Saville *et al.,* 2015; Veena *et al.,* 2018).	4.5	9
(Feng *et al.,* 2012)	4	1
(Chen *et al.,* 2014; Shuwen and Changli, 2015)	3.95	2
(Langendoen *et al.,* 2006; Jain *et al.,* 2008; Jiber *et al.,* 2011; Vo and Vo, 2013; Li *et al.,* 2014; Kuroda *et al.,* 2015; Roy *et al.,* 2015; Jayaraman *et al.,* 2015; Nguyen *et al.,* 2015; Xu, Zhang *et al.,* 2015; Uddin *et al.,* 2017; Yoon *et al.,* 2018).	3.6	12
(Zhao *et al.,* 2010)	3.5	1
(Khandani and Kalantari, 2009; Ye *et al.,* 2013; Liu *et al.,* 2013; Postolache *et al.,* 2013; Valenzuela *et al.,* 2018; Kar and Kar, 2015; Capello *et al.,* 2016; Rajeswari *et al.,* 2017; Jha *et al.,* 2017; Mekala and Viswanathan, 2017; Grimblatt *et al.,* 2019; Araby *et al.,* 2019; Abbasi *et al.,* 2019)	3.4	13
(Patil *et al.,* 2006; Yoo *et al.,* 2007; Salas *et al.,* 2014; Zhao *et al.,* 2010; Charoenpanyasak *et al.,* 2011; Lee *et al.,* 2012; Lee *et al.,* 2013; Jiang and Zhang, 2013; Chavez *et al.,* 2014; Islam *et al.,* 2014; Tao *et al.,* 2013; Kaewmard and Saiyod, 2014; Mathurkar *et al.,* 2014; Luan *et al.,* 2015; Culibrina and Dadios, 2015; Nguyen *et al.,* 2015; Patil and Kale, 2016)	3	17
(Fourati *et al.,* 2014)	2.9	1
(Hakala *et al.,* 2008; Mittal *et al.,* 2012; Smarsly, 2013; Postolache *et al.,* 2013; Soontranon *et al.,* 2014)	2.5	5
(Sawant *et al.,* 2014; Zhao and Zhu, 2015)	2.4	2
(Jayaraman *et al.,* 2015)	2	1

are accessed by sensors. It has two communication protocols which areUser Datagram Protocol (UDP) and Transmission Control Protocol (TCP). The ESP8266 depend on the TCP protocol for operations of transport layer which guarantees the integrity of transferred data (Papastergiou *et al.,* 2016).

Network layer: This layer is an area of technology that is required for smart farming and it is responsbile for transferring the data of agriculture to the layer of application. To support the technical capabilities like connectivity of network layer, the IP is a great deal which has two varsions of IPv4/IPv6. The IPv6 was designed because of incresaing the number of ESP8266 relies on the IPv4 for the communication of network layer (Wan *et al.,* 2019)

The research area of IoT in agriculture has increased since 2013, 2014, 2015 and 2019 as they were the years in which the 56% selected papers have been published in conference, 34% papers published in journals and 10% papers published in symposia. The quality of the publication indicates that in future the attention of agricultural explorer will increase.

The selected papers 86% of the experiments, 8% of case studies and only 3% of survey have been conducted by the authors. In the domain of IoT in agriculture the ratio of experiments (Ehsan *et al.,* 2012; Jiang and Zhang, 2013; Sawant *et al.,* 2014) are high because authors do the personal experience

to enhance the productivity and management of crops. All of the selected papers are empirically validated for this systematic mapping study.

Approximately 58% of the selected papers provide IoT solutions for agriculture. These results indicate that the field of IoT in agriculture has not yet reached to maturity level of evaluation. The objective of the solution proposals (Culibrina and Dadios, 2015; Li *et al.,* 2014; Luan *et al.,* 2015; Mafuta *et al.,* 2013) indicates the awareness of farmers that existing methods of agriculture are not more efficient than IoT. This is also evidenced by the fact that the experiences of authors (Kaewmard and Saiyod, 2014; Khandani and Kalantari, 2009; Patil *et al.,* 2006 have been presented in the empirical literature, while solution proposals have also presented to get information for related domain.

The selected papers have been categorized into four domains as per the solution of IoT in agriculture like monitoring, control, prediction and logistics. About 52% of the selected papers still focus on monitoring, 25% for control and the ratio of other domains are less. Like monitoring the researchers should focus on prediction and logistic because it needs the more attention to discover smart agriculture. Only monitoring and controlling is not enough to automate the agricultural fields. Prediction needs more attention of researchers.

Hierarchy of IoT in agriculture: The finest findings of SLR have been précised by designing the hierarchy of

IoT in agriculture which has been shown in Fig. 9. The developed hierarchy of smart agriculture contains the three main functions. The functions or activities were IoT based agricultural solutions, sensors and protocols of communication that consolidate many of the findings which have been investigated in this paper. IoT agricultural solutions with their sub domains monitor, control, prediction and logistics have been discussed in the section 3 (RQ5). The IoT agricultural sensors/ devices provide important information by sensing and monitoring the multiple agricultural parameters by using wireless sensor network. the collected data from sensors has been transmitted over protocols of communication (Bluetooth, ZigBee, RFID, SigFox, Wi-Fi, LoraWan) to other plateforms for farmer viewing.

