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Smart Farming using latest efficient Devices, Robotics, Intelligent Automation and IOT with Artificial Intelligence

[1]Pawan Kumar Sharma, [2]Jayant Bhardwaj, [3]Saneh Lata Yadav, [4]Yogita Yashveer Raghav, [5]Divya Jindal

[1,2]Research scholar,Department of Electronics and Communication, Bhagwan Parshuram Institute of Technology, Rohini, Delhi, India

[3] Research scholar, Department of computer science and engineering, K.R. Mangalam University, Gurgaon,Haryana

[4] Research scholar ,Department of computer science and engineering, Dronacharya College of Engineering,Gurugram

[5] Research scholar, Department of Applied Mathematics, Bhagwan Parshuram Institute of Technology, Rohini, Delhi, India

Abstract:

Advancement in latest technologies and integration of embedded hardware with Internet of Things using latest sensors, efficient devices (Raspberry Pi, ESP32); Machine Learning with Artificial Intelligence technologies has emerged as a robust solution for efficient resource management in smart agriculture environment. In smart agriculture for precise monitoring and prompt response real-time data is required from the agriculture site. This is possible by using sensors with IOT for collecting the real-time data for the parameters like soil moisture, temperature, humidity and health of the crop. This real-time data collected from the field act as a input for the AI algorithms using ML or DL. The analyzed data will be used as important information to the farmers for taking the necessary steps for efficient resource management. This predictive modeling helps farmers to predict the patterns for crop growth and pest infestation. By using historical data and machine learning techniques, the AI system can be used for optimized resource utilization like water usage, requirement of fertilizer and pest control. By utilizing the real-time data analytics and intelligent decision-making, smart agriculture systems can drive efficiency, sustainability, and resilience in the face of evolving environmental challenges.

Introduction:

Efficient resource management is one of the important aspects in smart agriculture. This involves the minimum utilization of the resources like water, fertilizers, pesticides and energy usage. In spite of optimum resource utilization in smart agriculture using IOT with AI maximizes the crop yield. In smart agriculture the integration of latest technologies with Internet of Things plays an important role. IOT sensors provide real-time data of temperature, soil moisture and humidity of the soil. This data is collected and analyzed using ML algorithms for analyzing the soil condition, crop health. Weather patterns, water usage growth patterns. By using this modern approach, the farmers can automate the agriculture processes by taking decisions using the collected and analyzed data from the different sources like sensors, weather stations and drones.

Smart Agriculture system (SAS) utilizes the applications of latest technology like IOT with ML and AI. In smart agriculture the real-time data is used by the latest information and technology for optimizing the complex problems of smart agriculture systems. As we know among the entire production sectors, agriculture sector is one of the important sectors throughout the world. In SAS all the real-time data related to agriculture information is utilize in a smarter way using ML with artificial intelligence. The real-time data has been processed using the algorithms designed according to the requirement in smart farming. These algorithms are used for making the computer programs used by machine learning for efficient processing of received data. The production of crop increases drastically by using smart agriculture technologies under the supervision of the farmers [1,2].

Most of the advanced countries focus on the research in the latest techniques used in smart agriculture system (SAS) to increase good quality food production while minimizing the natural resource utilization. Agriculture sector has been influenced drastically by using these latest IOT techniques with ML and AI, WSN's, Wi-Fi communication, advanced low power and cost effective processing devices (Raspberry Pi, ESP32) as shown in Figure1.

