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Precision agriculture using IoT data analytics and machine learning

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ABSTRACT

In spite of the insight commonality may have concerning agrarian practice, fact is that nowadays agricultural science diligence is accurate, precise, data-driven, and vigorous than ever. The emanation of the technologies based on Internet of Things (IoT) has reformed nearly each industry like smart city, smart health, smart grid, smart home, including "smart agriculture or precision agriculture". Applying machine learning using the IoT data analytics in agricultural sector will rise new benefits to increase the quantity and quality of production from the crop fields to meet the increasing food demand. Such world-shattering advancements are rocking the current agrarian approaches and generating novel and best chances besides a number of limitations. This paper climaxes the power and capability of computing techniques including internet of things, wireless sensor networks, data analytics and machine learning in agriculture. The paper proposed the prediction model of Apple disease in the apple orchards of Kashmir valley using data analytics and Machine learning in IoT system. Furthermore, a local survey was conducted to know from the farmers about the trending technologies and their effect in precision agriculture. Finally, the paper discusses the challenges faced when incorporating these technologies in the traditional farming approaches.

Contents

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1. Introduction

In India one of the main economic activity is the agriculture. Around 60–70% of employment in India is dependent on agricultural sector. It has the maximum arable land that is second largest after U.S. This is because of the high soil fertility and large network of water sources for irrigation. Due the varying nature of climatic conditions at different locations it ensures the high availability and productivity of flora. Although the well presence of resources it does not produce the results equivalent to the availability.It is because of scarcity and incompetent use of technology, deficiency of knowledge and awareness among the agrarians, use of some antiquate methods (Bhargava et al., 2014). In addition most of the crops are affected by pests, insects, diseases resulting in decreased yields. Many crops are affected by the attack of insects or pests. Insecticides or pesticides are not always proved effective because they may be toxic to some kind of birds and animals. It also damages the natural animal food web and also food chains (Shinde and Kulkarni, 2017). Crop disease results in considerably low throughput. The authors in Oerke (2006) outlines the yield depletion between 20% and 40 % of worldwide agricultural production caused by insects, pests, viruses, animals, and weeds. In addition, they have a number of facets, some with short-term, and others with long-term consequences for the global food security (Savary et al., 2012). Crop production losses due to pests and diseases are quite substantial, particularly in the Indian weather semi-arid conditions (Shinde and Kulkarni, 2017). Weather has an extremely extensive role in agricultural production. Generally crops are more common in the weather based frangible agriculture systems. Survey have challenged that with the rise in population up to 10 billion, then definitely by 2050 we are moving towards food doomsday. It implies food production ability will bankrupt unless we establish and advance the smart technologies in agriculture. So for proper management of limited resources it is necessary to develop an economical technology for Indian farmers. The system should help the farmers to prevent the diseases of crops on time and improve the quantity and quality food.The system should be reliable enough to sustain in hilly areas like Jammu and Kashmir for timely prevention and cure (Bhargava et al., 2014). It is because of their capability to monitor environmental parameters, soil parameters, plant parameters by spatially deploying sensors remotely. On time prediction of diseases caused by the various harmful entities whether by the lack or exceed in the normal values of the monitored parameters can aid the agriculturalists. So that they can take special measures against the attack of these pests and insects in a controlled manner. This will prevent any usage of chemicals and reduce the diseases occurring in fauna. In addition, it would definitely boost the Aggie productivity and hence will bridge the gap tween increasing population and increasing demand of food. Evidently, overall loss percentage of crops would be reduced. In the last decade science and technology has revolutionized the globe. Current era is the technological era. To provide applicable information to the agriculturalists, presently, remote monitoring techniques are being used.Wireless Sensor Networks and Internet of Things plays an essential role in this connection. The miniaturization of the technology resulted in Internet of Things (IoT) utopia (Buyya and Dastjerdi, 2016). The term "Internet of Things" (IoT) was first time used by Kevin Ashton, while the presentation on Management of supply Chain in 1999 (Ashton et al., 2009). IoT is an interconnected network of computational objects like sensors which are uniquely identifiable smart objects. The term "Things" represents a general array of objects, sensors, people, smart devices and any other entity having the ability to connect and share information with other entities, that is aware of its context and is making anything available at anytime, anywhere. It means everything is accessible without any place or time restrictions. In the IoT, wireless technologies play a central role in data gathering and data communication (Abdmeziem et al., 2016). Wireless Sensor Networks (WSN) and radio- frequency identification (RFID) are considered as the two main building blocks of sensing and communication technologies for IoT (Marjani et al., 2017; Fortino et al., 2020). Wireless sensor networks have been used in different applications, such as military, agriculture, sports, medicine, and industry (Jawad et al., 2017). Due to which voluminous amount of data is being generated (Marjani et al., 2017). Wireless sensor networks sensors, smart devices, RFID tags, tablets, palmtops, laptops, smart meters, smart phones, smart healthcare, social media, software applications and digital services generate the volume of data. They continuously generate large amounts of structured, semi-structured and unstructured data which is strongly increased. The growth of data in various domains of applications like network operation, healthcare management, social media,intelligent traffic system, business, marketing, resource optimization, precision agriculture and social behavior etc. to study all this, data analytics committed for diverse wireless sensor networks to take benefits. Data analysis is a process of data collection, data transformation, data cleaning and modelling data with the goal of discovering the required knowledge (Dai et al., 2019). The results and findings so obtain are communicated by suggesting conclusions and supporting decision making. Data analytics is the process of examining large data sets that contain a variety of data types (Mital et al., 2015) to reveal unseen patterns, hidden correlations, market trends, customer preferences, and other useful business information (Saura et al., 2019). Agronomy consideration is the most well-intentioned ability for WSN, data analytics and machine learning to rise the crop yields and to decrease the herculean task of farmers (Kim et al., 2014). Precision Agriculture (PA) or site specific farming is the technological approach that uses modern data technology and knowledge to develop the high quality agricultural production. WSN are economical procedures to improve crop yield (Jawhar et al., 2014). Precision agriculture is in its advanced phase, and some farmers have started to implement PA in their terrains, and have obtained best results, managing to return the investment essential for its implementation. Hence, the activities related to PA include: identification and localization of crops, insects and weeds, performance monitoring, machinery, variable dozing of fertilizers, herbicides, insecticides and fungicides, planting monitoring and mapping (Buyya and Dastjerdi, 2016). In Ayaz et al. (2019) precision agriculture has been discussed broadly. They gave the detailed overview of how IoT is playing a role in precision agriculture by making the fields talk. With the help of IoT they gave the idea how to increase the agricultural yield to meet the needs of the bulky population by using the limited available arable land for cultivation, fresh water for irrigation etc. by giving the precise and required quantities of fertilizers, insecticides, water, etc. In Xia et al. (2011) environment monitoring system has been designed and deployed for precision agriculture using WSN. The system was tested in a red bayberry greenhouse situated on a hillside by collecting the following parameters; temperature, voltage, humidity etc. The system proved to be scalable, stable, and accurate and can provide real time data for precision agriculture. Data Analytics and Machine Learning techniques are playing an important role in the agrarian sector in order to handle the increasing challenges due to the weather and climatic changes like temperature, rain, humidity etc which are causing serious damage in crop production. It is necessary to increase the accuracy of data analysis for vigorous and proliferating production. The capability to analyze large amounts of data can help an organization deal with considerable information that can affect the business (Russom et al., 2011). The procedures and algorithms used in such analytical tools must discover hidden patterns and correlations in the data (Oswal and Koul, 2013). The field data collected by the deployed sensors is in the form of multimedia which helps in disease detection in stems, leaves fruits and roots, quality, health of fruits (Suksawat and Komkum, 2015), and presence or detection of weeds and smart irrigation (Tripicchio et al., 2015; Jhuria et al., 2013; Kapoor et al., 2016; Roopaei et al., 2017; Cambra et al., 2017). In order to produce higher quantity and increase the quality of food and reduce the crop failure, integration of IoT sensing devices and drones seem to be helpful, the same devices monitor the things in regular intervals for best results (Tripicchio et al., 2015; Kapoor et al., 2016; Cambra et al., 2017). In Fig. 1.1 we have shown the various steps of how IoT and data analytics are related to each other. By using IoT data analytics with the machine learning we can make the precision agriculture practical. Initially in the first step which comprises managing IoT data sources, where connected sensors devices use applications to interact with one another. For example, the interaction of devices such as CCTV cameras, drones, environmental sensors, soil sensors, plant sensors etc produces huge amounts of data in diverse formats. This generated data can be hoarded on the cloud using commodity hardware devices. In the second go, data is complex due to its volume, velocity, and variety. Depends upon the precision agriculture application specification and the type of data we are interested in collection of, mainly precision agriculture datasets having data related to crop patterns, crop rotations, weather parameters, environmental conditions, soil types, soil nutrients, Geographic Information System (GIS) data, Global Positioning System (GPS) data, farmer records, agriculture machinery data, such as yield monitoring and Variable Rate Fertilizers (VRT) (Bendre et al., 2015). These enormous amounts of data are stored in big files of data in shared and distributed fault- tolerant databases. The last step applies analytics tools such as Map Reduce, Spark and Skytree that can analyze the stored IoT data sets and find the value out of it. This implies integrating IoT data analytics and machine learning techniques, there is the need to develop forecasting models for crop management including disease and yield prediction. The main aim of the paper is as follows; i) To provide a thorough review on the use of IoT(sensors) and data analytics for precision agriculture; ii) To present a case study on adoption of IoT and data analytics on apple orchards; iii) To understand the challenges faced by traditional farmers in adopting technologies to complement traditional farming.

The rest of the paper is organised as; Section 2 presents the literature survey of precision agriculture under the following sub headings i) IoT-Sensors and Networks; ii) Data Analytics; iii) Applications of IoT and Data Analytics as smart System in agriculture. Section 3 discusses the case study on adoption of IoT (sensors) and data analytics in traditional Kashmir farms for prediction of apple scab. Section 4 discusses several challenges and open issues in adoption of IoT data analytics in precision agriculture for traditional farmers, which is further categorized into the following four categories: i) commercial; ii) Technical; iii) Sectorial; and iv) Data Analytics. Section 5 concludes a paper by highlighting important findings briefly and gives some future directions.