The open challenges and issues: There have been various challenges which can be raised about agriculture. Some challenges have been mentioned below.

Implementation and maintenance: Implementation and maintenance of IoT based agricultural system into the large area of field can bea major challenge to resolve issues.

Lack of technology awareness: Lack of accepting the IoT technology is a major problem in the farmers of rural areas which is mutual problem for the development of every country, where many farmers are illiterate (Elijah *et al.,* 2017). Implementing IoT in agriculture is a big challenge, as many investments are required to train the farmers before installation of IoT tools in the field.

Reliability: The extreme bad environmental conditions can lead to communication failure and degradation of deployed resources Sensor because the IoT tools are deployed in open agricultural field (Asikainen *et al.,* 2013). That's why it becomes significant to guarantee the security of IoT sensors and devices for protecting from adverse condition of weather.

Scalability: The IoT sensors and devices were installed into the field of agriculture, as a resulta refined IoT control system is required to detect and control the each sensor's node (Al-Fuqaha *et al.,* 2015).

Data transparency: An IoT device deals with sensitive agricultural information to use the services of IoT cloud. That's why the services of data transparency must be developed to trace and control the sensed data of agriculture.

Advice for farmers: After examining the selected papers for this SLR the following list is summarized at

agriculture explorer who intends to contribute for the IoT solutions in agriculture and environmental fields. The studies mentioned in this SLR were selected by considering their content. The selected studies provide practical guidance for the IoT solution in agriculture, were divided among those found in the phase of study selection by reading their abstracts.

Learn how to identify the scope of problems and avoid inappropriate information. Researchers can take questionnaire answers from farmers to assess their crop qualities. The results of this questionnaire helped farmers to manage field that show good work. The farmers should take advantage of IoT technology because using IoT can help to improve the cultivation. The IoT could be enabled to integrate a service that permits to have a common storage of data, further interaction among farmers and agricultural experts. Farmers should be involved in business models that support the chances of profit from the data accumulated of their fields using the IoT technology. Mostly among the IoT platform providers, they are offering free limited services and full service with different level of subscriptions. The data provided are exploited by the IoT service providers and this remains an area of contention by farmers for control and ownership of their data (Farooq *et al.,* 2019).

Physical layer: This layer is the bottom layer of IoT based agriculture system that is responsible for detecting and activating multiple parameters of agriculture. In this layer, the IEEE 802.11 is most significant standard which is designed for low difficulty, low cost and low consumption. The IEEE 802.11 operates in the 2.4 GHz and 5 GHz ISM band which are not licensed that's why ESP8266 module operates in 2.4 GHz band (Wang *et al.,* 2019).

The framework of IoT based smart agriculture consists of five interrelated sub-systems. The sub-systems which interconnected with each other are sensing (Kaewmard and Saiyod, 2014) , data analysis (Li *et al.,* 2019) communication (Wang *et al.,* 2015), visualization (Dachyar *et al.,* 2019) and execution. The sub-system of sensing has been interrelated with sub-system of data analysis that collected data of every sensor manipulated, processed and then analyzed with the help of algorithms which are implemented in Micro controller unit for the visualization and execution (AshifuddinMondal and Rehena, 2018). The nodes of wireless sensor have to be installed depends upon the area being cultivated. Each of these wireless sensors nodes have been fitted with the required sensors. Every sensor has been collected the data from the agricultural parameters and then data has processed through a microcontroller. The sensor of humidity and

temperature has been sensed the required factor of the agricultural field, a sensor of barometric pressure has used to measure the pressure of atmospheric for the prediction of weather. The sensor of water detector has used to sense the rainfall (if agricultural field is not too large then by temporarily detecting of rainfall neutral and automatic systems can trigger the shedding system to prevent crop damage from the rainfall). The soil moisture sensors has used to measure the quantity of moisture in soil. The process of visualization of manipulated data of sensor has been depended upon the sub-system of communication due to visualize sensed data through PC or mobile. That's why it has to be linked with communication module as per dependency of visualization process. All data of sensors has been transferred to central node by using the module nRF24L01. By using the module nRF24L01 as a central receiver, the data of every sensor node has been collected. The value of threshold has been fixed into the center of microcontroller unit for every sensor. A central node continues to compare the agricultural data of sensors fromthe node of wireless sensor and if resultant value of threshold exceeds or less than the fixed value, the central node has been send the data of sensor and send a message to smart phone through GSM. The proposed framework has the ability to monitor sensed data of any node of wireless sensor via webpage, smart phone or PC through the module of Wi-Fi ESP8266 (Mesquita *et al.,* 2018). The visualization process means that if a farmer needs to view the sensed data through a web browser, the Wi-Fi module of IoT has required, if he needs to get message alert on smart phone than the module GSM needed and if he wants to get envision on Arduino like serial monitoring or sketch then nRF24L01 module is required (Wu *et al.,* 2019). The intelligent system has the ability to decide and execute based on the sensor data that generated by sensing the agricultural parameters which have been major concern of the IoT based smart agriculture. The central node is equipped with the ability to perform certain automatic functions like relying on sensed data of the soil moisture sensors (Han *et al.,* 2014) the automated pumping system of water can be start to pump the water into the field of agriculture. It can send an alert to the farmer through sensor of pH when fertilizers have needed in agricultural field. The spraying of pesticide and fertilizer can also treated with agricultural copter to protect the crops against diseases.

