Prospects of 'SMART Farming' in Cold Arid Region of Ladakh, India

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1 Introduction

The Union Territory of Ladakh with its distinct geography and climatic conditions altogether offer a tough life managed with meager resources. The agriculture sector being the primary occupation of this region has, directly and indirectly, contributed towards the sustenance of the region. The new era of change and development also demands the advancement in the farming sector of the region with advanced technology and inputs. While working in the crop fields, farmers are required to carry out several responsibilities. Seeding, weeding, fertilizing, and watering, for example, appear to be repetitive and labor-intensive operations undertaken by farmers in the field. However, to make the farming cycle more effective, preliminary decision-making is required before commencing the actual activities. This is being taken care of under a set of interrelated technologies that take care of the farming needs right from seed selection to sowing, harvesting, storing, processing and value addition, marketing, weather parameters, and all other relevant needs of the farming communities. This set of interrelated technologies also aids in decision-making and is referred to as Smart Farming. Smart farming is a type of agriculture management that makes use of contemporary technologies to boost the quantity and quality of agricultural products [1]. Smart agriculture helps to address the aforementioned problems by reducing crop waste, making better use of fertilizer thereby increasing the yield of the crop. Smart Farming is being practiced using different tools and technologies.

The Internet of Things (IoT) is a network of interconnected computing devices, digital and mechanical equipment, humans or animals, and objects that can perceive,

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gather, and transport data over the internet without the need for human intervention. It is a technology that aims to link all of the world's items to the Internet. The Internet of Things' main objective is to link everything in our environment and enable seamless communication between them with minimal human involvement. It emphasizes the ability to connect with anybody, anywhere, at any time. It allows real-life physical objects (e.g. sensor nodes) to work together to develop an information-based system that maximizes the benefits (e.g. improved agricultural production) with minimized risks (e.g. environmental impact).

IoT helps in predicting crop production, crop pricing, the temperature of the soil, and real-time data on air quality, water level, and crop delivery timing, all of which helps in boosting the productivity of the crop. As the world's population grows, so does the demand for food, and IoT in agriculture is a key driver in meeting that demand. While IoT-based agriculture is thriving in developed countries, in India, it is still in its infancy. Lack of awareness about technical equipment among the farmers is the major challenge that we are facing. Furthermore, in India, the cost of implementation is also a big issue [2]. As a result, we should concentrate on building more specialized and effective sensors and implementing them using the right technique (Fig. 1).

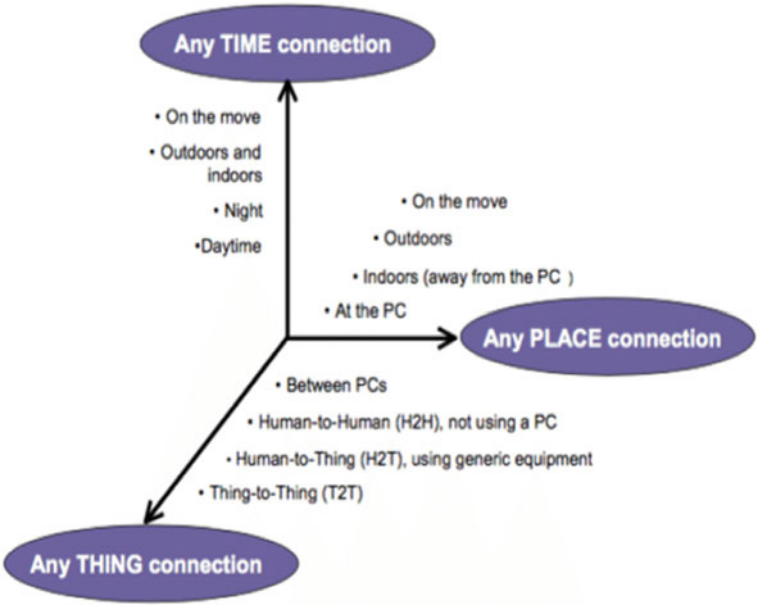

Fig. 1 Internet of Things [2]

2 The Problem Faced by Farmers

Like in the rest of the state, agriculture is the main source of livelihood in this district. Of the 45,167 ha, the area under cultivation in this district is 10,542 ha as per the revenue department village paper. As land holdings are small (0.68 ha) [3], more people are working invariably on farms in rural areas, and with conventional manual methods, outdated equipment limits the production thereby reducing revenues from farming. The main problems faced by the farmers of this region are mentioned below [4].