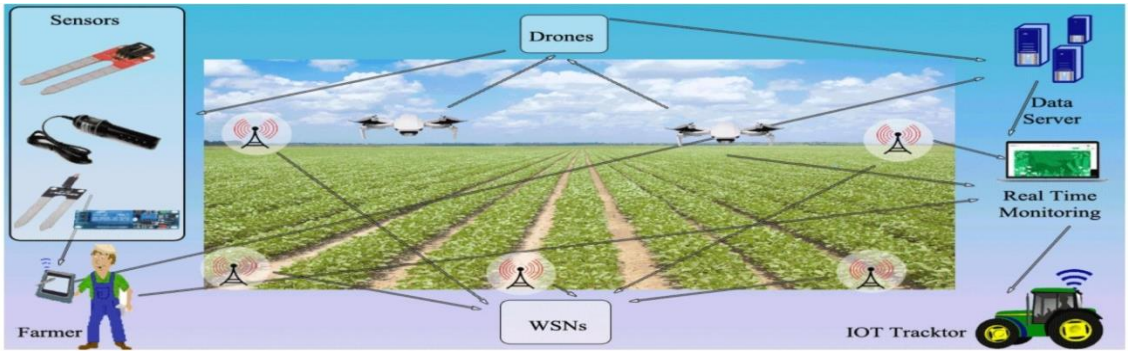

Fig.1. Smart agriculture system using IOT

There are various applications of artificial intelligence regarding smart agriculture using IOT and ML in computer discipline. In smart agriculture we can manufacture using AI advanced machines, different types of robots and sensors used for automated irrigation system [3]. The farmers can monitor all the features related to environment using the ML, AI and IOT. It will be useful for selecting the best environment condition for a particular crop using the information gathered from ML programs with AI.

For monitoring the real-time health of the crops and the soil, IOT with ML and AI tools can be implemented that predict the favorable time for harvesting to maximize the production of the crops and farmers profit. In the same way, if the plant disease can be detected earlier then it will be useful for the farmers for using the pesticides on right time [4]. The SAS is also useful in predicting the right time to sow seeds and use of fertilizers in the fields. In this way, the farmers can remove the pest, bacteria's and fungi for better cultivation of crops. Efficient resource management can be further improved by implementing the latest irrigation techniques using AI and ML with IOT. The irrigation system became smarter by using IOT with AI and it will be beneficial to farmers by using smart automation in irrigation systems. In smart irrigation various sensors are integrated as a complete system for monitoring the various parameters for example humidity, moisture, temperature, Ultra Violet radiations that will affect the growth of the crop as shown in figure 2.

For efficient resource management various smart agricultural techniques have been proposed by different authors for monitoring the various parameters like moisture of the soil, utilization of fertilizer, pest control etc.

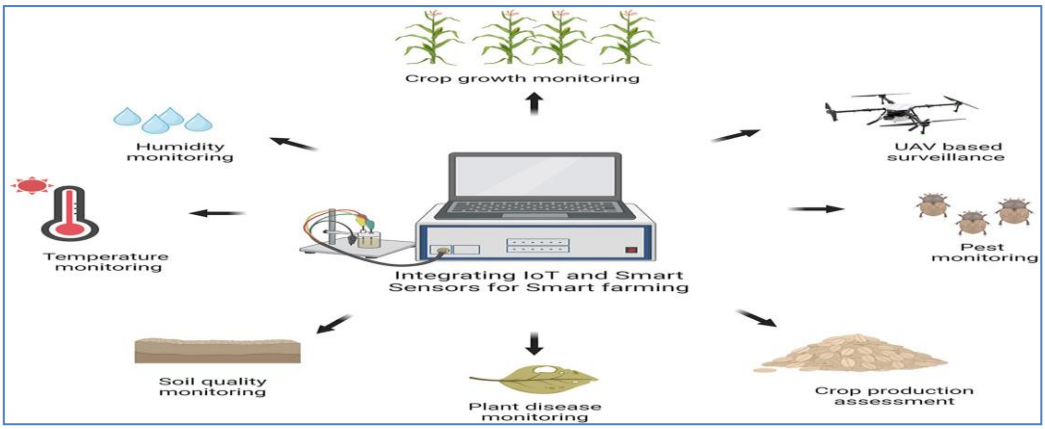

Fig.2. Integrating IOT with smart sensors for SFS

An important technique based on wireless sensor proposed by Vandome that will consume less energy and also cost effective. This wireless sensor required accurate calibration and by using smart irrigation real-time data can be used for monitoring the water flow in the crop field. By using pilot plots this sensor has been evaluated using WSN and significantly address the efficient way of water usage [5]. Another technique has been proposed by Fernandez in which a cloud based economical smart irrigation system was used. This IOT – based system use efficient and power saving board ESP-32 having internet connectivity. This system based on WSN and highly stable and robust [6].

A technique has been proposed by Routis based on IOT for precise irrigation. In this system a single microprocessor with a computer board (Raspberry Pi) has been utilized for real-time data analysis and monitoring [7]. Mathew proposed a system based on IOT for water requirement analysis by the farmers. Cropwat software has been used by Mathew for measuring the moisture and temperature of the soil. For un-interrupted wireless connectivity ESP32 has been used for data transferring between the sensors and the smart devices [8].