Quality assessment

The quality assessment score for each paper is signified in Table 10. About 52% papers of selected studies have above than average score and 36% papers of selected

studies have an average score whereas 12% papers have low average score. IoT agricultural scholars can select related studies with the help of this quality assessment criteria described in methodology section.

The results related to this Systematic Literature Review have been discussed as follows.

Principle findings

The purpose of this SLR has to research the current knowledge in the field of IoT in agriculture by selecting 80 papers. They have been classified according to the following criteria: research type, empirical type, IoT based solution and their sub domains. The principal findings of this paper study are following:

The research area of IoT in agriculture has increased since 2013, 2014, 2015 and 2019 as they were the years in which the 56% selected papers have been published in conference, 34% papers published in journals and 10% papers published in symposia. The quality of the publication indicates that in future the attention of agricultural explorer will increase.

The selected papers 86% of the experiments, 8% of case studies and only 3% of survey have been There are different tools for that can be found in marketplace. Scholars should be known about current structures of IoT tools and should also be taught that how a farmer can choose the best tool for his field (Marino *et al.,* 2010).

Moreover, in our country government and media should address the technical solutions related to the problems of agriculture and IoT is best option for the development of economy.

Threats to validity: Three different types of threats are following:

Selection of publications: The research methodology has been presented in section 2. This systematic literature review has general guideline to choose finest and important appropriate study. We present the strategy of selection which used to select the appropriate readings. But there was still a possibility that some studies were ignored. The major cause for this problem was the existence of gray literature such as technical report and data of Ph.D. In this case, this literature could be important, if the authors present the whole studies but they just reported incomplete studies. That's why thesis of Ph.D. was not included. The second issue was the struggle of finding the relevant search string. In section 2, justifications are given for the selection of source repositories and the search string used to explore the related articles to be used in this SLR.

Inaccurate data extraction: The cause for this possibility was the deficiency of accurate data from the

selected studies. This is may be due to the extraction of unstructured or inconsistency of data. First, we tried to minimize the risk of inaccurate data by concentrating on the material collected from the selected studies. Second, all extracted data were reviewed three times. The validate and experimental studies were focused. Their experimental process and design sorts it possible to collect the papers accurately.

Problem of quality assessment: Improving the quality of selected studies was a problem which may lead incorrect results. It was not easy to classify the quality assessment due to the nature of steps. For this purpose, we set up the proposed framework presented in Table 7. This framework enables researchers to evaluate and selection of empirical studies to ensure the quality of the data they need in accordance.

CONCLUSION

This article introduces an SLR into the domain of IoT in agriculture that sum up discussion of quality based research papers published in well-known journals and conferences. The study has conducted by using systematic approach to select 80 studies for further classification. An exploration of selected articles has been presented which includes various research types, empirical validation of studies, IoT agricultural solutions, communication protocols, sensors and practice of IoT in agriculture. In addition to this, the framework has been presented to show all key elements of IoT in agriculture. The agriculture has become one of the major issue of the world due to the much growing in population and the demand of agricultural facilities has also increased so it has been very important to provide sufficient nutrients to enrichment. This is why researchers can delve deeper into the development of modern agricultural systems.Hopefully, this article will be of great help for researchers to practice IoT knowledge related to sustainable agriculture as this article incorporates the above mentioned points.

ACKNOWLEDEGEMENTS

REFERENCES

Abbasi, M., M.H. Yaghmaee and F. Rahnama. 2019. Internet of Things in agriculture: A survey. 3rd International Conference on Internet of Things and Applications (IoT), Italy.

Adel, Z., A.A. Hamou and S. Abdellatif. 2018. Design of Real-time PID tracking controller using Arduino . Computer Science. DOI:10.1109/CISTEM.2018.8613560.

Al-Fuqaha, A., M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash. 2015. Internet of things: A survey on enabling technologies, protocols, and applications. IEEE Communications Surveys & Tutorials, 17(4):2347-2376.

Araby, A.A., M.M.A. Elhameed, N.M. Magdy, N. Abdelaal, Y.T.A. Allah, M.S. Darweesh, H. Mostafa. 2019. Smart IoT Monitoring System for Agriculture with Predictive Analysis. 8th International Conference on Modern Circuits and Systems Technologies (MOCAST). Delhi Technical University, India.