- Very short growing season, extreme climate, harsh winters, high-temperature variation, extremely arid conditions, negligible rainfall, and inhospitable weather conditions.
- Geographically difficult zone, demographically disadvantaged, and politically sensitive.
- Scarcity of high-quality planting material both in agricultural as well as horticultural crops.
- Inadequate irrigation and electricity supply.
- The fertility status of the soil is low.
- Inadequate technical know-how among farmers for improvement in agriculture and allied sector.
- Poor marketing facility (due to which local produce does not fetch a genuine price.).
- Lack of network, cooperative societies for storage, marketing, supply of farm inputs, etc.
- Lack of feed and fodder.
- Lack of mechanization in agriculture.
- Inaccessibility to villages hampers in transferring of technology.
- The district remains cut off from the rest of the country for more than 6 months.

3 Smart Agriculture

The modern practice of advanced technology and equipping the farm is conclusively termed Smart Farming or Smart Agriculture. Smart farming is a modern information and communication technology idea that aims to enhance the quantity and quality of goods to control farm management. IoT-controlled smart farming can be called a wireless system designed to automate the irrigation process and to monitor the field using different sensors. These different sensors may be light, temperature, humidity, soil, etc. [5]. Smart farming (or precision agriculture) has the potential to significantly increase agricultural production in terms of both sustainability and productivity [6]. The adoption of smart farming techniques is constantly growing, and the market is still dynamic for these connected devices. By adopting various smart agriculture gadgets, farmers have become more efficient in raising livestock and growing crops,

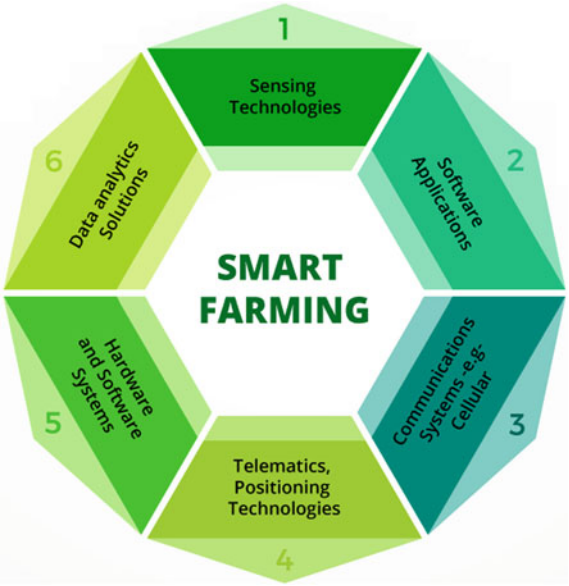

Fig. 2 Smart farming [7]

making it more predictable and efficient. Smart farming is a term that refers to the use of modern technologies in agriculture. The smart agriculture industry is growing very fastly and constantly. By using the advanced technology, they are gaining better control over the complete production efficiently [7] (Fig. 2).

Smart technologies are not only confined to the agriculture sector but these find a wide application in other sectors too. These technologies are used to locate the location of the accident and the information of the location can be sent through the GPS to the emergency offerings for assistance [8]. Data mining is another field where the use of smart technology is on the rise. Data mining is an analytic process that is used to investigate data (business or market related) in search of consistent patterns or to find out the systematic relationship between variables and to validate the findings [9].