2. Literature survey

A lot of activity has already been accomplished in the area of precision agriculture using different technologies like IoT, machine learning for making decision support system, data analytics, etc. We have divided the literature survey under three subsections: 1) IoT/ Sensors and networks, 2) Data Analytics and 3) Applications of IoT and data analytics as smart system in Agriculture. The work on precision in different fields in the literature are comprehensively mentioned in these subsections below:

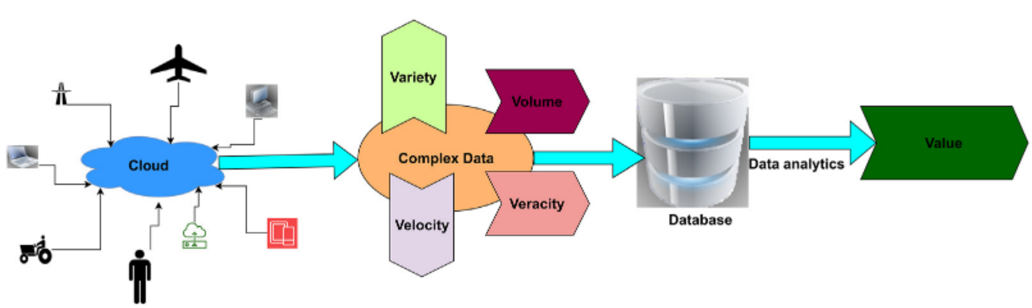

Fig. 1.1. Internet of Things and Data Analytics Relationship.

2.1. IoT-sensors and networks

Wireless sensor networks are used in diverse agronomic applications, for example remotely observing environmental and soil conditions in order to predict the healthfulness of crops. Watering schedule of agricultural fields is forecasted by employing WSN as observant of environmental conditions like pressure, humidity, temperature, soil moisture, soil salinity and soil conductivity. A lot of work has been done in the literature, main contributions by various researchers are discussed. In Ahmed et al. (2018) authors proposed the scalable network architecture to monitor and control agriculture fields in rural areas. They proposed a control system based on IoT for development of farming and agriculture. All the system components and improvements are examined and analyzed in all aspects.The solution of routing and MAC in IoT achieved energy efficiency, less delay and high throughput.To achieve this performance the system combines Wi-Fi based long distance (WiLD) network and fog computing solution. In Bhargava et al. (2014) authors have proposed WSN framework design, intentionally to setup a DSS for the detection of Apple Scab in Himachal Pradesh using Mills tables. In Muangprathub et al. (2019) IoT was applied in agriculture to improve crop yields, improve crop quality and reduce costs. Based on wireless sensor networks they proposed and developed a system which can optimally water agricultural crops like lemon, home grown vegetables. To control the effect of environmental factors in the crop fields, the system proposed consist three main parts Hardware (Control box), Web application and Mobile application. Control box was actually a WSN and electronic control system which was helping in data collection. Using web application the data collected from the control box is large scale data that was analyzed using data mining association rules. The mobile application was used to notify the farmer about water content of the soil and accordingly automatic or manual watering was done. Data mining showed for high productivity of home grown vegetables and lemon temperature should be 29–30^{o}C and humidity 72–81%. In Fonthal et al. (2018) the authors have designed a system for precision agriculture which is economical known as Smartnode. For the optimal crop development they used the platform of hardware and software that allows monitoring of agro climatic parameters. They deployed the system into crop field to increase its yield. The main aim of Trilles Oliver et al. (2019) was to apply a model to alert farmers when would be the suitable moment to treat the downy mildew disease in a vineyard context. Following the IoT paradigm they proposed the system named SEnviro (Sense our Environment platform) to monitor vineyard fields. They used the edge computing paradigm to mitigate the communication between ends. In Shinde and Kulkarni (2017) authors showed that the existing systems are not reliable and cheap. They gave the information of using IoT and machine learning in the precision agriculture to predict the diseases of crop. They proposed a system model using machine learning and IoT. They took the environmental sensors like temperature, humidity etc and collect the data. After the final output was generated the same was sent to the local farmers as an SMS. In Jawad et al. (2017) the authors presented a review of WSN based agricultural applications. Authors compared various wireless technologies and protocol suites like Wi-Fi, Bluetooth, GPRS/3G/4G, ZigBee, LoRa and Sig Fox. They showed LoRa and ZigBee wireless technologies are highly efficient to use for Precision Agriculture because of suitable communication range and low power consumption. Categorization of various techniques and algorithms related to energy efficiency of wireless sensor networks are mentioned. They have also mentioned the techniques that can be used in PA. Challenges and limitations of WSN in PA are also mentioned. In Sikeridis et al. (2018) authors have combined the machine learning approaches with the internet of things and showed their applicability in next generation networks.They improved the energy efficiency in NOMA(non-orthogonal multiple access) public safety networks by using UAV (Unmanned Aerial Vehicle) and WPC (wireless powered communication) collectively which results in Public Safety IoT (PS-IoT) ecosystem. In Hsu et al. (2018)the authors study proposes a creative service process based on the cloud computing platform of the Internet of Things and it can be used to improve the integration of the current cloud-to-physical networking and to improve the computing speed of the Internet of Things. This research uses innovative platform technology to be applied to the cloud agriculture platform. Through cloud integration, it can be applied to large area data collection and analysis, allowing farmland with limited network information resources to be integrated and automated, including agricultural monitoring automation, pest management image analysis.In Lavanya et al. (2020) authors presented system based on IoT by designing Nitrogen-Phosphorus-Potassium (NPK) sensor which is a novel approach with Light Dependent Resistor (LDR) and Light Emitting Diodes (LED). To monitor and analyze the nutrients present in the soil the principle of colorimetric is used. Google cloud database is used to store the data collected from fields for fast retrieval of data. Fuzzy logic concept has been applied in order to know the lack of nutrients from sensed data. The sensed data is distinguished into five fuzzy values which are very high, high, medium, low and very low while fuzzification. The intended hardware and the software incorporated in the micro-controller are developed in Raspberrypi3 using Python. Three different samples of soil like red, desert, and mountain soil have been tested by the proposed model. With respect to the concentration of the solution soil the developed system resulted in linear variation. In order to analyse the performance of developed NPK sensor in the form of end to end delay, throughput and jitter a sensor network scenario is deployed using Qualnet simulator.The developed IoT system was found to be most needful to the agrarians for high yielding of crop production when compared with the existing solutions. In this article researchers have identified the most important applications using IoT and an elaborated survey has been done particularly in precision agriculture (Khanna and Kaur, 2019). Challenges faced while using IoT in smart agriculture. In Sethi and Sarangi (2017) the authors surveyed protocols, methodologies and applications in developing area that is IoT. The article mentions new taxonomy for Internet of things technologies.It climaxes the most essential technologies that have the capability to make an extraordinary variation in human beings lives, specially for the handicapped and the elderly. In comparison to the same survey articles, this paper has covered major technologies from sensing devices to applications exhaustively and comprehensively. In Abdmeziem et al. (2016) authors have proposed a survey regarding the prime architectures in the history. Furthermore, the elementary unit technologies which are well-accepted to suit IoT application requirements. They also introduce a classification presenting the appropriateness of proposed architectures in IoT characteristics. In addition, they have highlighted the advantages of present solutions and proposed future directions on the basis of state of the art. In a future research they are planning to design an approach which will be able to mitigate the drawbacks of the IoT at each individual layer of the internet. In Ojha et al. (2015) authors examined the promising Wireless sensor network applications, challenges and limitations associated while distributing WSN to improve crop yield. Smart devices, sensing devices and communication technologies lined with WSN in agronomy applications are emphasized completely. They mentioned different case studies to explore the present solutions proposed in the literature. They have mentioned in the literature survey that how precision agriculture has been implemented globally including India. They have depicted the drawbacks of these existing solutions by presented the future directions using advanced technologies. In Zhao et al. (2010) authors have investigated application of IoT in precision agriculture. They used wireless communication technology to achieve site specific monitoring of greenhouse. They proposed Remote greenhouse monitoring system using wireless communications. An information management system has been designed while system management has been taken into account. The field data has been utilized for research. By using this remote monitoring system, the field data like temperature, humidity from the greenhouse has been sensed precisely and after the proper research, system resulted in good growth condition of vegetables. The proposed system has resulted in increased performance and reliability. The interface of the system was user friendly for ordinary farmers. In Balaji et al. (2018) authors have proposed a method for efficient crop monitoring for agricultural field. With the application of IoT the data can be stored and retrieved from anywhere. Various sensors are used to monitor and collect information about the field conditions. Collectively the farm condition is sent to the farmer through GSM technology. In the proposed work, the sensor part is limited only for monitoring of crops. In Jayaraman et al. (2016) authors research have focused on data collection from agricultural fields through various technologies. Using WSN, IoT, Weather stations, smart-phones, drones and cameras are found to be useful during their study. In addition, authors advanced the platform based on IoT called SmartFarmNet. This was able to process the collection of data from the field related to various parameters like soil, moisture, irrigation, soil fertility, humidity, temperature etc. The proposed system was able to correlate the analyzed data and was able to forecast crop status. In Paustian and Theuvsen (2017) authors emphasize the hoe various technologies are important in precision agriculture. How the farmers of Germany are able to accept the precision agriculture using smart devices like smart-phones. Regression analysis showed a positive effect of precision agriculture on farmers. The authors have given some research directions using IoT in agriculture.