Ashifuddin Mondal, M. and Z. Rehena. 2018. Iot based intelligent agriculture field monitoring system. 8th International Conference on Cloud Computing, Data Science & Engineering (Confluence), Delhi, India.

Asikainen, M., K. Haataja and P. Toivanen. 2013. Wireless indoor tracking of livestock for behavioral analysis. 9th International Wireless Communications and Mobile Computing Conference (IWCMC), Sardinia, Italy.

Botta, A., W. De-Donato, V. Persico and A. Pescapé. 2016. Integration of cloud computing and internet of things: a survey. Future generation computer systems, 56:684-700.

Capello, F., M. Toja and N. Trapani. 2016. A real-time monitoring service based on industrial internet of things to manage agrifood logistics. Proceedings of the 6th International Conference on Information Systems, Logistics and Supply Chain, Bordeaux, France, Available from: http://ils2016conference.com/wpcontent/uploads/2015/03/ILS2016_FB01_1. pdf, Accessed.

Charoenpanyasak, S., W. Suntiamorntut, T. Phatthanatraiwat and J. Ruksachum. 2011. Smart shrimp hatchery using mikros platform. 4th Joint IFIP Wireless and Mobile Networking Conference (WMNC 2011), Sydney, Australia.

Chavez B.P., I. Marin-Garcia and A. Muñoz-Arcentales. 2014. Ad-hoc network implementation and experimental testing using low cost and COTS components: An ecuatorian case study. 3rd IEEE International Work-Conference on Bioinspired Intelligence, Madrid, Spain.

Chen, K.T., H.H. Zhang, T.T. Wu, J. Hu, C.Y. Zhai and D. Wang. 2014. Design of monitoring system for multilayer soil temperature and moisture based on WSN. International Conference on Wireless Communication and Sensor Network. MacArthur Blvd., Bourne.

Chen, Y., J.P. Chanet, K.M. Hou, H. Shi and G. De Sousa. 2015. A scalable context-aware objective function (SCAOF) of routing protocol for agricultural low-power and lossy networks (RPAL). Sensors, 15(8):19507-19540.

Culibrina, F.B. and E.P. Dadios. 2015. Smart farm using wireless sensor network for data acquisition and power control distribution. International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM). Peru.

Dachyar, M., T.Y.M. Zagloel and L.R. Saragih. 2019. Knowledge growth and development: internet of things (IoT) research, 2006–2018. Heliyon, 5(8): 55-61.

Dorcea, D., M. Hnatiuc and I. Lazar. 2018. Acquisition and calibration interface for gas sensors. 24th International Symposium for Design and Technology in Electronic Packaging(SIITME). Iasi, Romania.

Ehsan, S., K. Bradford, M. Brugger, B. Hamdaoui, Y. Kovchegov, D. Johnson and M. Louhaichi. 2012. Design and analysis of delay-tolerant sensor networks for monitoring and tracking free-roaming animals. IEEE Transactions on Wireless Communications, 11(3):1220-1227.

Elijah, O., I. Orikumhi, T.A. Rahman, S.A. Babale and S.I. Orakwue. 2017. Enabling smart agriculture in Nigeria: Application of IoT and data analytics. 3rd International Conference on Electro-Technology for National Development (NIGERCON). Comp. Sci. DOI: 10:1109/NIGERCON.2017.8281944.

Eom, K.H., K.H. Hyun, S. Lin and J.W. Kim. 2014. The meat freshness monitoring system using the smart RFID tag. International Journal of Distributed Sensor Networks, 10(7):591-603.

Fang, S., L. Da Xu, Y. Zhu, J. Ahati, H. Pei, J. Yan, and Z. Liu, Z. 2014. An integrated system for regional environmental monitoring and management based on internet of things. IEEE Transactions on Industrial Informatics, 10(2):1596-1605.

Farooq, M. S., S. Riaz, A. Abid, K. Abid and M. A. Naeem. 2019. A Survey on the Role of IoT in Agriculture for the Implementation of Smart Farming. IEEE Access, 7:156237-156271.

Farooqui, M.F. and A.A. Kishk. 2018. Low-Cost 3D-Printed Wireless Soil Moisture Sensor. SENSORS. 4:122-129.

Feng, C., H.R. Wu, H.J. Zhu and X. Sun. 2012. The design and realization of apple orchard intelligent monitoring system based on internet of things technology. Advanced Materials Research. 2: 66-72.

Fourati, M., W. Chebbi and A. Kamoun. 2014. Development of a web-based weather station for irrigation scheduling. 3rd IEEE International Colloquium in Information Science and Technology (CIST). Corpus. ID: 2210644.

Grimblatt, V., G. Ferré, F. Rivet, C. Jego and N. Vergara. 2019. Precision Agriculture for Small to Medium Size Farmers - An IoT Approach. International Symposium on Circuits and Systems (ISCAS). USA.

Gutiérrez, J., J.F. Villa-Medina, A. Nieto-Garibay and M.A. Porta-Gándara. 2013. Automated irrigation system using a wireless sensor network and GPRS module. IEEE transactions on instrumentation and measurement, 63(1):166-176.