Greenhouses play an important role in agriculture and gardening as they allow plants to grow under regulated climatic conditions. The disadvantage of the hand-operated greenhouse is that it always requires inspection of plant growth visually, turning on and off the temperature controllers manually. The environmental factors within a greenhouse may be monitored and controlled with the help of an IoT-based greenhouse. It offers a controlled environment for the plants, preventing damage and so improving total yield. By maintaining any climatic condition in these greenhouses, it is possible to cultivate any type of crop [10].

Among the advanced smart farming technologies, some available technologies in the present scenario are:

– Sensor-based technology: soil scanner, water, and light management, temperature control, etc.

- Software-based technology: specialized software solution system.
- Communication-based technology—cellular communication.
- Positioning-related technology: including Global Positioning System.
- Hardware and software-related systems: it is related to robotics and automation.
- Data analysis-related technology: decision-making and prediction processes.

4 Major Factors for Smart Farming Using IoT

IoT has transformed the old agricultural perspective into advanced agriculture, which is geared towards the information network and involves automation, the usage of intelligent devices, and their networking in the agricultural production process. The following are some of the key points for Smart farming

- An Irrigation System can be used to provide water to the plant as and when required. The moisture sensor detects moisture in the plant and supplies water appropriately, reducing water usage to a bare minimum. Smart sensors are implanted in the soil. This sensor can quickly detect moisture levels and helps the farmer in sprinkling the correct quantity of water on the land.
- Farmers can use mobile applications to remotely track and manage yields, costs, and other vital farm metrics.
- Sensing technology (on-field sensors, such as soil moisture measurement) has shown to be quite beneficial, and smart positioning technologies (GPS) for making agricultural methods smarter have grown in popularity.
- When combined with weather data, it may provide farmers with weather forecasts.
- Set temperature, humidity, and other variables for agricultural storage to trigger alerts and alarms.
- Telematics (the transmission of data across vast distances) and advanced data analytics tools and platforms have also been important components of smart agriculture [11].

5 Uses of Internet of Things (IoT) in Agriculture

Farmers that rely on manual methods for crop monitoring, disease detection, and other tasks have several disadvantages, including the fact that it takes a long time, that they must physically show themselves on the farm, and that they are unable to identify the precise condition [12]. Farmers want very fundamental information of agriculture such as soil information, seed type, required pesticide for the specific crop at all stages of growth, fertilizer type, crop diseases, and crop selling. The following are the questions that must be addressed to improve crop output.

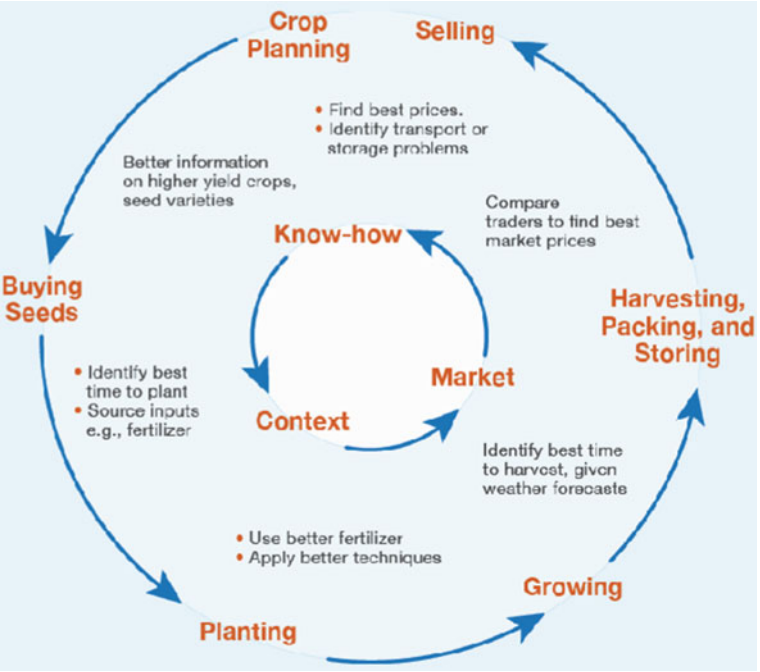

Fig. 3 IoT application in agriculture [14]

– Basic knowledge, such as which crop to plant?
– What seed varieties should be used?
– What weather information is needed?
– Best farming practices for his crops and soil.
– What kind of fertilizer and insecticides will be necessary for the crop?
– Transport prices, demand indicators, and logistical information [13] (Fig. 3).