2.2. Data analytics

Before the advent of information technology, various traditional methods like manual detection of crop diseases and pests, calculations based on statistics to estimate the quantity and predict the production and loss of crops were generally cumbersome, this results in human error due to the lack of experience of inspectors (Rumpf et al., 2010). Machine learning is the ability of technology to learn through experiences. Data analytics and machine learning allows us to draw the most important conclusions from the large data collected from the crop fields. It reveals the hidden patterns, hidden relationships between the parameters affecting the horticulture like temperature, soil salinity, humidity etc. The mostly used and related machine learning techniques in forecasting crop diseases and pests in which weather data are analysed are Artificial Neural Network (ANN), SVM Regression and Logistic Regression, recognition technology using neural network, Support Vector Machine (SVM) (Singh and Gupta, 2016), fuzzy technology for recognition etc. In Singh and Gupta (2018) authors proposed a system for classification of apple diseases using the machine learning classification algorithms. The two diseases which they classify are apple scab and marsonina coronaria by using the images of leaves of the apple trees as input. Classification algorithms Support Vector Machine, K Nearest Neighbour, Decision Tree and Naïve Bayes were used on the same data. Matlab 2016 was used for the simulation proposed system. They showed it is the K nearset neighbour which classified the diseases with the 99.4% accuracy. The system was developed in the state of Himachal Pradesh, Uttarkhand. In Shinde and Kulkarni (2017) authors showed that the existing systems are not reliable and cheap. They gave the information of using IoT and machine learning in the precision agriculture to predict the diseases of crop. They proposed a system model using machine learning and IoT. They took the environmental sensors like temperature, humidity etc and collect the data. After the final output was generated the same was sent to the local farmers as an SMS. In Huang et al. (2018) authors have used machine learning approaches to create the intelligent communications. In order to improve the QoS (quality of service) of limited wireless assets, intelligent machine learning approaches have been used. In Geetha (2015) the authors used IoT technology and ML techniques for the prediction of late blight disease in potatoes. The environmental parameters like Temperature and humidity were captured by the use of sensor devices deployed in the farm fields which transmit the information to the central gateway. The data collected helps to detect the level and risk of blight. In Geetha (2015) authors have focused on a moderate susceptible cultivation of potato crop using a back- propagation network with an accuracy of 94%. In Aggelopoulou et al. (2011) authors have used image processing and data analysis algorithms for precision agriculture for predicting the site-specific yield. They proved that there is a high correlation between flower density and the fruit yield by predicting the yield of the apple orchard with an accuracy of more than 80%. In Mazilu and Trandafir (2002) authors have established five onsite weather stations in orchards that collect data. The collected data can be used in models to predict the apple scab infection periods. Such models can help farmers to determine the need (or lack) of fungicide sprays to control apple scab. They posted the information on http://www.pomosat.ro for neighboring apple growers in Romania to access for and use in decision making. In Cetişli and Büyükçingir (2013) a new prediction model for warning of apple scab is proposed. The model proposed is based on Artificial Intelligence and time series prediction. Infection period of apple scab was evaluated as the time series prediction model instead of summation of wetness duration. Important hours were determined with feature selection methods Pearson's Correlation Coefficient, Fisher's Linear Discriminant Analysis, Adaptive Neuro fuzzy Classifier with Linguistic hedges. Prediction was done by adaptive neural network model. To determine the apple scab infection 24 h are needed to capture the measurements. Five meteorological measurements relative humidity, leaf wetness, temperature, day light and rainfall. After every 12 min data was collected so time was one more parameter for time series prediction. They marked correlation between apple scab and meteorological measurements. They detect appropriate time for infection. Besides this, classification and prediction of apple disease was done. In Foughali et al. (2018) the authors present a novel decision support system (DSS) for the prevention of late blight using the integration of WSN, cloud and IoT. The model proved to be beneficial for preventing potato late blight disease. DSS was capable to estimate the precise quantity of fungicide to apply. Besides this IoT sensors related to weather were deployed to collect real time data and was then sent to cloud IoT framework for processing. The forecast model used the weather related data from weather stations and historical data for the prediction of late blight. The system was quite efficient and cost effective for the farmers. In Balducci et al. (2018) authors intended to organize heterogeneous data approaching from diverse sources in the form of datasets as a result of sensory systems. They also showed how useful companies whether large scale or a small scale, a public or a private are trying to improve profitability. Finding proper ways to use data that are recorded continuously are the best possibility to achieve goals. It suggested how Regression analysis, Neural networks and Machine Learning are useful decision-making. In Hamad et al. (2018) authors have emphasized the importance of smart mobile phones for obtaining agronomy facts information of different parameters like soil moisture, humidity, temperature etc. In the same article they have highlighted benefits

Table 2.1
Literature Survey.

Reference	Contribution	Results
(Jayaraman et al., 2016)	SmartFarmNet application	Proposed framework was capable of: • Making predictions related to crop performance • Computation of crop forecasts
(Ahmed et al., 2018)	They proposed a scalable network architecture for minitoring and controlling agriculture and farms in rural areas	Improved performance in terms of: • Latency • Bandwidth
(Muangprathub et al., 2019)	Based on wireless sensor networks they proposed and developed a system which can optimally water agricultural crops like lemon, home grown vegetables.	Data mining showed for high productivity of home grown vegetables and lemon: • Temperature should be 29–30 °C • Humidity 72–81 %.
(Fonthal et al., 2018)	The authors have designed a system of precision agriculture at a low cost called Smartnode.	They deployed system: • Increased the yield in tomato crop field.
(Mazilu and Trandafir, 2002)	They proposed an Orchard System for Monitoring and Modelling Apple Scab (Venturia Inaequalis for that they established five onsite weather stations in orchards that collect data.)	The proposed scheme: • Performed well in the locality of Romania in terms of quality and quantity
(Hamad et al., 2018)	Understanding the perception of farmers regarding the usage of smartphones in performing agricultural activities	Results obtained after applying Chi-square test: • Lack of trust • High cost.
(Trilles Oliver et al., 2019)	They proposed the system named SEnviro (Sense our Environment platform) to monitor vineyard fields.	They used: • The edge computing paradigm to mitigate the communication between ends.
(Jawad et al., 2017)	Authors compared different wireless technologies and protocols such as Wi-Fi, Bluetooth, ZigBee, GPRS/3G/4G, LoRa, Sig Fox	They showed: • ZigBee and LoRa wireless protocols are more convenient for Precision Agriculture.
(Lavanya et al., 2020)	They present an IoT based system by designing a novel Nitrogen-Phosphorus-Potassium (NPK) sensor with Light Dependent Resistor (LDR) and Light Emitting Diodes (LED).	Proposed model proved to be helpful: • For high yielding of crops.
(Shinde and Kulkarni, 2017)	The information about machine learning and IoT implementation used for crop diseases is given.	The review given concludes that: • Existing system are not reliable and cheap

of smart-phones in the agricultural field. The authors conducted the survey of around 230 farmers through questionnaires and interviews to know what they want. After completing the process they come to the conclusion that farmers are interested to make use of smart-phones to acquire information about current farm data. Table 2.1 summarizes the key points of the literature survey, how the authors in the existing technologies have contributed in the precision agriculture and what they achieved.

2.3. Applications of IoT and data analytics as smart system in agriculture

IoT/sensor nodes are playing a key role in precision agriculture to collect the real time data (Sri et al., 2019). These nodes have the capability to make the system more practical by collecting the real time data from the crop fields to make the agriculture system precise. By incorporating data analytics and machine learning the agriculture system becomes more workable. All these technologies have tremendous applications in other fields. In precision agriculture various applications for farmers are developed to inform them about the status of crops on time. The architecture for precision agriculture is usually composed of three main phases as shown in Fig. 2.1. The first phase it consists of the number of sensors/ IoT nodes to monitor physical or environmental conditions, soil conditions, plant conditions, e.g the soil moisture sensor records soil wetting reading, or soil nutrient sensor will check the fertility of the soil. In the second phase we need to collect this precise data, we can either store the data locally to the nearest fog node or we can send it on the cloud for higher computation and remote monitoring it depends upon the need. In third phase of the architecture the analytics methods are applied to know the status of the crop fields. This information is then communicated to the end users(farmers) that helps them to identify that if the reading is below or above threshold. Accordingly they initiate communication to the actuator that would switch on(or off) the watering system to pour water to the soil or farmer(end user) may need to spray some fertilisers potassium, nitrogen and phosphorous to balance the fertility of soil. Using analytics and actuators a response mechanism is activated upon recognition (sensing/predicting) of any critical scenario. There are number of applications of IoT and WSN in the precision agriculture, some of them are mentioned here. Fig. 2.2 shows the applications related to precision agriculture.

2.3.1. Soil selection and planning

Soil is the basic building block of every agrarian practice. Without soil, the word crop does not exist. Soil is considered to be the stomach of flora (Manna et al., 2014). So to analyze the condition of soil is the first and foremost step towards the best agrarian practice. By doing the soil testing we can analyze the physical, biolog-