Challenges in Smart Agriculture using AI

Smart agricultural models are beneficial and productive, but there are still a lot of issues that needs to be fixed, like the high cost of smart agricultural machinery and the handling of enormous volumes of data necessary for making informed choices. The several issues faced by the farmers, notably water scarcity and climate change, their corresponding artificial intelligence-based remedies. The farming sector has distinctive challenges. A few of the challenges impacting the agriculture sector are increasing demand for food owing to the world's population growth, scarcity in water supplies, irrigation, decreased production efficiency, soil degradation, worldwide economic variables, and changes in the climate [9-12].

The challenges involved are described below:

Water Scarcity: The most significant and prevalent issue that farmer encounter globally is water scarcity. Water scarcity can be caused by a multitude of variables, such as excessive consumption in households, businesses, and farms. There is insufficient water available for the fields due to widespread water pollution caused by factories and other enterprises disposing off their waste in water bodies. Farmers that are unable to access groundwater or surface water lose a great deal of money. Water shortages are also brought on by the extensive cultivation of crops having huge water demand and the ineffectiveness of terrain to confine water [13].

Low Productivity: When the crop production fell short of expectations, it is referred to as low agriculture productivity [14]. The most prevalent root causes of limited productivity are infertile soil, which reduces crop quality and variety, high fertilizer costs that impoverished farmers cannot pay, and the inadequate nutrients availability in crops. Another factor is the reduction of fertile land, also, agricultural illnesses caused by pests, rodents, and undesirable weeds can spread and harm crops, reducing their potential for output.

Growing demand for food: A crop's cost and yield in the market are primarily influenced by its demand. There seems to be reduced food output in nearby local markets, as a result of population growth, technological advancement, the rise of urbanization and destruction of forests, which in turn stimulates demand/needs for food. Modest farmers having limited acres typically struggle to meet the unforeseen spike in demand for food [15]. As a result, agricultural prices rise, which lowers sales and results in production losses.

Irrigation: A key element in providing nutrients to the crop and determining its health is effective irrigation. The problem with irrigation is that it doesn't apply enough water, which results in less water being absorbed by the crops. Other issues in agriculture include the usage of obsolete irrigation techniques and a dearth of modern innovations like surface, drip, and sprinkler irrigation [16].

Soil eroding: This is the process wherein the uppermost layer of soil is carried away by strong winds or water, depleting the nutrients in the soil and often rendering plant roots exposed to extrinsic damage and disease. The main causes of soil erosion are floods or fast-moving water, which removes loose sand. Sand or dry dust is further swept away by strong winds. Agriculture is impacted by soil erosion in a variety of ways. The

most prevalent issue is reducing the land's capacity to retain water, depleting the soil's nutrients, and raising the likelihood of flooding [17,18].

Global Economics Factors: Numerous global and economic issues have an impact on the agricultural sector owing to the fact that, it is worldwide practiced profession and also the world's principal origin of food availability. Growing global population is pressing world market for increased yield from agriculture, which is the principal factor impacting agriculture. The production of agricultural products is also directly impacted by global economic growth. Another element that enables the spread of different cuisines and recipes over the world is transportation [19].

Climate Change: Every year, the climate is known to alter significantly from the year before, particularly in regards to heat, which has a substantial impact on agriculture. The difficulties brought on by the climate change are severe. Floods largely devastate the land and crops as a result of excessive rains. Droughts, which are brought on by rising temperatures and a lack of precipitation, dry off crop water even in the winter and render the land unusable. Some crops lose nutrients and become dry as a result of extremely low temperatures. Trees, crops, and plants are frequently destroyed by strong winds and high temperatures.

Changing diet and rising income: As a nation develops, its citizens' per capita income rises as well. This, however, also affects many people's lifestyles and, consequently, their choices of foods they eat. The majority of individuals used to consume a nutritious diet at home, but they have since adapted to harmful junk food that is laden with fat, oil, and less nutrients. Many people have also switched from eating vegetarian to non-vegetarian meat products. This led to a sharp decline in the demand for several foods, which drastically altered agricultural productivity. As a result, many of the items that were common place in the past are now scarce. In an effort to get more money, people are increasingly changing careers from agriculture to other fields [20].