Smart farming is a high-tech and efficient method for sustainable farming and food production in agriculture. It is a technique of integrating connected devices and innovative technologies into agriculture. Smart farming is highly reliant on IoT, which helps in eliminating the need for physical labor on the part of farmers and producers while improving production in every possible manner. With modern agricultural developments reliant on agriculture, the Internet of Things has provided significant benefits such as efficient water usage, input optimization, and many more. As the food demands of a growing global population put increasing strain on agriculture throughout the world, using IoT technology can drive farming efficiency to entirely new heights [15]. IoT-based smart farming strengthens the whole agriculture system by monitoring the land in real time. With the help of sensors and other gadgets, the Internet of Things in agriculture has not only saved farmers' time but also help in reducing the resources such as water and electricity. It keeps the track of a variety

of factors such as humidity, temperature, and soil, among others, and provides an accurate result.

6 Sensors Used in Agricultural Internet of Things

Sensors are important tools used in IoT. Sensors are devices that gather and analyze data to produce the necessary analysis. Sensors are mostly used in agriculture to obtain readings for measuring NPK levels, detecting diseases, and determining soil moisture content.

(a) **Soil Moisture Sensor**

A soil moisture sensor is shown in Fig. 4. It is used to determine the volumetric water content of the soil. It determines the moisture content of the soil based on soil characteristics such as resistance, dielectric constant, and neutron interaction, as well as ambient factors such as soil type, temperature, and electrical conductivity. It has two probes that are placed into the field, and when a current is passed through the probes, moisture % is determined based on resistivity. Soil moisture analysis enables water to be applied just when it is required, reducing water waste.

(b) **Temperature sensor**

A temperature sensor is a device that measures how hot or cold an object is. This sensor is more accurate than the thermistor, which was used to monitor the temperature in the beginning. This sensor is resistant to overheating since it has three terminals: input, output, and ground. Temperature sensors come in a variety of shapes and sizes. The LM-35 IC, as illustrated in Fig. 5, is one form of a temperature sensor.

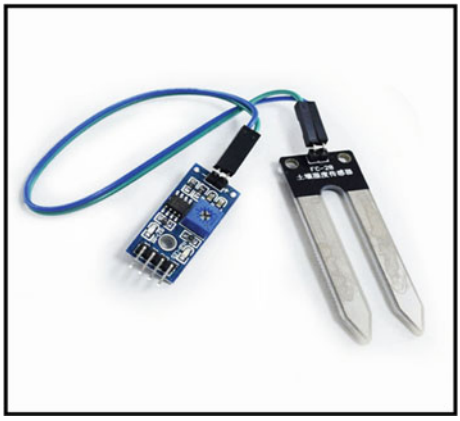

Fig. 4 Soil moisture sensor [16]

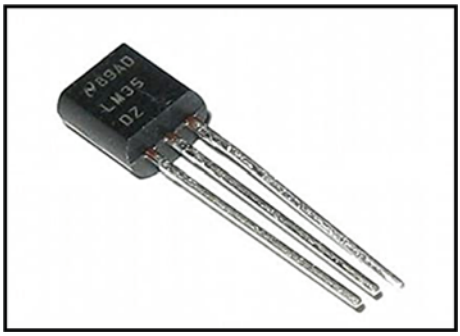

Fig. 5 Temperature sensor [16]

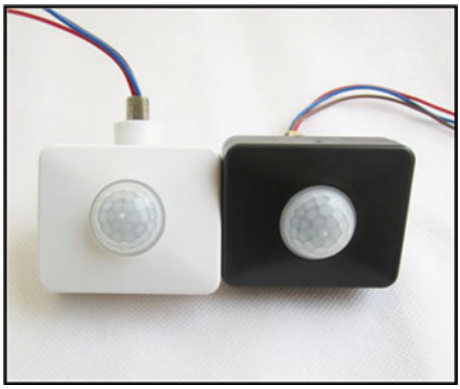

Fig. 6 PIR sensor [16]