Hachem, S., V. Mallet, R. Ventura, A. Pathak, V. Issarny, P.G. Raverdy and R. Bhatia. 2015. Monitoring noise pollution using the urban civics middleware. 1st International Conference on Big Data Computing Service and Applications. Sensors. 2596; https://doi.org/10.3390/s18082596

Hakala, I., M. Tikkakoski and I. Kivelä. 2008. Wireless sensor network in environmental monitoring-case foxhouse. Second International Conference on Sensor Technologies and Applications (sensorcomm 2008). Cap Esterel, France.

Han, X., R. Jin, X. Li and S. Wang. 2014. Soil moisture estimation using cosmic-ray soil moisture sensing at heterogeneous farmland. IEEE Geoscience and Remote Sensing Letters, 11(9):1659-1663.

Heble, S., A. Kumar, K.V.D. Prasad, S. Samirana, P. Rajalakshmi and U.B. Desai. 2018. A low power IoT network for smart agriculture. 4th World Forum on Internet of Things (WF-IoT). Hydrabad, India.

Islam, M. A., T. Islam, M.A. Syrus and N. Ahmed. 2014. Implementation of flash flood monitoring system based on wireless sensor network in Bangladesh. International Conference on Informatics, Electronics & Vision (ICIEV). Sensor. doi: 10.3390/s19225012.

Jain, V.R., R. Bagree, A. Kumar and P. Ranjan. 2008. wild CENSE: GPS based animal tracking system. International Conference on Intelligent Sensors, Sensor Networks and Information Processing. Snsor Network. DOI: 10.1109/ISSNIP.2008.4762058.

Jayaraman, P.P., D. Palmer, A. Zaslavsky and D. Georgakopoulos. 2015. Do-it-Yourself Digital Agriculture applications with semantically enhanced IoT platform. 10th international conference on intelligent sensors, sensor networks and information processing (ISSNIP). Available with updates DOI: 10.3390/s16111884.

Jha, R.K., S. Kumar, K. Joshi and R. Pandey. 2017. Field monitoring using IoT in agriculture. International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT). IJERT. 952: IJERTV8IS120185.
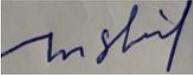
Jiang, R. and Y. Zhang. 2013. Research of agricultural

information service platform based on internet of things. 12th international symposium on distributed computing and applications to business, engineering & science. ASER. 1:176-180.

Jiao, J., Ma, H.M, Y. Qiao, Y.L. Du, W. Kong and Z.C. Wu. 2014. Design of farm environmental monitoring system based on the internet of things. Advance journal of food science and technology, 6(3):368-373.

Jiber, Y., H. Harroud and A. Karmouch. 2011. Precision agriculture monitoring framework based on WSN. 7th International Wireless Communications and Mobile Computing Conference. Istanbul, Turkey.

Kaewmard, N. and S. Saiyod. 2014. Sensor data collection and irrigation control on vegetable crop using smart phone and wireless sensor networks for smart farm. IEEE Conference on Wireless Sensors (ICWiSE). Engineering. DOI:10.1109/ICWISE.2014.7042670.

Kar, A. and A. Kar. 2015. A novel design of a portable double beam-in-time spectrometric sensor platform with cloud connectivity for environmental monitoring applications. 3rd International Conference on Computer, Communication, Control and Information Technology (C3IT). Hooghly, India.

Khandani, S.K. and M. Kalantari. 2009. Using field data to design a sensor network. 43rd Annual Conference on Information Sciences and Systems. Eng. J. 18:43-51.

Khriji, S., D. Houssaini, M.W. Jmal, C. Viehweger, M. Abid and O. Kanoun. 2014. Precision irrigation based on wireless sensor network. IET Science, Measurement & Technology, 8(3):98-106.

Kuroda, M., H. Ibayashi and H. Mineno. 2015. Affordable 400MHz long-haul sensor network for greenhouse horticulture. International Conference on Information Networking (ICOIN). DOI: 10.1109/ICOIN.2015.7057850.

Langendoen, K., A. Baggio and O. Visser. 2006. Murphy loves potatoes: Experiences from a pilot sensor network deployment in precision agriculture. Proceedings 20th IEEE international parallel & distributed processing symposium. Rhodes, Greece.

Lee, J., H. Kang, H. Bang and S. Kang. 2012. Dynamic crop field analysis using mobile sensor node. nternational Conference on ICT Convergence (ICTC). Electronics. 9(2):https://doi.org/10.3390/electronics9020319

Lee, M., J. Hwang and H. Yoe. 2013. Agricultural production system based on IoT. 16Th international conference on computational science and engineering. BCS. DOI:10.1109/CSE.2013.126.

Li, D., Y. Zheng and W. Zhao. 2019. Fault analysis system for agricultural machinery based on big data. IEEE Access, 7:99136-99151.

Li, R.A., X. Sha and K. Lin. 2014. Smart greenhouse: A real-time mobile intelligent monitoring system based on WSN. International Wireless Communications and Mobile Computing Conference (IWCMC). Electronics. https://doi.org/10.3390/electronics9020319.