AI-Based Solutions for smart agriculture

Agriculture with precision, organic cultivation and agricultural forestry are among the sustainable farming practices enabled by artificial intelligence. Encouraging the use of artificial intelligence in systems for irrigation, soil preservation measures and drought-tolerant plants can optimize water utilization and maintain soil health. AI-based technologies can create crop varieties that are high-yielding, disease-resistant, and climate-adaptable [21]. Artificial Intelligence-based solutions are shown in Figure 3, and detailed further:

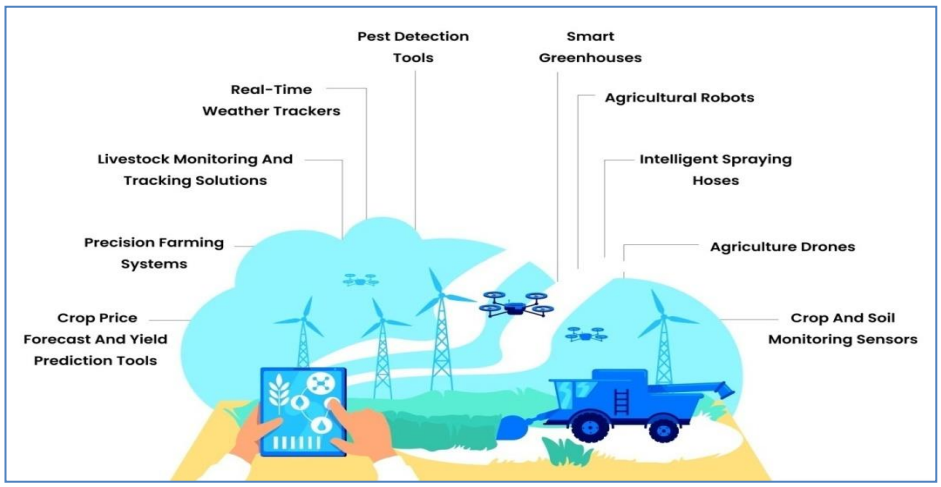

Fig.3. IOT and AI based smart agriculture

Precision spraying: Variable-rate or intelligent spraying is another name for precision spraying. This current agriculture method optimizes the use of pesticides and crop protection goods with improved technology [23,24]. Precision spraying reduces chemical use while increasing, pest and disease management effectiveness. Precision sprayers use sensors to

detect and track field variables, including insect's infestations, vegetation health changes and disease outbreaks. Global Positioning System (GPS) technology properly tracks the sprayer's location in the terrain. Sensor and GPS insights are integrated to create detailed field maps that identify treatment areas.

Pest Management and Disease Prognosis: In order to preserve healthy yield and guarantee productivity in agriculture, pest management and disease diagnosis are essential. It includes plans and methods for managing pests, such as weeds, insects, and other creatures that harm crops, and for lessening their effects. It's important to regularly check crops for indications of insect damage and presence. It's critical to identify peculiar bugs causing concerns and thereafter comprehend their biological cycle. Companion planting, timing plantings to rattle with bug's biological cycles, crop rotation, and keeping plants clean and spaced properly to minimize pest habitats are all beneficial practices.

Agrobots: Often referred to as agri-bots, Agrobots are agricultural robots that play an important part in modernizing and enhancing many facets of agriculture. These sophisticated robots can carry out activities either entirely on their own or with little assistance from humans. With the help of agricultural robots, seeds may be planted precisely where they are needed to ensure the right depth and spacing for better crop growth as depicted in figure 4. Sensor-equipped robots can accurately apply fertilizer where it is needed and assess soil conditions, minimizing overuse and its negative effects on the environment. Farmers can make knowledgeable decisions about irrigation and managing plant nourishment by using the insights that Agrobots gather on hydration of soil, nourishment levels in terms of nutrients etc. Agricultural robots gather data that can be utilized for trend analysis, outcome prediction, and practice optimization for improved yields. Agrobots can be lined up programmatically, and also be adapted in order to meet unique requirements of various batches of crops, and also ensuring that chores are completed quickly and efficaciously [25].

Weather forecasting: A lot of websites and applications offer the most recent weather forecasts for particular areas. These devices allow farmers to keep an eye on a variety of daily and weekly weather parameters, such as temperature, humidity, precipitation, wind speed, and more. The Weather Channel, AccuWeather, and Weather.com are a few well-known weather resources. Real-time weather information particular to the farm can be obtained by installing weather stations. Farmers are able to precisely monitor the conditions of their crops thanks to these stations, which detect temperature, humidity, wind direction, and precipitation. A more comprehensive picture of weather patterns is provided by satellite and radar data, which can also be used to forecast severe weather occurrences like storms and torrential rain. Through commercial firms that offer radar images or government authorities, farmers can obtain this information. In order to produce more precise and localized weather forecasts, sophisticated ML and artificial intelligence models evaluates past meteorological insightful data along with other pertinent variables like crop type, soil moisture, and geographic location. These models are adaptable to certain farms or geographical areas.