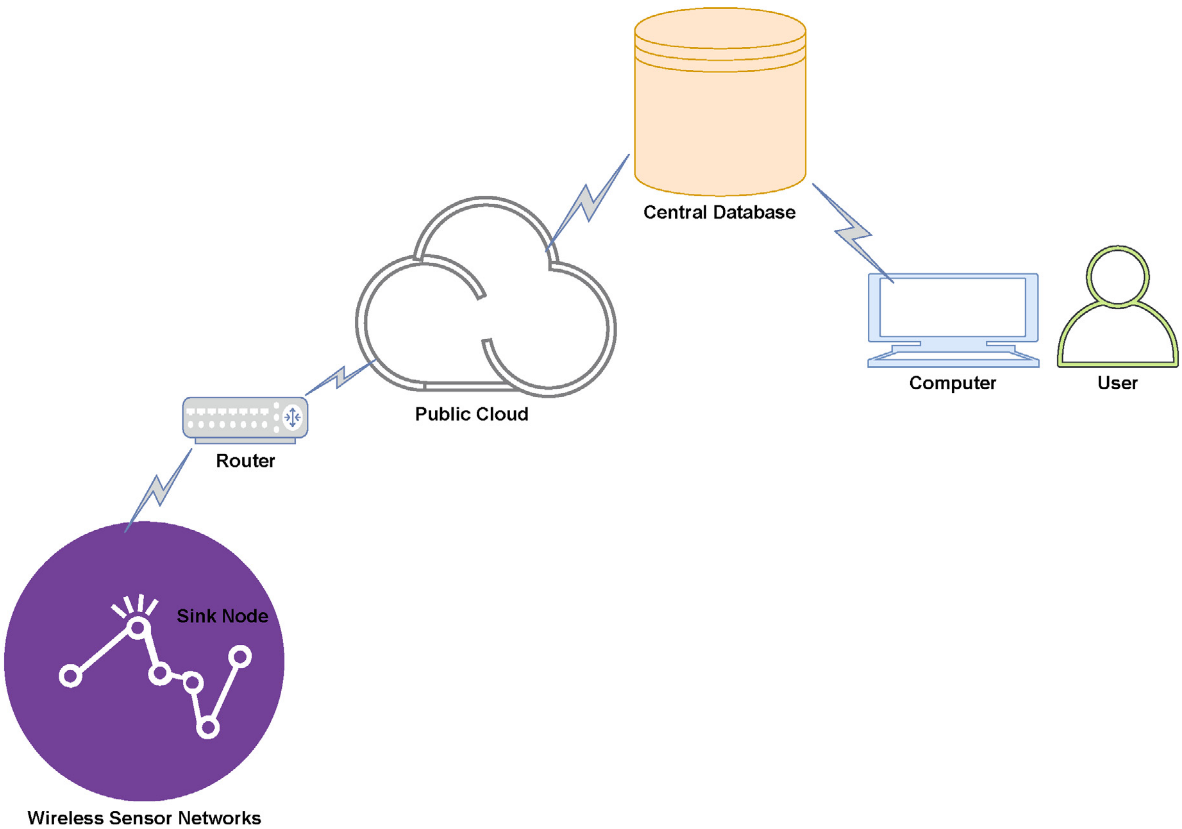

Fig. 2.1. Precision Agriculture Model.

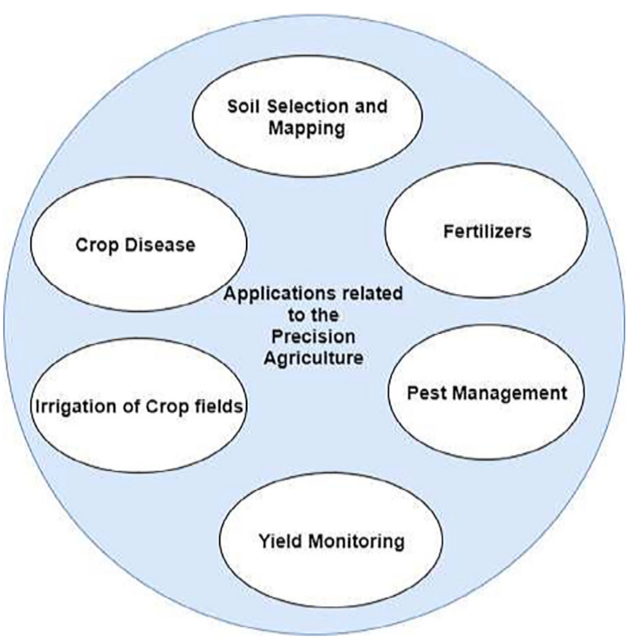

Fig. 2.2. Applications related to precision agriculture.

ical, chemical statuses of the soil. Based on this the farmers can take decisions accordingly regarding their fields. The main motive of precision farming is to produce more from the scarce cultivable land. So to implement the new era technologies is very important across the globe as we have to satisfy the increased population with the limited resources. Usually soil tests based on weather and soil conditions are done in Fall (Dinkins and Jones, 2019). By doing the soil tests we can analyze the soil nutrients which include the information related to the fertilizers requirement, copping history, soil kind, irrigation level, etc. Presently we have various sensor based technologies which are very helpful in soil selection and planning. These technologies help us to decide the best crop for the best fit soil. A soil testing toolkit, Lab-in-a-Box, developed by Agrocares is considered to be the complete laboratory test toolkit (Dinkins and Jones, 2019). It can be used by any farmer to test the soil of their fields without going without going any agriculture laboratory. According to this toolkit it is said that around 100 samples per day can be tested by any farmer without having any lab experience. It means around 36000 samples per year can be tested without visiting any lab. Using the vision based technologies with the sensors agriculturists can make a determination of depth and distance for implant a seeds and plants proficiently (Manna et al., 2014). In Santhi et al. (2017), using the GPS (Global positioning system), sensors and autonomous robot based on vision called Agribot was advanced for seed sowing. So in short we can say that present technology is very helpful for every farmer to help them to select the best fit land for the suitable crop.

2.3.2. Irrigation of crop fields

Irrigating the crop fields on requirement bases is one of the best ways to generate more and more crops and manage the available fresh water bodies. Humanity relies only on the 0.5% available fresh water. Approximately 97% of the available water on the planet earth is salt water and the remaining 3% is fresh water. About 67% of the fresh water is either in polar ice caps or glaciers that is frozen (Ice, 2020; What percent of earth is water?, 2020). It means only remaining percentage of fresh water is unfrozen which lies underground and only 0.5% is available for the flora and fauna to survive (Water facts-worldwide water supply, 2020). It has been mentioned in (Water for sustainable food and agriculture by fao, 2020; Motoshita et al., 2018) that it is agricultural area which consumes around 70% of the 0.5% available fresh water, even around 85% is utilized for the same in underdeveloped countries. So it is the responsibility of the humanity to manage the water resources. For that very purpose many researchers are working. So the traditional methods of irrigation can be managed by adopting the emergent technologies like IoT and WSN. We can deploy the WSN based system related to the soil moisture which will notify us whenever we need to irrigate the system. In (Zhang et al., 2018; Irrigation & water use, 2020) based on IoT, crop Water stress index (CWSI) has been developed, which can be used to increase the efficiency of crop. In CWSI system we are deploying the required sensors in the needed field and collect the data, sending that data to the central processor. A the central node we are also collecting the data from weather stations and including the satellite images, based on all thus we decide whether we should irrigate the field or not. In nutshell we can say by adopting the emerging technologies we can maintain the required moisture for the crop and in turn will save the fresh water resources.

2.3.3. Fertilizers

Fertilizers provide the nutrients to the soil which in turn are transferred to the plants through roots. Fertilizers like potassium (K), Phosphorus (P), Nitrogen (N) etc. all have their own uses to maintain the health of flora. Plants need mainly NPK macro nutrients to maintain the health. P is used to maintain the health of roots, flowers and helps in fruit development, K is used to for stem growth and for proper functioning of xylem so that water can be transferred to every part of the plant, and N helps the leaves in growth. So we need to prevent any sort of deficiency of NPK fertilizers in plants or improper use may also lead bad results. Excessive use of fertilizers imbalance the ecosystem. Precision agriculture helps in proper use of NPK fertilizers by using WSN, machine learning and IoT technologies, hence helps us in avoiding the negative results over the ecosystem. Using the aerial/ satellite images to monitor the crop nutrients, in (Benincasa et al., 2018; Liu et al., 2018) authors have used NDVI (Normalized Difference Vegetation Index), from vegetation it is working on reflection of visible and near infrared light. It helps the farmers in the estimation of vegetation vigor, crop health, and density. It also helps in assessing the soil nutrient level. Hence it helps the efficient use of fertilizers. NDVI contributing the precision agriculture uses the emerging technologies like VRT (Variable Rate Technology) (Colaço and Molin, 2017; Basso et al., 2016), autonomous vehicles (Khan et al., 2018), geo mapping (Suradhaniwar et al., 2018) and Global positioning system (GPS) accuracy (Shi et al., 2017). In short we can say that if the proper use of fertilizers cannot be done then there we are creating difficulties for our incoming generations. So it is better to develop our globe by adopting the new era technologies.

2.3.4. Crop disease

Presently our entire globe is suffering from various crop diseases such as leaf spot, apple scab, potato scab, anthracnose, late blight, early blight, powdery mildew etc. These diseases cause financial losses up to billions. Besides financial and economic losses crop disease affect the health of fauna. According to the FAO (Food Agriculture Organization), it has been estimated that 20–40% crops are lost due to the crop diseases and pest use (Keeping plant pests and diseases at bay, 2020). It is the time to work on it, because if we will leave this all untreated we will lose much more that this in near future. IoT plays an important role in monitoring the condition of crop by using the wireless sensors, drones, other IoT based intelligent devices which capture the condition of the crop and analyses it in the high end processors and take the decisions accordingly based on decision support systems using machine learning. A lot of work has been applied to overcome all this by using various new era techniques. In Oberti et al. (2016) various approaches like automatic chemigation and vehicle spray, those are mainly used under precision agriculture to treat diseases of crop.

2.3.5. Pest management

By using various pesticides, herbicides, insecticides, in order to remove the enemies of the crop, we try to maximize the yield. Most of the farmers are ordinary people who are unaware about the current trends and techniques. They are completely unaware about the precision farming technologies. Over and under usage of pesticides, insecticides, etc. imbalance the nature. Excessive use of pesticides leads bad effect over the environment. By using these germicides we are creating more chances of chronic and fatal diseases like cancer, asthma, etc. In Kim et al. (2018) and Venkatesan et al. (2018) with the help of IoT we can stop the improper use of these pesticides. Modern IoT based pest management based on real time environment monitoring, provides disease prediction, modeling, etc. hence results more effective.

2.3.6. Yield monitoring

Last but not the least application of internet of things is to monitor the farm lands. In order to maximize the yield both qualitatively and quantitatively good farmers should never hesitate in adopting the modern technologies because all farmers are interested in producing the best quantity from their fields, they always prefer to increase the quantity and quality of the crop. Yield monitoring monitors the whole crop area from beginning till end means from cultivation to harvesting. In harvesting we need to check how to store food? How to transport it? How to deal with the diseases which are caused while storing it? All these problems are solved using the wireless sensors and other related technologies. In Wietzke et al. (2018), Chung et al. (2016) and Gholami et al. (2014) it has been mentioned that quality of the crop and the yield of the crop depends upon self-pollination and other environmental conditions. During dry conditions to monitor the foods like papayas, multiple optical sensors are used (Udomkun et al., 2016).