Liping, W. 2012. Study on agricultural products logistics mode in Henan Province of China Software Engineering and Knowledge Engineering: Theory and Practice Springer. p.635-640.

Liu, Z., J. Huang,Q. Wang, Y. Wang and J. Fu. 2013. Real-time barrier lakes monitoring and warning system based on wireless sensor network. 4th International Conference on Intelligent Control and Information Processing (ICICIP). WCMC. https://doi.org/10.1155/2017/1864847.

Luan, Q., X. Fang, C. Ye and Y. Liu. 2015. An integrated service system for agricultural drought monitoring and forecasting and irrigation amount forecasting. 23rd International Conference on Geoinformatics. IJSDTR. 8:222-228.

Ma, D., Q. Ding, Z. Li, D. Li and Y. Wei. 2012. Prototype of an agricultural information system based on internet of things E-Nose. Intelligent Automation & Soft Computing, 18(5):569-579.

Mafuta, M., M. Zennaro, A. Bagula, G. Ault, H. Gombachika and T. Chadza. 2013. Successful deployment of a wireless sensor network for precision agriculture in Malawi. International Journal of Distributed Sensor Networks, 9(5): 150703-150713.

Marino, P., F.P. Fontán, M.A. Domínguez and S. Otero. 2010. An experimental ad-hoc WSN for the instrumentation of biological models. IEEE Transactions on Instrumentation and Measurement, 59(11):2936-2948.

Marjanović, M., L. Skorin-Kapov, K. Pripužić, A. Antonić and I.P. Žarko. 2016. Energy-aware and quality-driven sensor management for green mobile crowd sensing. Journal of network and computer applications, 59:95-108.

Mat, I., M.R.M.Kassim, A.N. Harun and I.M.Yusoff. 2018. Smart Agriculture Using Internet of Things. IEEE conference on open systems (ICOS). IEEE ASS. 7:15663-15671.

Mathurkar, S.S., N.R. Patel, R.B. Lanjewar and R.S. Somkuwar. 2014. Smart sensors based monitoring system for agriculture using field programmable gate array. International Conference on Circuits, Power and Computing Technologies [ICCPCT-2014]. Berlin, Germany.

Mekala, M.S. and P. Viswanathan. 2017. A Survey:

Smart agriculture IoT with cloud computing. International conference on microelectronic devices, circuits and systems (ICMDCS). Cis. Sys. DOI: 10.1109/ICMDCS.2017.8211551.

Mesquita, J., D. Guimarães, C. Pereira, F. Santos, and L. Almeida. 2018. Assessing the ESP8266 WiFi module for the Internet of Things. 23rd International Conference on Emerging Technologies and Factory Automation (ETFA). DOI:10.1109/ETFA.2018.8502562.

Minbo, L., Z. Zhu and C. Guangyu. 2013. Information service system of agriculture IoT. Automatika, 54(4):415-426.

Mittal, A., K. Chetan, S. Jayaraman, B.G. Jagyasi, A. Pande and P. Balamuralidhar. 2012. MKRISHI wireless sensor network platform for precision agriculture. 6th International Conference on Sensing Technology (ICST). CSE. DOI: 10.1109/EEEIC.2016.7555614.

Muangprathub, J., N. Boonnam, S. Kajornkasirat, N. Lekbangpong, A. Wanichsombat and P. Nillaor. 2019. IoT and agriculture data analysis for smart farm. Computers and electronics in agriculture, 156:467-474.

Nguyen, C.M., J. Mays, D. Plesa, S. Rao, M. Nguyen, and J.C. Chiao. 2015. Wireless sensor nodes for environmental monitoring in Internet of Things. International Microwave Symposium. Springer, Switzerland. p.1-444.

Pahuja, R., H. Verma and M. Uddin. 2013. A wireless sensor network for greenhouse climate control. IEEE Pervasive Computing, 12(2):49-58.

Pang, Z., Q. Chen, W. Han and L. Zheng. 2015. Value-centric design of the internet-of-things solution for food supply chain: Value creation, sensor portfolio and information fusion. Information Systems Frontiers, 17(2):289-319.

Papastergiou, G., G. Fairhurst, D. Ros, A. Brunstrom, K.J. Grinnemo, P. Hurtig and D. Damjanovic. 2016. De-ossifying the internet transport layer: A survey and future perspectives. IEEE Communications Surveys & Tutorials, 19(1):619-639.

Patil, K., nd N. Kale. 2016. A model for smart agriculture using IoT. International Conference on Global Trends in Signal Processing, Information Computing and Communication (ICGTSPICC). Available with update at DOI: 10.1109/ICGTSPICC.2016.7955360.

Patil, N., Y. Sawant, T. Kaur, S. Kate and C. Wagh. 2006. IOT Based Weather Monitoring for Agriculture. International Journal on Recent and Innovation Trends in Computing and Communication, 6(4):21-24.