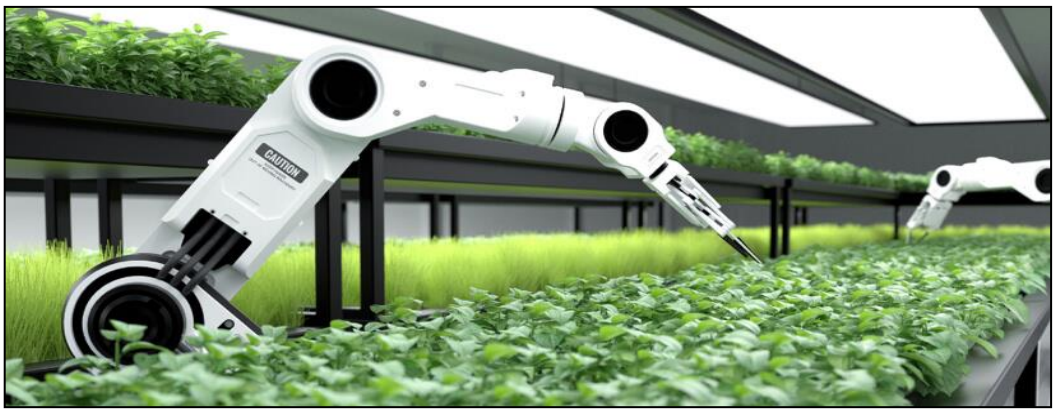

Fig.4. Agriculture robots used in smart farming

Soil and Yield Monitoring: This vital practice of contemporary agriculture entails a constant observation of soil and crops conditions. Through careful decision-making, consideration of resource utilization, and optimization of agricultural output while reducing environmental effect, farmers benefit from this monitoring. With the use of satellites and other modern technology, agricultural fields may be monitored to provide high-resolution photos and insights on yield health and growing patterns. Drones equipped with sensors and cameras may gather comprehensive data and pictures from various angles to keep a close eye on crops and soil. The measurement of soil moisture levels at varying depths by soil moisture sensors, which enables farmers to manage irrigation and avoid overwatering, makes the Internet of Things (IOT) indispensable. Crop health sensors use leaf temperature and chlorophyll content measurements to identify symptoms of illness, stress, or nutrient deficits in crops. Farmers are able to modify their fertilization techniques for the best plant nutrition by using nutrient sensors, which detect the levels of nutrients in the soil. Modeling and data analysis are also essential for periodically monitoring soil and crops.