(c) **Private Infrared (PIR) sensor**

All things with a temperature greater than absolute zero produce heat energy in the form of radiation. Figure 6 shows a PIR (private infrared) sensor that detects infrared radiation produced or reflected from an object. It is used to track the movement of humans, animals, and anything else. The temperature at the spot will rise from room temperature when any impediment passes through the field. It is converted to a voltage by the sensor, which then activates the detection.

(d) **Water level sensor**

Figure 7 shows a sensor that detects the amount of water or other fluids. It comes with a detecting probe that can detect the surface level of almost any fluid, including water, saltwater, and oils. This sensor is not readily broken, and it connects to Aurdino with ease. It includes two buttons, one for recording the lowest fluid level and the other for recording the highest fluid level. The voltage will be used to determine the level.

(e) **pH sensor**

The pH sensor in Fig. 8 is being used to measure the pH value of a solution. The pH scale ranges from 0 to 14, with 0–6 being acidic, 7 being neutral, and 8–14 being

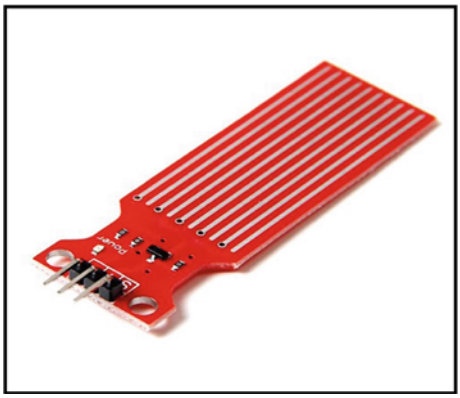

Fig. 7 Water level sensor [16]

Fig. 8 pH sensor [16]

non-acidic or basic. It calculates the pH value depending on the concentration of hydrogen ions, which is detected using a pH electrode. The response time is more than 2 min. The temperature range is about 600 °C, the input voltage is 5 V, and the output voltage is 414.12 V.

(f) **Temperature and humidity sensor**

In Fig. 9, the DHT11 is a simple, low-cost digital temperature and humidity sensor. This sensor has two components, a capacitive humidity sensor, and a thermistor. Both moisture and air temperature are sensed, measured, and reported by the humidity sensor. Temperatures range from 0 to 50 °C, with humidity levels ranging from 20 to 90%. These sensors are mostly used in the Internet of Things. There are many other sensors in addition to these; however, DHT11 is the most common temperature sensor.

Fig. 9 Temperature and humidity sensor [16]

7 Benefits of Adopting IoT in Agriculture [3]

(a) **Climate Condition**

In farming, climate plays a very important role. Climate change has a direct impact on all agricultural aspects. It has an immediate impact on crop quality and yield. As a result, an immediate solution to this problem is required. IoT solutions allow us to know the weather conditions in real-time. Sensors are placed both within and outside of agricultural areas. Environmental data are gathered by using these sensors, which are then used to choose the best crops for growing and sustaining under the given climatic conditions. The whole Internet of Things comprises sensors that can reliably monitor real-time weather variables such as humidity, rainfall, temperature, and more. A wide range of sensors is available to detect all of these characteristics and adjust them to meet the needs of smart farming. These sensors help in monitoring the health of crops as well as the weather conditions around them. When unexpected weather conditions are found, an alarm is sent. The necessity for human presence during inclement weather is removed, thus allowing farmers to enjoy additional agricultural advantages and enhance productivity (Fig. 10).