Petersen, K., R. Feldt, S. Mujtaba and M. Mattsson. 2008. Systematic mapping studies in software engineering. 12th International Conference on Evaluation and Assessment in Software Engineering (EASE). DOI=10.14236/ewic/EASE2008.8

Pokric, B., S. Kreo, D. Drajic, M. Pokric, I. Jokic and M.J. Stojanovic. 2014. ekoNET-environmental monitoring using low-cost sensors for detecting gases, particulate matter, and meteorological parameters. 8th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing. Sis. 1:43-51

Postolache, O., J.D. Pereira and P.S. Girão. 2014. Wireless sensor network-based solution for environmental monitoring: Water quality assessment case study. IET Science, Measurement & Technology, 8(6):610-616.

Postolache, O., M. Pereira and P. Girão. 2013. Sensor network for environment monitoring: water quality case study. Symposium on Environmental Instrumentation and Measurements, Lecce, Italy.

Rajakumar, G., M.S. Sankari, D. Shunmugapriya and S.U. Maheswari. 2018. Iot Based Smart Agricultural Monitoring System. Asian Journal of Applied Science and Technology (AJAST), 2(2):474-480.

Rajeswari, S., K. Suthendran and K. Rajakumar. 2017. A smart agricultural model by integrating IoT, mobile and cloud-based big data analytics. International Conference on Intelligent Computing and Control (I2C2). Coimbatore, India.

Rosli, R.S., M.H. Habaebi and M.R. Islam. 2018. Characteristic analysis of received signal strength indicator from esp8266 wifi transceiver module. 7th International Conference on Computer and Communication Engineering (ICCCE). Bulletin of Electrical Engineering and Informatics 8(3): DOI: 10.11591/eei.v8i3.1511.

Roy, S.K., A. Roy, S. Misra, N.S. Raghuwanshi and M.S. Obaidat. 2015. AID: A prototype for agricultural intrusion detection using wireless sensor network. Paper presented at IEEE International Conference on Communications (ICC). Comp. Sci. DOI:10.1109/ICC.2015.7249452.

Ruan, J., Y. Wang, F.T.S. Chan, X. Hu, M. Zhao, F. Zhu and F. Lin. 2019. A life cycle framework of green IoT-based agriculture and its finance, operation, and management issues. IEEE communications magazine, 57(3):90-96.

Ryu, M., J. Yun, T. Miao, I.Y. Ahn, S.C. Choi and J. Kim. 2015. Design and implementation of a connected farm for smart farming system. Sen. J. 3:199-205.

Salas, J., H. Vega, J. Ortiz, R. Bustos and C. Lozoya. 2014. Implementation analysis of GPRS communication for precision agriculture.

40th Annual Conference of the IEEE Industrial Electronics Society. Sensor. 1:44-51.

Sales, N., O. Remédios and A. Arsenio. 2015. Wireless sensor and actuator system for smart irrigation on the cloud. 2nd World Forum on Internet of Things (WF-IoT). Milan, Italy.

Saville, R., K. Hatanaka and M. Wada. 2015. ICT application of real-time monitoring and estimation system for set-net fishery. Paper presented at the OCEANS 2015-MTS/IEEE, Washington, USA.

Sawant, S.A., J. Adinarayana and S.S. Durbha. 2014. KrishiSense: A semantically aware web enabled wireless sensor network system for precision agriculture applications. Geoscience and Remote Sensing Symposium. IEEE. p.4090-4093

Shuwen, W. and Z. Changli. 2015. Study on farmland irrigation remote monitoring system based on ZigBee. International Conference on Computer and Computational Sciences (ICCCS). J. Sen. https://doi.org/10.3390/electronics9020319.

Smarsly, K. 2013. Agricultural ecosystem monitoring based on autonomous sensor systems. 2nd International Conference on Agro-Geoinformatics (Agro-Geoinformatics). Fairfax, USA

Soontranon, N., P. Tangpattanakul, P. Srestasathiern and P. Rakwatin. 2014. An agricultural monitoring system: field server data collection and analysis on paddy field. 14th International Symposium on Communications and Information Technologies (ISCIT). DOI: 10.1109/ISCIT.2014.7011985

Sun, E., X. Zhang and Z. Li. 2012. The internet of things (IOT) and cloud computing (CC) based tailings dam monitoring and pre-alarm system in mines. Safety science, 50(4):811-815.

Talavera, J.M., L.E. Tobón, J.A. Gómez, M.A. Culman, J.M. Aranda, D.T. Parra and L.E. Garreta. 2017. Review of IoT applications in agro-industrial and environmental fields. Computers and Electronics in Agriculture, 142, 283-297.

Tanumihardja, W.A. and E. Gunawan. 2015. On the application of IoT: Monitoring of troughs water level using WSN. Conference on Wireless Sensors (ICWiSe). Melaka, Malaysia.

Tao, R., S. Yang, W. Tan and C. Zhang. 2013. Secure gateway of internet of things based on AppWeb and secure sockets layer for intelligent granary management system. International Conference on Computer and Computing Technologies in Agriculture. Comp. Electron. Agri. 142:283-297.