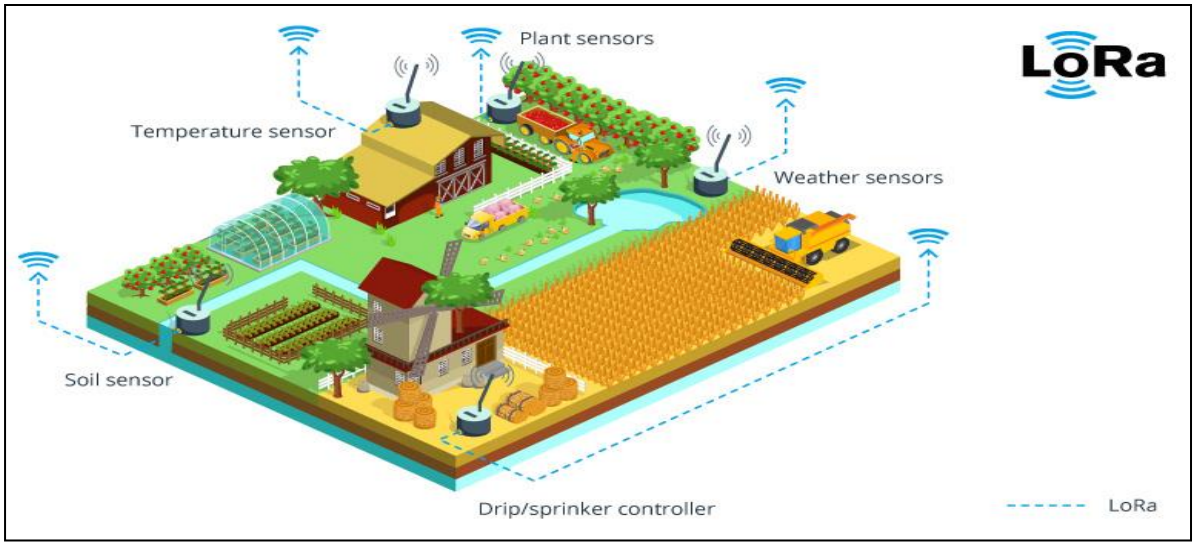

Fig.4. Smart irrigation model using IOT

Yield prediction using AI and ML

Efficient Resource Management can be effectively implemented due to advancement of Internet of Things in agriculture industries. The efficient IOT devices are equipped with reliable and power efficient sensors connected with the internet. Artificial intelligence combined with these smart systems for real-time monitoring system implementation to improve crop yields and production without crop failure. Smart systems using ML and AI monitoring, analyzing and forecasting the real-time data received from the sensors.

The efficiency and production can be increased further by using tailor made irrigation systems based on IOT and AI solutions. These types of systems can be implemented using thermal cameras, infrared sensors, humidity and moisture sensors or sound sensors. Thus customization makes smart agriculture that will use the natural resources efficiently. Now this real-time data is combined and analyzed with the previous data like historic weather data, crop data. All the collected data will be used to identify the patterns using machine learning making AI a reality in yield prediction. These AI based smart systems enable the automation for precise irrigation that will save water as shown in figure 5. As a component of artificial intelligence (AI), machine learning helps the agricultural industry by tracking and managing agricultural operations, which raises output and enhances the grade of the yields that are harvested. By identifying products in agricultural

areas, machine learning algorithms are crucial to precision agriculture [26].

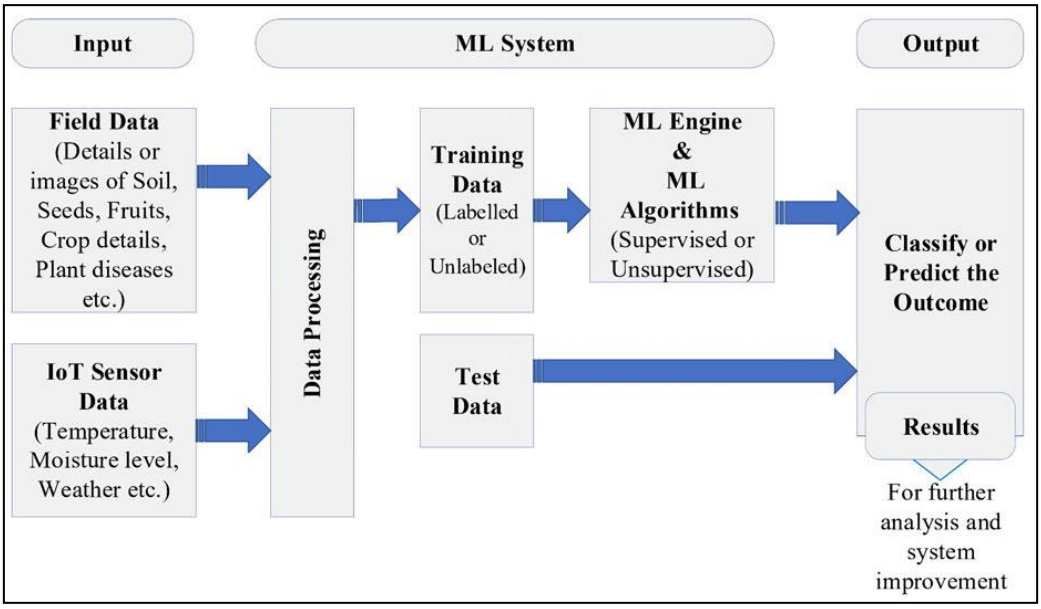

Fig.5.Smart agriculture model based on ML

It has been demonstrated that 94.27% accuracy in object detection using machine learning methods, shows the significant influence of such applications in intelligent farming. Using supervised and unsupervised learning techniques, machine learning algorithms enable machines to learn about specific agricultural lands, the topography of farming regions, plants and crops [27]. In the former scenario, datasets are predetermined and arranged, in the latter, datasets are not classed. The system can monitor and forecast humidity and temperature, crop production, soil moisture and plant diseases once it has learned about agricultural tasks.