(b) **Disease Detection and Diagnosis**

Plants like any other organisms are vulnerable to many diseases. Diseases in plants occur when external factors like pathogens and environmental conditions disturb the normal natural structure and function of the plant. There is numerous type of diseases that affect plant species, and the factors responsible for these diseases are all different. Diseases may affect any part of the plant including root, stem, leaf, flower, and fruit. While disease grows within the plant, external factors like rain, wind, water, soil aid in transmitting these diseases to the neighboring plant. Many crops get spoiled due to a lack of proper pesticide control mechanisms. With the help of IoT enable systems, images of plant leaves are captured and investigated for

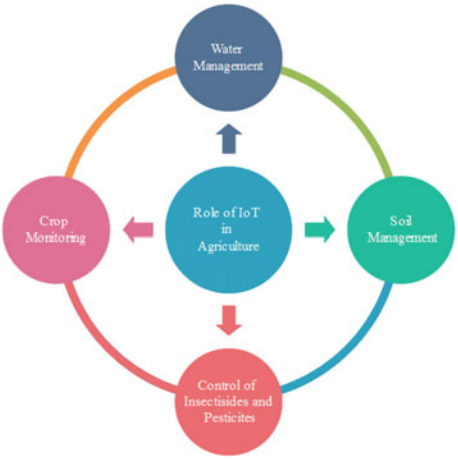

Fig. 10 Role of IoT in agriculture [3]

diseases, which can then be preprocessed and transmitted to remote laboratories. To decrease the cost of transmitting diseased leaf images to plant pathologists in remote laboratories, image preprocessing is required. Further clustering techniques aid in the segmentation of leaf images.

(c) **Fertilizer Calculator**

The soil fertility and soil type play very important roles in agriculture. Based on the type of soil, fertilizer can be injected into the soil for better crop yield production. Fertigation assures equal distribution of fertilizers to all of the vegetation and better absorption of nutrients. Based on recent technology, the climatic conditions like temperature, humidity, moisture, and Ph in the soil can be analyzed, and fertilizers like nitrogen, phosphorous, and potassium are injected into the flora. Fertilizer application is a crucial farming activity that can greatly boost agricultural production. For each crop, farmers must make judgments about which chemicals to use and in what quantities [17]. An IoT-based automated fertigation machine that reduces water and fertilizer wastage can be used to overcome these shortcomings.

(d) **Study of Soil**

Another essential aspect of farming that has a big influence on agricultural performance is soil. Soil monitoring with IoT allows the farmers and producers to enhance output, decrease disease, and optimize resources by leveraging technology. IoT sensors can be used to detect soil temperature, NPK, volumetric water, photosynthetic radiation, water potential of the soil, and soil oxygen levels. The data from the IoT sensors are subsequently sent to a centralized location (or the cloud) for analysis, visualization, and trend analysis. The information gathered may then be utilized to improve agricultural operations and make minor modifications to improve crop output and quality.

(e) **Crop water estimation and water study**

Water quality has a great impact on farming and agricultural output. Farmers must make prior decisions about how much water their crops require. Crop water needs are determined by several factors including crop type, season, climate, and crop growth stage. Crops lose water due to transpiration, while the canopy loses water due to evaporation. Using sensors, water management can be done efficiently using IoT with no wastage of water.

(f) **Analysis of Crop Produce Readiness**

Farmers that are provided with crop pricing information ahead of time may sell their harvests at a specified time and earn a high profit. To detect the freshness of fruits, a unique application of smartphone-based sensors is employed. To evaluate maturity levels and ripeness of green fruits, an IoT-based application, and a smartphone camera are used to collect pictures of fruits under white and UV-A light sources. Farmers should use these methods in their fields by sorting crops based on ripeness levels before shipping them to market.

8 Use of Smartphone in Agriculture

Information and communication technologies have played a significant influence in farmers' daily lives. ICT (Information and Communication Technology) in agriculture is a new discipline that focuses on agricultural and rural development. The use of ICT in agriculture allows for the timely distribution of critical information.