3. Adoption of IoT (Sensors) and Data Analytics in tradtional Kashmir farms for the prediction of apple scab

Apple is one amongst the most grown fruits in the world. It grows mostly in dry areas. In Jammu and Kashmir where people from most of the districts are dependent on farming and agriculture, it produces the large quantity and diverse apples in India. Its industry is worth of thousands of crores in J & K. As shown in Table 3.1 the district wise production of Apple crop in Kashmir division.

But due to the various diseases, wide range of pests and lack of technology in the fields we lose both quantity and quality of the crop. Apple scab is the most troublesome disease for apple growers

Table 3.1
District wise production of apples in Kashmir.

District	Production (In metric tonnes)
Baramulla	469.3
Anantnag	161.182
Pulwama	121.9
Kulgam	45.53
Srinagar	36.1

Table 3.2
Relationship between production and factors.

Factor	Multiple R-Squared Value
pH	0.0653
Phosphorus(P)	0.0209
Nitrogen(N)	$0.07867 * 10^{-5}$
Potassium(K)	0.236
Organic content(OC)	0.00029

in all parts of Kashmir. Scab is caused by a fungus that infects both leaves and fruit. Scabby fruit are often unfit for eating and continued infection of leaves weakens the tree. Small black spots develop on fruit, enlarging more slowly than on leaves. As these spots grow and become older, the center loses the velvety appearance and becomes brown and scabby. Heavily infected fruit becomes deformed and cracked when infected at an immature stage. Apple scab infections occur during wetting periods when moisture stimulates the pathogen spores to germinate and penetrate plant tissue. For this we did literature survey related to the crop and the factors affecting its growth. We did a local survey to find data regarding the factors on which we were going to work on. So, for this purpose we went to SKUAST (Sher-e-Kashmir University of Agriculture Sciences and Technology, Srinagar, Kashmir) and visited departments of Soil and Pathology to gather the relevant data. Therein, certain information regarding the Apple Scab disease was collected. At SKAUST we came to know about the factors affecting the growth of Apple crop. We analyzed the collected data to verify the factors which actually affect the production and occurrence of diseases. Studying the R-Squared values, we see factors like pH, P (Phosphorous) and K(Potassium) play a very important role in the overall production of crop as shown in Table 3.2 OC(Organic content) is a slightly less important factor while nitrogen plays the least important role. Based on these values, we designed some prediction models as shown in Fig. 3.1. Factors like pH, K, P and OC together are crucial for a quality crop as is evident from its R-Squared value 0.788. The scab prediction table given here can be used to determine whether or not conditions have been sufficient for infection so that appropriate spray decisions can be made. Based on a certain combination of temperature and hours of leaf wetness, we can identify whether that region is safe (no chance of apple scab occurring) or unsafe (higher probability of the disease occurring with less incubation days) (MacHardy et al., 1989; Belete and Boyraz, 2017). From the data following two graphs have been drawn see Fig. 3.2. Safe zone where there is 0% chances of apple scab while Fig. 3.3 shows the unsafe zone where there is no chance to stop apple scab.

3.1. Framework

The main aim of this study was to predict the apple scab that is the most common disease of apple crop. In this problem we used the real time data of wireless sensor/IoT nodes as input for linear regression model. In this an application is developed for farmers which is simple and user friendly to inform them about the status of their apple orchards on real time basis. The framework consists of a number of WSN/IoT nodes scattered in the orchards of the apple with nearby gateway for collection of the data from the mesh of the nodes While performing the research on the said problem various steps have come in the way that forms the basis of our study. These steps are shown in the Fig. 3.4. The nodes are deployed in the apple orchard for data collection. A network is established between the nodes, data acquisition is done by nearby gateway or a fog node from prefixed number of nodes in the network. The data analysis is done on the real time basis for each location/orchard for quick action if needed. In this work data is

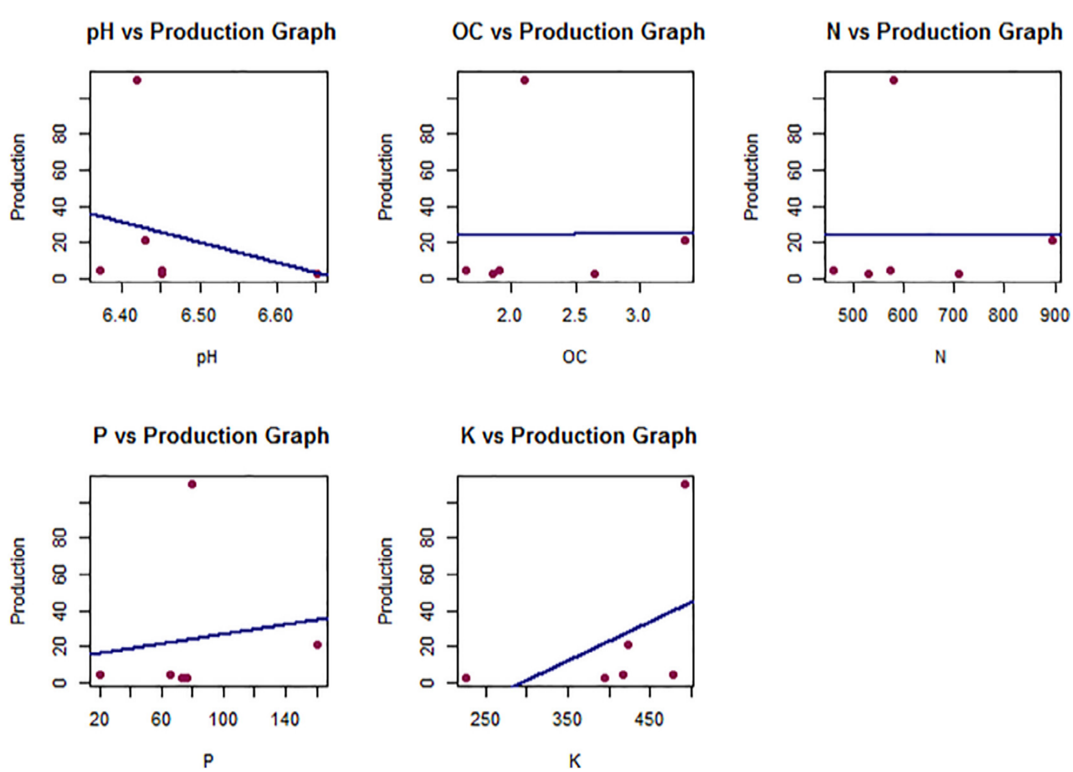

Fig. 3.1. Plots of Factors vs Production.

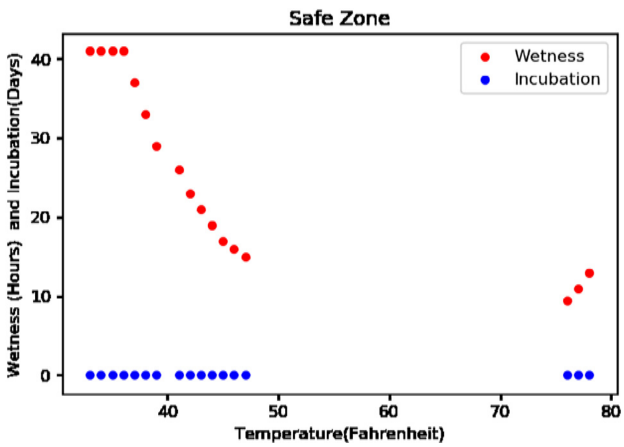

Fig. 3.2. Safe zone.

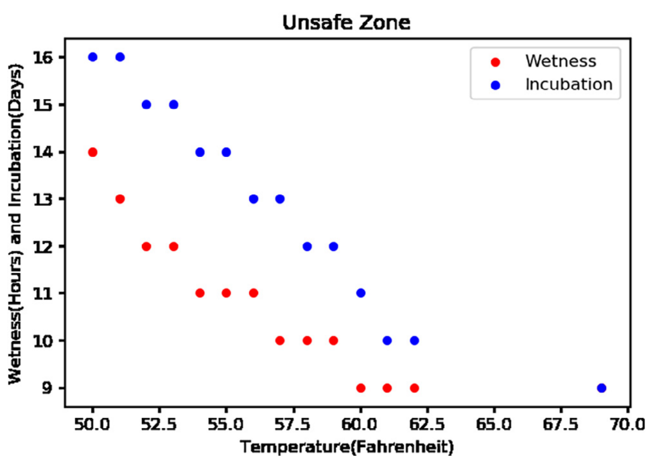

Fig. 3.3. Unsafe zone.

collected from many orchards of the Kashmir Valley using the same models as discussed above. The results are shown in Section 3.6. The detailed framework is explained below:

3.2. Sensors assembled

In precision agriculture IoT plays an important role. IoT are the embedded systems which have the capability to sense and share information related to any field in any application. IoT devices and its services play an important role in wireless world as they can provide users all required services at anywhere at any time. Diverse number of sensors related to agriculture like plant sensors, soil sensors, environmental sensors etc. collect the real time data respectively. This data is very helpful in predict the crop diseases. In our prediction model we required to monitor two parameters temperature and hours of wetness in a field.The sensors comprised of an IRIS mote and MTS420 sensor board. The IRIS is a 2.4 GHz module used for enabling low power, wireless sensor networks. MTS420 offer five basic environmental sensing parameters and an optional GPS (global positioning system). The five basic environmental sensors included in MTS420 are temperature, humidity, barometric pressure, ambient light sensor and dual-axis accelerometer. Among these we are interested in temperature and Leaf wetness hours only. For this DHT22 sensor is used which is embed on MTS420, gives us temperature and humidity. Leaf wetness hours are then calculated using humidity.