In parallel, different agricultural statistics are categorized using machine learning algorithms based on the types of land and soil. These categories aid farmers in choosing the right crops. These datasets can be classified using machine learning techniques like K-means, naive Bayes and random forest to determine which crops are most suited for each region. Using these methods will surely help farmers with various farming tasks to produce crops in an economical and effective manner. Thus, machine learning is used in agricultural field to create computer systems that can process input data and thereafter forecast things like best time to plant or harvest, how much water to use, and how to select different types of soil, temperatures, and species of plants. Farmers may find the best farming prospects by using these inputs to train the machine learning model to make wise judgments in the field [28]. The variety of features, linearity, accuracy or/and explicability of the resultant data, size of the training set, speed or time of training, and the modeling process, which includes learning, clustering, classification and regression all play a significant role in the choice of machine learning algorithms.

ML systems in smart farming use methods related to computer vision including key point detection, panoptic segmentation, image classification and object detection to identify and analyze agricultural objects. Data from numerous sensors can be utilized to model the system and train and evaluate machine learning algorithms. To prolong regulated water irrigation, a self-sustaining drip system for irrigation can be constructed and controlled by utilizing data such as humidity, rain, light and temperature, from sensors in the planting area [29, 30].

Smart Irrigation for Efficient Resource Management

Efficient resource management can be further improved by implementing the latest irrigation techniques using AI and ML with IOT as shown in

Figure 6. The irrigation system will become smarter by using IOT with AI and ML and it will be beneficial to farmers by smart automation in irrigation systems. This type of system receives data from the sensors using the latest processors like Raspberry Pi. This collected data is processed and analyzed using ML with AI and find the best suitable technique for switching ON and OFF the water pump. In the similar way by using smart irrigation the farmers can control the wastage of water, minimize human work. It is also useful in controlling abnormal conditions like soil characteristics, moisture level, contents of the nutrients etc [2].

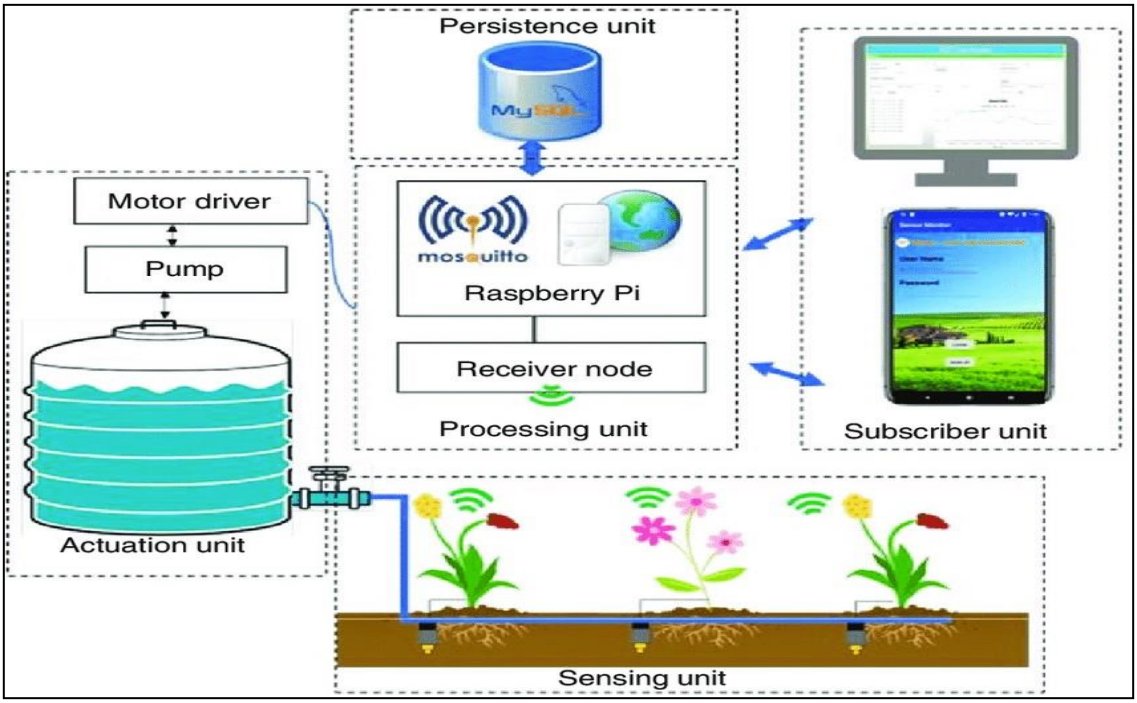

Fig.6. Resource management using smart automated irrigation

In smart irrigation various sensors are integrated as a complete system for monitoring the various parameters for example humidity, moisture, temperature, Ultra Violet radiations that will affect the growth of the crop. Smart irrigation uses various sensors like capacitive soil moisture sensor for measuring the moisture in the soil, DHT22 is used for measuring the temperature and humidity of the environment, VEML6070 sensor is used for Ultra Violet (UV) radiations and its effect on the crop condition. It has been observed that the nutrients and health of the crop depends on the reliable and efficient irrigation system. Several techniques have been proposed by different researchers for the efficient utilization of resources like water, fertilizer, energy consumption etc.