The fast expansion of mobile telephony and the advent of mobile-enabled information services have made it possible to overcome current information asymmetry in the fields of agriculture, healthcare, and education. There is a significant gap between the availability and distribution of agricultural inputs and agricultural infrastructure, which mobile technology can help to bridge. A smartphone is a device that is used to make phone calls and includes additional features and abilities such as the ability to send and receive an email, Wi-Fi and modem capabilities, internet access, office documents, easy touch screen control, and, most significantly, the ability to run custom software. Another essential feature of a smartphone is its user interface. A smartphone includes a touch screen and the ability to zoom in and out using basic interface buttons, menus, and forms, as well as the support of a 'qwerty' keyboard, making it straightforward to use for those who are unfamiliar with ICT technology and even not having enough educated. The program must be simple to use and the farmer must give only the information needed to complete an operation or procedure. The price of a smartphone ranges between low and expensive. As a result, farmers may easily purchase any type of smartphone that fits within their budget.

Smartphones and IoT are interrelated to each other. As a result, it is important in smart agriculture. Farmers can easily afford smartphones now that they are more affordable on the market. Furthermore, its computational capability allows users to

develop a diverse range of useful apps. The android mobile application, also known as the android app, allows the user to monitor and operate the field from any location. An internet connection is required to monitor and operate the field. Rural farmers who formerly had limited access to up-to-date agricultural information (e.g., market, weather, and crop disease news) and assistance from agricultural experts and government extension workers now have new options, thanks to low-cost smartphones with a variety of sensors on the market. Even though all information is available in the public domain, accessing it is a time-consuming job for farmers. Mobile or smartphone applications may provide all of this information with changing seasons and climate. One of the platforms where a farmer may obtain all solutions and information in one touch is the mobile app. Farmers can use their smartphones to monitor their equipment, crops, and livestock remotely, as well as to obtain information on livestock nutrition and productivity. They may even utilize this technology to provide statistical forecasts for their crops and cattle [18]. Smartphone apps revolutionized connectivity and are used for sending agri-information to farmers. Farmers will also be notified via smartphone if an emergency arises on their farms.

9 Android Architecture

Android is an open-source development platform that allows developers to create extremely sophisticated applications. The Android operating system is made up of several software components that are grouped into five categories: Applications, Application Framework, Libraries, Android Runtime, Linux Kernel, and four major layers. It allows developers to take full advantage of the device's hardware, access location data, perform background services, call divert, and send SMS messages, among other things. After the program has been published, it can be downloaded through third-party websites or from online shops such as Android Market and the application store of Google [19]. Some of the android-based mobile apps for agriculture are:

- Agri App: Smart Farming App for Indian Agriculture.
- Kisan Suvidha.
- Damini.
- KVK Sandesh.
- MKisan Application.
- Agrimarket.
- Pashu Poshan.

10 Challenges in Implementing IoT

Farmers residing in rural areas are unable to take the benefit from IoT technology due to a lack of network infrastructure. As a result, they have limited access to the internet. A farmer needs consistent access to agricultural data at all times and from any place, thus a faulty connection renders an advanced monitoring system worthless. In addition, the types of equipment required to implementing IoT systems in agriculture are costly. Further, most people in this region still feel agriculture belong to their forefather generation; therefore they are hesitant to enter this industry. However, IoT should be brought closer to the primary sector by combining with complementing instruments to develop more efficient products. In this context, commercials and on-air promotions about new technology might be beneficial. To achieve an aggregated output, information from one farm can be shared with other farms.

11 Conclusion

Although IoT in agriculture is still in its early stage in India, how we are adopting this technology gives us reason to be optimistic in this area. The use of IoT in this cold arid region of Ladakh which remains inaccessible for half of the year from the rest of the country and physically reaching farmers in inaccessible areas is a real problem that has very good prospects. The use of the different types of sensors and other artificial intelligence devices can help ineffective ways of controlling, monitoring, and managing the farms. This will make the farmers in the region improve quality, quantity, minimize risks and wastes thereby making food items more accessible to customers and saving farmers time and money. Smart farming technology will also reduce the environmental effect of farming in this fragile region, ensuring long-term sustainability. What is required is to impart training to the farmers about these technologies so that they can perform their agriculture tasks quite easily without even reaching their field.

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