3.3. Sensor/IoT network setup

This step involves setting up of the WSN for capturing the data. We created a WSN of several sensors and a gateway. Six sensors have been used to cover the particular area of an orchard. Each sensor comprises of a IRIS fitted with a MTS 420 sensor board. The gateway is incorporated in WSN that provides connectivity back to the wired world and distributed nodes using Zigbee module. The IRIS needs to be programmed to be able to act as a sensor with sensor board. Six such sensors were developed which are enough to cover the length of an average apple farm. For the gateway, MIB 520 fitted with an IRIS is used. Here the IRIS is programmed to act as the gateway in order to communicate with the computer. For programming of IRIS and MIB 520 MoteConfig Application is used. MoteConfig is a Windows-based GUI utility for programming Motes. This utility provides an interface for configuring and downloading pre-compiled XMesh/TinyOS firmware applications onto Motes. MoteConfig allows us to configure the Mote ID, Group ID, RF channel and RF power. We can also enable the over-the-air-programming feature present on all XMesh - based firmware. High-power and low-power XMesh applications are available for each sensor board and platform. The Local Program tab is used to upload firmware onto the Motes via a gateway. To program motes correctly, we set up the hardware as follows:

- The gateway(in this case the MIB 520) should be powered and connected to the PC via a serial, USB or Ethernet port.
- The motes should be firmly attached to the gateway.
- The motes should be turned off before the programming.Next Click on Settings followed by Interface Board, to select the correct gateway and port settings. Since we are using MIB 520 we'll select that one. To program the IRIS as a gateway for all the other sensors we have to upload XMESH file over it. To program the IRIS as a MTS 420 sensor mote we select XMTS420-M2110-hp file for the sensor board as shown in Figs. 3.5 and 3.6.

After the sensors were successfully programmed, these sensors were carefully placed throughout in each field and the gateway was connected to the system. Topology used for WSN is mesh in the proposed work. Main advantage of using mesh topology is that it covers the maximum area of the orchard, it reduces loss of the data and there is not any single point failure problem. The WSN thus deployed is highly scalable and reliable.

3.4. Data acquisition

Next step is to collect the data from various parts of the Kashmir Valley. Data collection is one of the basic and fundamental task while doing data analysis. To collect data, we selected three districts of Kashmir: Zakura Area of district Srinagar, Pinpora area of district Kulgam and Kanelwan area of district Anantnag, spread over a area of 4–5 kanals, 7–8 kanals, and 6–8 kanals respectively. The system was kept in place for over 12 h to collect a single days

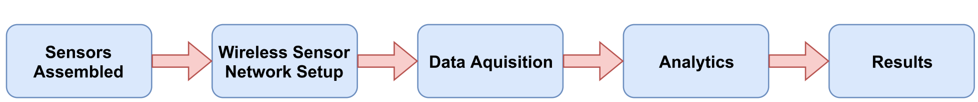

Fig. 3.4. Block Diagram:Steps involved throughout the process.

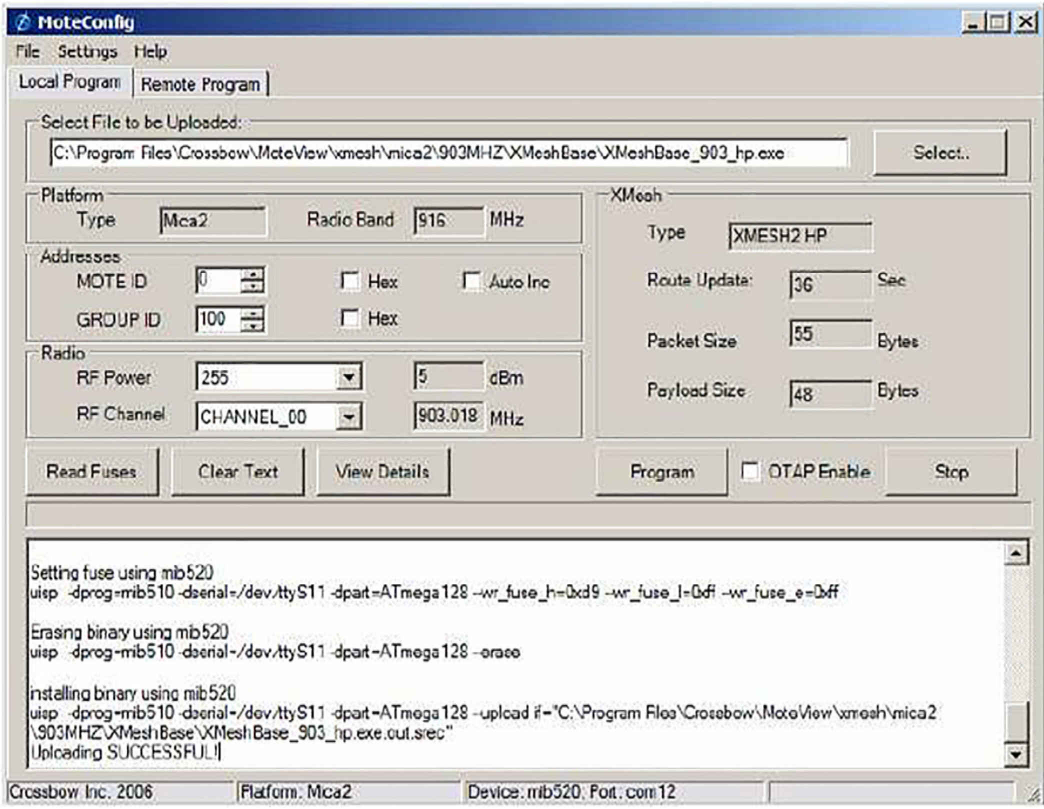

Fig. 3.5. MoteConfig programming successful.

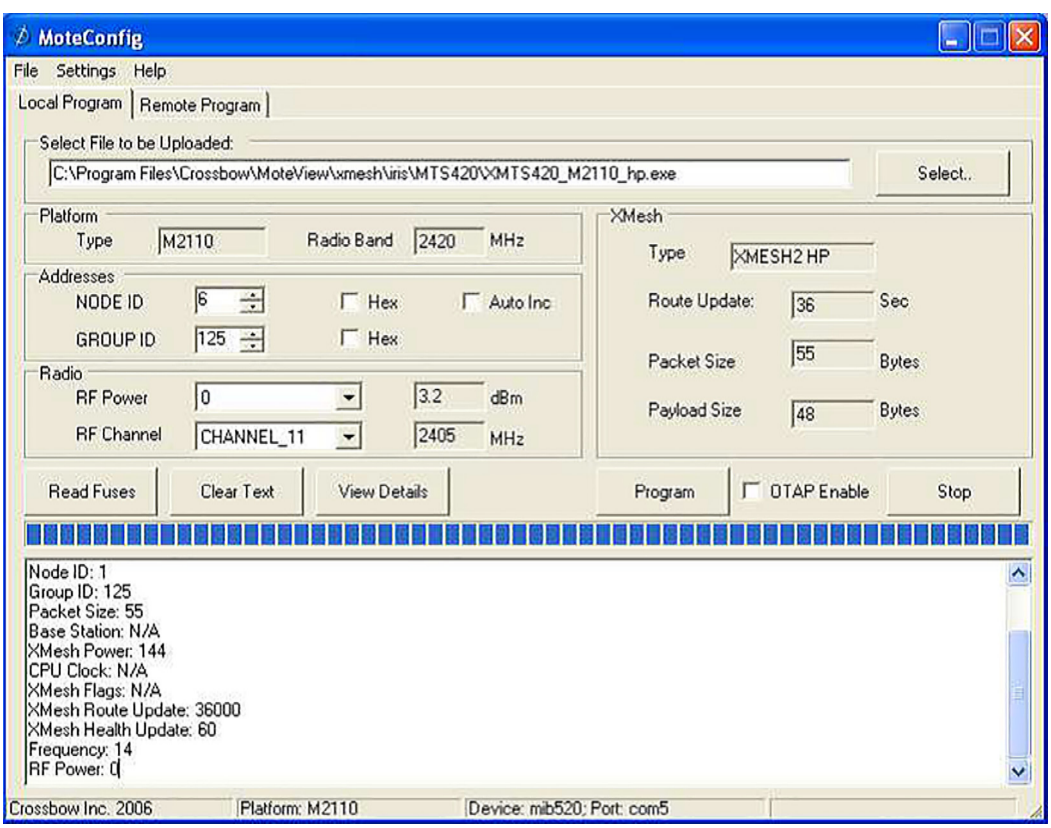

Fig. 3.6. MTS 420 Sensor programming successful.

data. Care was taken to ensured that the motes weren't damaged by water leading to wrong readings. To note any variation sensors were kept 100 meters apart, so that whole data from the field can be collected. MOTE-VIEW monitoring software was used as an interface between user and the deployed WSN. It provides the tools that simplifies the deployment and monitoring of WSN. It helps in data collection into the database. We used PostgreSQL database for it, this resides on our personal computer system (acts as a local-host), a remote server.

3.5. Analytics

After the WSN was deployed, the sensors logged their data in a Postgres database. Next step was to analyse this data and find a prediction model fitting the data captured. The data from the database table first extracted in the form of a .CSV file.

Data pre-processing: The .CSV file contains certain extra columns which are not required by us. These columns are dropped first. Next we need to take care of the anomalous values such as a high peak in temperature which is impractical. This kind of thing happens only few times but can harm our results. Hence are removed.

Analysis using linear regression: We applied the machine learning on the same data and predicted the status and requirements of the disease treatment in advance by applying simple linear regression model. We analysed the captured data and found the prediction model fitting that data. In our prediction model using linear regression we have three variables. T, W, and I are respectively the temperature, duration of wetness of leaf and incubation period of the infection causing pathogen. So we have analyzed the collected data and found a prediction model fitting the data captured. Our model has three variables as such. The first of these is the temperature (T), second is the duration of wetness (W) and the final is the incubation period of the infection causing pathogen (I). The main purpose was to find a relationship which makes I as a function of W and T. Later on this equation is found to be useful in finding the vulnerability of some specific combination of wetness duration and temperature with respect to an attack of infection. In a simple linear regression model, a single response measurement is related to a single predictor (covariate, regressor) X for each observation. The critical assumption of the model is that the conditional mean function is linear as shown in Eq. 3.1:

$$E = aX \tag{3.1}$$

In most problems, multiple number of predictor variables may be available. This will result in the following "multiple-regression" mean function as shown in Eq. (3.2):

$$E = a + b_1X_1 + b_2X_2 + \dots \tag{3.2}$$

Where a is called the intercept and the b are slopes or coefficients of X variables. Keeping the other predictors constant, each coefficient estimates the change in the mean response per unit increase in X. The equation that we found out is shown in Eq. (3.3):

$$I = 37.774 - 0.3328T - 0.886W \tag{3.3}$$

The Eq. (3.3) we obtained using linear regression model shows the incubation period is being predicted by the temperature value and the value of wetting period. The negative coefficients (−0.3328 and −0.886) indicates inverse relationship between incubation period with the temperature and wetting duration. In other words we can say that with decreasing in the values of temperature and wetting period there is an increase in the value of I.