Smart Irrigation for monitoring moisture in the soil:

Smart irrigation system utilizes WSN for observing the condition of the soil and also moisture. It can be used for measuring the parameters like moisture, nutrient and PH value of the soil. For real-time WSN based fully automatic irrigation system has been proposed by Mohammed. In this for measuring the moisture a low cost capacitive soil moisture sensor has been used with every ZigBee node. The WSN based architecture on Long – Short – Term – Memory for developing the virtual soil moisture sensor has been proposed by Patrizi. In this a microcontroller board ESP 32 has been utilized for effective processing and then transmission of data receives from the sensors to the main gateway using WiFi protocols. Ten separate sensors have been used in the WSN for measuring the temperature of the air and soil, humidity, temperature and humidity of the soil etc. In this system measuring the humidity of the soil was a challenge. To overcome this problem a soft sensing based algorithm has been proposed [41]. Another system has been proposed by Wu, based on real-time data monitoring using IOT and

a mobile application for increasing the agricultural productivity. In this, a central cloud based platform using LoRa module used for monitoring the data received from wireless sensors. The accuracy in terms of moisture and temperature of the soil was very accurate [31, 32].

Optimum Fertilizer Usage:

The globe is experiencing food availability turmoil, with scarcity in food being generated than growth in population. Additionally, there is a need for better integration and execution of cutting-edge technology in smart agricultural applications. A shortage of fertile soil, moisture, and NPK essential nutrients also reduces yearly food production. Conventional methods for evaluating soil nutrients and applying fertilizer can be damaging to the soil and crop. Excessive fertilizer can harm agricultural soil nutrition and the normal PH scale. To address this difficulty, precision agriculture should be implemented via IOT and WSN. A WSN-based testing of soil nutrient and fertilizer also enables remote soil fertility analysis among other applications [33, 34].

Control of Pest and Crop Diseases:

There are various factors for reduced crop production; one of them is crop disease and pests. These pests and diseases cause significant amount of crop wastage in every production cycle. To ensure profitable harvesting, farmers require initial stage sustainable and consistent decision-support framework. A smart tracking system should use advanced sensor technologies to address plant diseases and insects-linked concerns. WSN systems use network protocols to gather and store data in a cloud platform, enabling early decision-making for insects/bugs and crop disease prevention. Crop disease identification poses a significant difficulty in precision agriculture due to the inability to accurately forecast specific causes [35].

Energy and Power consumption saving:

Precision agriculture is an example of advanced agriculture that optimizes workflow while considering environmental impact. WSN is integrated with IOT, utilizing network protocols and technologies. Various actuators and WSN nodes are also included. Continuous supply of power is necessary for this type of device to provide uninterrupted services. Energy usage in PA-based WSNs might vary depending on factors such as sensor density discrepancies or computational overload. Traditional energy harvesting techniques may not meet these requirements, thereby shortening the lifespan of the system and network. To achieve the energy requirements, an extensive energy harvesting configuration is necessary. Advancements in low-power technology, WSN and IOT have been widely used for SA applications. WSN has increased agricultural production and effectiveness in yield. WSNs face a significant energy and power deficit due to the need for immediate battery charging [36, 37].

Conclusion:

Efficient resource management is one of the important aspects in smart agriculture. This involves the minimum utilization of the resources like water, fertilizers, pesticides and energy usage. In spite of optimum resource utilization in smart agriculture using IOT with AI maximizes the crop yield. Efficient resource management can be further improved by implementing the latest irrigation techniques using AI and ML algorithms. The irrigation system will become smarter by using IOT with AI and ML and it will be beneficial to farmers by using smart automation in irrigation systems. It has been observed that the nutrients and health of the crop depends on the reliable and efficient irrigation system. The efficiency and production can be increased further by using tailor made irrigation systems based on IOT and AI solutions. These types of systems can be implemented using thermal cameras, infrared sensors, humidity and moisture sensors or sound sensors. Thus customization makes smart agriculture that will use the natural resources efficiently.

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