Torres-Ruiz, M., J.H. Juárez-Hipólito, M.D. Lytras and M. Moreno-Ibarra. 2016. Environmental noise sensing approach based on volunteered geographic information and spatio-temporal analysis with machine learning. International

Conference on Computational Science and Its Applications. Beijing China.

Uddin, M.A., A. Mansour, D. L. Jeune and E.H.M. Aggoune. 2017. Agriculture internet of things: AG-IoT. 27th International Telecommunication Networks and Applications Conference (ITNAC). Pro. Comp. Sci. 171:1166-1173

Valenzuela, A.A., M. Schwab, A.A. Silnik, A.F. Debattista and R.A. Kiessling. 2018. Low Power Wireless Sensor Node Platform for Agriculture Monitoring in Argentina. International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery (CyberC). Universidad Nacional de San Luis. Brazil.

Veena, S., K. Mahesh, M. Rajesh and S. Salmon. 2018. The survey on smart agriculture using IoT. Int. J. Innovative Res. Eng. Manage, 5(2):63-66.

Vo, T.T., T.D. Nguyen and M.T. Vo. 2013. Ubiquitous sensor network for development of climate change monitoring system based on solar power supply. International Conference on Advanced Technologies for Communications (ATC 2013). Comp. Electron. Agri. 142:283-297.

Wan, Z., Y. Song and Z. Cao. 2019. Environment Dynamic Monitoring and Remote Control of Greenhouse with ESP8266 NodeMCU. 3rd Information Technology, Networking, Electronic and Automation Control Conference (ITNEC). Computer Science. DOI:10.1109/ITNEC.2019.8729519.

Wang, D., B. Bai, K. Lei, W. Zhao, Y. Yang and Z. Han. 2019. Enhancing information security via physical layer approaches in heterogeneous IoT with multiple access mobile edge computing in smart city. IEEE Access, 7: 54508-54521.

Wang, J., M. Wang, K. Zheng and X. Huang. 2018. Model checking nRF24L01-based internet of things systems. 9th International Conference on Information Technology in Medicine and Education (ITME). Sensors. 17(8): 1781-1788.

Wang, P., R. Valerdi, S. Zhou and L. Li. 2015. Introduction: Advances in IoT research and applications. Information Systems Frontiers, 17(2):239-241.

Watthanawisuth, N., A. Tuantranont and T. Kerdcharoen. 2009. Microclimate real-time monitoring based on ZigBee sensor network. Agri. System. 190:103084-103084. .

Wu, G., J. Tao and X. Xu. 2019. Application and Design of Wireless Community Alarm System Based on nRF24L01 Module. Chinese Control and Decision Conference (CCDC). Wireless Algorithms, Systems, and Applications. 5:66-90.

Xu, J., J. Zhang, X. Zheng, X. Wei and J. Han. 2015.

Wireless sensors in farmland environmental monitoring. IWCMC. 4:190-201.

Ye, J., B. Chen, Q. Liu and Y. Fang. 2013. A precision agriculture management system based on Internet of Things and WebGIS. 21st International Conference on Geoinformatics. Pro. Agri. 2: 22-32.

Yoo, S.E., J.E. Kim, T. Kim, S. Ahn, J. Sung and D. Kim. 2007. Automated agriculture system based on WSN. International Symposium on Consumer Electronics. Milan, Itlay.

Yoon, C., M. Huh, S.G. Kang, J. Park and C. Lee. 2018. Implement smart farm with IoT technology. 20th International Conference on Advanced Communication Technology (ICACT). Copu. Sci. DOI:10.23919/ICACT.2018.8323907.

Yun, S.O., H.W. Cho, J.H. Suh, J.H. Park, B.G. Choi, T.J. Lee and H.J. Yoo. 2017. Flexible pH sensor and system fabricated using PET film. Sen. 1: 77-84.

Zhang, S., X. Chen and S. Wang. 2014. Research on the monitoring system of wheat diseases, pests and weeds based on IOT. 9th International Conference on Computer Science & Education. IJITEE. 8:213-218.

Zhao, J.C., J.F. Zhang, Y. Feng and J.X. Guo. 2010. The study and application of the IOT technology in agriculture. 3rd International Conference on Computer Science and Information Technology. Compu. Sci. DOI:10.1109/ICCSIT.2010.5565120.

Zhao, L. and X. Zhu. 2015. The development of remote monitoring system for cultivation environment of Pleurotus eryngii. International Conference on Information and Automation. J. Sen. https://doi.org/10.1155/2018/8672769.

Zheng, R., T. Zhang, Z. Liu and H. Wang. 2016. n EIoT system designed for ecological and environmental management of the Xianghe Segment of China's Grand Canal. International Journal of Sustainable Development & World Ecology, 23(4):372-380

CONTRIBUTION OF AUTHORS

S. No.	Author's name	Contribution	Signature
1.	Muhammad Shoaib Farooq	Supervised the research work	
2.	Sobia Akram	Prepared the write-up	