Table 3.3
Table of Results.

Coefficient	Estimated Value	Standard Error	True Value
Intercept	37.774	9.3111	4.057
Average Temperature	−0.3328	0.1308	−2.545
Wetting Duration	−0.886	0.1755	−4.563

3.6. Results

Table 3.3 shows the table of results obtained by using linear regression and shows the Estimated Value, Standard Error, True Value of Intercept, Average Temperature and Wetting Duration. The Eq. 3.3 thus obtained using linear regression model shown above indicates that the incubation period is being predicted by the temperature value and the value of wetting period. With decreasing in the values of temperature T and wetting period W there is an increase in the value of incubation I. The Algorithm 1 shows the various steps used in order the get the correct results.

Algorithm 1: Apple scab prediction using IoT and Data Analytics

Input : Real time data of temperature and leaf wetness hours
Output: Apple Scab Prediction

i← 1 **to** n;
Deploy WSN_i in Crop Field CF_i;
for WSN_i **do**
  Deploy 6 Sensors $S_1, S_2, S_3, S_4, S_5, S_6$;
  Deploy Gateway G_i;
  while $Time \leq 12$ **do**
    Collect $Dataset_i$ *in the PostGreSQL Database;*
    $Time = Time + 1$;
  end
  foreach $Dataset_i$ **do**
    Apply Data Preprocessing;
    Do Data Analysis;
    Get Results;
  end
end

The results showed the incubation period of the areas based on safe and unsafe-zones. The incubation period for Kulgam was 5 days and for Anantnag district it was 3 days. Hence Kulgam and Anantnag were categorized as unsafe zones while as Srinagar was categorized as safer zone under the present climatic conditions. The system was proved to be useful for the local farmers and hence we got our results attested. In Fig. 3.7 the residuals vs. fitted is a scatter plot of residuals on the y axis and fitted values (estimated responses) on the x axis. The scatter plot is used to

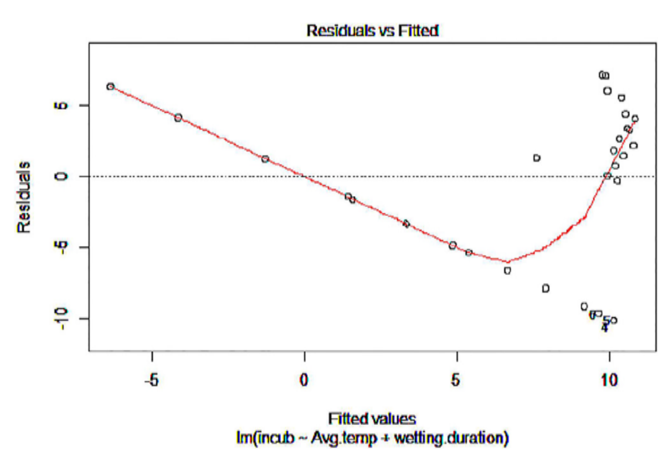

Fig. 3.7. Residuals vs. fitted.

detect unequal error variances, non-linearity, and outliers. Any data point that falls directly on the estimated regression line has a residual of 0 i.e. no error in the predicted value. If we compare the previous work done with the proposed work, wherein they have not used the real time data for prediction of apple scab disease hence time to respond to the disease is more but by time we come to know about the disease the response time has already elapsed and the crop will be affected. In our approach using the IoT for disease prediction the delay is minimised to the extent that if a corrective mechanism like temperature control, spray of chemicals, pesticides, watering etc. for real time precise agriculture can be used. Although we may need to increase the number of parameters for disease prediction in our proposed mechanism in future but this work can give us a platform, architecture and algorithm to move ahead.

4. Challenges in IoT Adoption for traditional farmers

Precision agriculture is a powerful technology to meet the challenges of the increasing needs from scarce resources. Besides the advantages there are number of challenges which agriculturalists, farmers, researchers and scientists are facing while adopting it. For this purpose a local survey was conducted to know what the regional people think about it.

4.1. Survey setup

Site Description: Jammu and Kashmir is the northernmost geographical region of the Indian Subcontinent. Kashmir lies between latitudes 32°and 36°N, and longitudes 74°and 80°E. It has a different climate for every region owing to the great variation of the level of the altitude. Wheat, maize and rice crops grown in about 250,000 hectares 210,000 hectares and 110,000 hectares area respectively are the major cereal crops of Jammu and Kashmir division. Apple is the valuable cash crop of Kashmir Valley. In India, agricultural risks are provoked by variety of factors, like climatic variability/change, extreme weather events, crop management practices and soil fertility status etc. which ultimately leads to uncertainties in yields and prices of the grain. We did the local survey in Kashmir Valley by using precision agriculture in the crop fields using Information and Communication Technologies (ICT) like IoT, Machine learning, Data analytics etc. The population of this study are small scale farmers to large scale farmer using simple technologies and mostly traditional ways in their apple orchards for agricultural information to improve their productivity. In order to bridge the gap of knowledge and skill regarding agriculture in this area, we asked some questions through interview to know its basic causes. 1100 people were selected who were engaged in these from three districts Kulgam, Srinagar and Anantnag where we have deployed our proposed system. Random sampling technique was used and 330 respondents (33% from the total frame) were interviewed in study area based on the population intensity. Table 4.1 shows the survey site, number of farmers selected in each site and number of respondent in the sample. While this survey various questions were asked to the farmers. Most of them were uneducated, some of them were educated, few of them have the knowledge of IoT and other technologies. In order to know their views various questions were asked to them either through questionnaire or by interview. Table 4.2 shows the various questions and the percentage of corresponding responses in terms of Yes or No. The positive (yes) response was mostly received from those farmers who were either educated, or whose field was under investigation.

Table 4.1
Survey of Farmers.

Survey Site	Duration	Farmers Selected	Respondents
Anantnag	July2020-Sep2020	400	110
Kulgam	May2020-Oct2020	300	130
Srinagar	June2020-Aug2020	400	90
Total		1100	330

4.2. Results

From the last decade, overall amount of funds for the agronomy area has developed enormous nearly 80%. In accordance with the experts of the agronomy sector smart agriculture is capable to take on an important role in attaining the proliferating demands of food of the increasing population throughout the globe. The financial worth of the worldwide smart aggie marketplace is approximately \$4.6 billion with CAGR (Compound Annual Growth Rate) between 2015 and 2020 being just a touch under 12% (Fakhruddin, 2020) mentioned in a fresh report. It has been predicted in many foreign countries especially in United States alone agriculture software will nearly increase around more than 14% between current and 2022. From the above it is expected that development and propagation of precision farming should be vigorous, efficient, etc. But like other technology based applications precision agriculture also faces number of challenges as we have seen in the local survey in Jammu and Kashmir that there are number of challenges. The challenges faced are mentioned in Fig. 4.1 and are discussed below:

4.2.1. Challenges based on commercial

Due to the tremendous advantages of the current technologies like Internet of things, wireless sensors, actuators, today's farmers are interested in business models. Using IoT technologies, they will accumulate the data from their farms to support their revenue. The data provided by the farmers are exploited by the most of the existing IoT platform service providers. They provide unrestricted limited services and full services with diverse level of subscriptions. This becomes the part of argument for farmers to supervise their owned data.

Table 4.2
Questions and Responses.

Questions Do you have knowledge on:	% of Farmers Yes	% of Farmers No
yield monitoring?	5	95
soil mapping techniques?	6	94
variable rate technology(VRT)?	3	97
precision agriculture?	7	93
data Analytics in precision agriculture?	2	98
interent of things (IoT)?	5	95

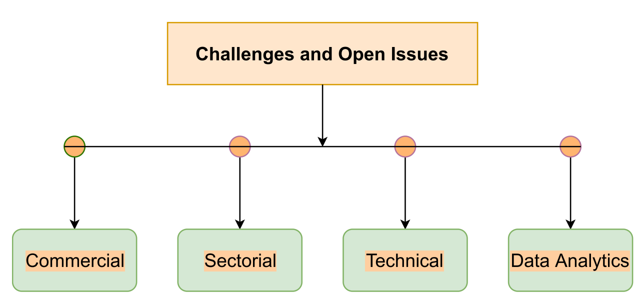

Fig. 4.1. Challenges of Adopting Precision Agriculture.

Budget: While developing any solution for smart agriculture, cost analysis should be done. As we know in IoT, the initial costs are very high due to the variety of sensors, gateways, base station infrastructure (Farooq et al., 2019). After this maintenance is also an important part of cost analysis. Here the researcher's goal should always remain such that increasing the production while decreasing the cost requirement.

Unawareness of Information and Technology era: As we know most of the agricultural working is happening in rural areas where farmers are not well educated. They are unable to accept the new trends and technologies early. This is the reason of slowing IoT in rural areas. So in order to overcome this issue, we need to educate farmers in order to generate best results (Marjani et al., 2017; Farooq et al., 2019).

Loss of manual employment: Around 60–70% of the workforce are working in the primary sector globally. The number is high particularly in Asia, Africa and Oceania. As the agricultural practices become automated and mechanized -a very great percentage of the agronomy workforce will lose their employment. It will make it necessary to accommodate these employs in other employable sectors. This will be only possible if these sectors are able to absorb such a very huge volume of unemployed people. But due to the poverty in most of the developing countries particularly in India it is hardly possible. So besides the large-scale benefits the precision agriculture lead but a massive displacement of labors may cause discontent and disappointment among populace.

Benefits not immediately apparent: While developing any system in any field, QoS is very important. In big IoT data and machine learning used in precision agriculture QoS should be highlighted at each layer so that system will give best results at end (Al-Fuqaha et al., 2015; Huang et al., 2017). There are number of challenges especially while transferring data from one layer to another QoS is usually compromised. Hence there is a need to do more research work by providing a solution that will guarantee QoS throughout the network system at each layer.

4.2.2. Challenges based on sectorial

There are number of parameters that need to considered for distribution of IoT systems. One of the main factor is the ability of an IoT device to place anywhere for perfect operation and remain connected globally. This means the ability to connect anywhere at anytime with least configuration. Other features are ability to support roaming and provide reliability to the system for proper results. We need to consider the IoT technology infrastructure for the static IoT devices.

Size of individual management zones: Production function refers to the quantity and quality of output keeping the land area under cultivation same. But the production function varies for most of the crops, in different zones of field etc. (Fakhruddin, 2020). But unfortunately farmers are not aware about it. Precision agriculture cannot be optimized unless and until farmers become aware about varying production function e.g. excessive or moderate use of fertilizers, pesticides etc. will lead to crop damage.

Interoperability: It refers to the capability of a device, product, service, system to be operated with others reciprocally. With the growing Original Equipment Manufacturers (OEM) approaching with innovative and advanced precision agronomy equipments, devices, platforms, etc., interoperability becomes the most important point of concern (Fakhruddin, 2020). This involves number of issues related to the technical, semantic, syntactic and organization interoperability (Elijah et al., 2018; Brewster et al., 2017; Vermesan, 2010; Tayur and Suchithra, 2017). So in order to overcome this issue researchers should focus on building the farmer friendly platforms which are holistic instead of smart standalone devices, gateways or other smart appliance.

Supervisory challenges: Organizing, managing and permissible foundation concerning the authority and proprietorship of field data between the owners of the fields and the data companies is required to sort out. Regulations like data privacy, data security, technical issues, available resources like bandwidth, etc. differ from country to country. Differing these supervisory features affect the use cases related to the agriculture. Hence due to the heterogeneity of supervising techniques becomes a challenge for most of the farmers.

4.2.3. Challenges based on technicality

Technology make jobs easy. Every work based on technology becomes automated using IoT and other mechanized ways. This increases the dependence of health, traffic, home and other related jobs on the technology. It can be very dangerous at times even if any individual subsystem of the system will stop working. Hence can become the cause of loss. If we take the example of the precision agriculture as in our case most of the hardware units are exposed to the outside environment. This makes it more possible that the sensors may get destroyed due the various reasons like, rain, wind, snow etc. So in short we can say that we cannot meet the food safety. Compromising the food safety means system is useless. Sometimes the downtime can be caused by power failure. Hence we need to make sure we are keeping the backups for everything in order to meet the requirement. Single point failure can never lead to success.

Internet Connectivity: In rural areas across the globe particularly in developing countries like India high speed and reliable internet connectivity is absent (Fakhruddin, 2020). Due to the wireless communication various issues like multipath propagation, which occurs due to the buildings trees etc. the IoT system is not able to work consistently. So there is a need to develop most robust and reliable technologies (Ojha et al., 2015).

Security Factor: It refers when the said system is compromised to restore personal information. It is one of the most important issues in every field of study. In our case of big IoT data and machine learning it may compromise any sort of information at any layer, lower or higher (Marjani et al., 2017). The main focus of researchers remain to secure the customers data. With the innovations and technological revolutions each and everything has become dependent on cloud computing, IoT, big data machine learning. But unfortunately these systems don't provide solid Service Level Agreements (SLA) (Marjani et al., 2017). Although there are number of ways to enforce data security like encryption, temporary identification, etc. But decisions should be made based on moral factors that is what to adopt, when to adopt, where to adopt, how to adopt and why to adopt? (Marjani et al., 2017; Tsai et al., 2015). There are number of existing solutions which are not pertinent (Marjani et al., 2017). They provide solutions which are applicable for static data sets. But the in our case, of big IoT data have dynamic nature (Marjani et al., 2017). In precision agriculture we cannot use the complex and sophisticated algorithms due to limited resources like memory, processing, power communication capabilities etc. In precision agriculture and farming the IoT sensing devices are most defenseless especially to environmental tempering like attacks by animals, thieves, and alteration of physical address (Varga et al., 2017; Duan et al., 2014). The IoT system when used in agriculture are mostly targeted by device capture attacks (Varga et al., 2017; Newell et al., 2014), the higher layers are then targeted by Dos attacks (Elijah et al., 2018). The farmers usually prefer the devices which are cheap but they are not supported by security and privacy related features. Hence to make internet of things more acceptable for every kind of farmer there is a necessity of strict security and endowment policies for precision agriculture (Fakhruddin, 2020).

Absence of Scalability and configuration: IoT system includes billions of devices which are developed and deployed across the globe over different locations. Existing systems and protocols should have the ability of support this large number of IoT nodes e.g. Sigfox gateway, Lora and Ingenu can support up to 10^6 ,10^4 and 10^4 nodes respectively (Elijah et al., 2018). This requires proper management system for each device and unique identification numbers.

Reliability: IoT sensing devices are mostly distributed in outdoor surrounding to sense the environmental conditions. This exposes IoT system to harsh environmental conditions which in turn destroys the sensors, gateways, etc. and hence creates the communication failures (Elijah et al., 2018). Hence physical safety of these devices should be ensured so that big IoT data precision system for agriculture will be properly developed.

Selection of technology: Number of challenges arises while developing a smart precision agriculture system using IoT and big data. It is due to the fact that all the devices which exist at the perception layer are directly exposed to harsh environmental conditions such as high or low temperature, extreme humidity, storm, rain and many other possible dangers which destroy electronic circuits and devices (Farooq et al., 2019). In precision agriculture to maintain the system working in open fields is a challenging task. It is the responsibility of researchers to address these issues.

Optimization of scarce resources: To determine the requirement of resources so that profit margins can be known in advance but due to the varying nature of farm sizes and different types of sensor requirement this is a challenging task (Elijah et al., 2018). In order to know the requirement of resources precisely there is a need to develop complex algorithm and mathematical models. Again the resources are limited in IoT system, e.g. Precision agriculture advantages have already been discussed. However, the need of powerful gateways, smart sensors, data centers and other IoT related gadgets can lead to a higher consumption of energy (Fakhruddin, 2020). Hence it is very important to determine optimal resource allocation while maximizing agricultural products and profits and minimizing the cost.

4.2.4. Challenges based on data analytics

Todays world is running every business and organization to get more profit using the data analytics. Same is the case with the smart agriculture. To deal wit the data, researchers face number of challenges which are mentioned under data analytics challenge category.

Integration: It refers to combine the data coming from different sources of different formats into a uniform view (Ahamed et al., 2014). Good information is achieved from good data which is achieved through proper integration (Liu and Zhang, 2014). But it is a challenging task to integrate data from diverse sources (Ma'ayan et al., 2014). To adjust the structure in semi-structured and unstructured data is again an issue to be addressed (Chen et al., 2015; Savaglio et al., 2019). In Savaglio et al. (2019) novel data mining methodologies have been investigated for IoT scenario with respect edge computing using two types of K-Means clustering algorithm; distributed and centralized. Performance analysis helps to choose the best among these two versions based on their computation, energy consumption and communication requirements. There is a need to develop solutions for integrating data from multiple sources efficiently.

Knowledge Mining: It refers to generate efficient and best fitting descriptive and predictive solutions for big IoT data which in turn can be generalized for new data items (Marjani et al., 2017; Mukhopadhyay et al., 2013). Information extraction and data exploration are the challenges which were evolved due to big data and cloud computing platforms (Marjani et al., 2017; Hu et al., 2012). Due to nature of big IoT data every task related to data mining becomes a challenge like heterogeneous communication, integration, exploration and extraction process, cleansing, reduction, transmission (Lerdsuwan and Phunchongharn, 2017; Khattab et al., 2016; Liu et al., 2007; Ahmed et al., 2016). The researchers are trying to find solutions to these issues. They have brought in sequential programming models, parallel programming models and proposed diverse algorithms to deal with big IoT data. Big data is increasing making precision agriculture data driven; this will become helpful only when we make sense of it using technology.

Visualization: It is an important part in IoT data especially while handling IoT related systems in which data is produced enormously (Marjani et al., 2017). Again it is a very challenging task while dealing with big IoT data due to the structured, semi-structured and unstructured nature of it. So we did not get good and clear results. Cloud computing platforms enriched with GUI facilities help us to find good insights (Wang et al., 2015). Dimensionality reduction techniques are very helpful to deal with the big IoT data (Azar and Hassanien, 2015). Again if we try to use parallelization techniques to deal with small manageable tasks is again a challenge in precision agriculture big IoT data (Childs et al., 2013).

5. Conclusion and future work

The arable land is reducing slowly due to constructions (houses, dams, factories, industries, etc.), natural shrinking of arable land (floods, earthquakes, landslides etc.). Hence, the emphasis on superior and proficient crop disease approaches is prerequisite so that increasing food demand of the growing population can be fulfilled. The paper has given an extensive literature survey on the precision agriculture using IoT data analytics and machine learning. Furthermore, the applications of these technologies in precision agriculture are highlighted. Moreover the paper tried to address one of the problems faced in apple crop in regions like Kashmir. Since the apple growers are still using the classical approaches of disease prediction without any technological intervention like IoT/ WSN. One of the major advantages of the proposed approach will be real time measures against any possible disease like scab if predicted precisely and in a timely manner. Results from a case study on adoption of apple scab disease prediction in the orchards of Kashmir has shown improvement in terms of dissemination of information regarding the factors/parameters responsible for the disease aforementioned. Finally, the paper highlighted the issues faced while developing and deploying such applications in real time, for this a local survey was conducted to know what are the views of people regarding precision agriculture. Although many challenges are ahead before implementing the proposed framework at large scale. These include initial cost of implementation, deployment, training, weather conditions and other parameters. But once the aforementioned limitations are overwhelmed, the profits will turn into visible and workable form. The work shall be extended in future to include more parameters influencing the crop. The paper generalize that precision Aggie is stand on four stakes; Appropriate source, Appropriate place, Appropriate quantity and Appropriate time.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jksuci.2021.05.013.

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