Smart Agriculture

Learning Technologies Project Course

Project Report - I

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1. Design a dashboard or APP that will give crop yield estimation, to improve the crop output and efficient use of fertilizers.

1. IDEA SUBMISSION

With the growing adoption of the Internet of Things (IoT), connected devices have penetrated every aspect of our life, from health and fitness, home automation, automotive and logistics, to smart cities and industrial IoT. Thus, it is only logical that IoT, connected devices, and automation would find their application in agriculture, and as such, tremendously improve nearly every facet of it. How could one still rely on horses and plows when self-driving cars and virtual reality are no longer a sci-fi fantasy but an everyday occurrence? Farming has seen a number of technological transformations in the last decades, becoming more industrialized and technology-driven. By using various smart agriculture gadgets, farmers have gained better control over the process of raising livestock and growing crops, making it more predictable and improving its efficiency. This, along with the growing consumer demand for agriculture products, has contributed to the increased proliferation of smart farming technologies worldwide. In 2020, the market share for IoT in agriculture reached $5.6 billion.

In this article, we will explore the IoT we are using in agriculture and examine its benefits. So, if you are considering investing in smart farming, or are planning to build an IoT solution for agriculture, dive right in. Smart agriculture, on the other hand, is mostly used to denote the application of IoT solutions in agriculture. So what is smart agriculture using IoT? By using IoT sensors to collect environmental and machine metrics, farmers can make informed decisions, and improve just about every aspect of their work – from livestock to crop farming. For example, by using smart agriculture sensors to monitor the state of crops, farmers can define exactly how many pesticides and fertilizers they have to use to reach optimal efficiency. The same applies to the smart farming definition.

We are planning to design a Web application in order to provide the farmers/users an approximation on how much amount of crop yield will be produced depending upon the given input. The application uses a Random Forest Machine Learning model, which was trained on over 20 years of data from 30 districts of Maharashtra, along with automatic live weather fetching for prediction. The model achieved an accuracy of around 86% and can be even further improved with more data.

There are many types of IoT sensors for agriculture as well as IoT applications in agriculture in general:

1. Monitoring of climate conditions

Probably the most popular smart agriculture gadgets are weather stations, combining various smart farming sensors. Located across the field, they collect various data from the environment and send it to the cloud. The provided measurements can be used to map the climate conditions, choose the appropriate crops, and take the required measures to improve their capacity (i.e. precision farming). Some examples of such agriculture IoT devices are allMETEO, Smart Elements, and Pycno.

2. Crop management

One more type of IoT product in agriculture and another element of precision farming is crop management devices. Just like weather stations, they should be placed in the field to collect data specific to crop farming; from temperature and precipitation to leaf water potential and overall crop health. Thus, you can monitor your crop growth and any anomalies to effectively prevent any diseases or infections that can harm your yield.

Arable and Semios can serve as good representations of how this use case can be applied in real life.

3. Precision farming

Also known as precision agriculture, precision farming is all about efficiency and making accurate data-driven decisions. It’s also one of the most widespread and effective applications of IoT in agriculture. By using IoT sensors, farmers can collect a vast array of metrics on every facet of the field microclimate and ecosystem: lighting, temperature, soil condition, humidity, CO2 levels, and pest infections. This data enables farmers to estimate optimal amounts of water, fertilizers, and pesticides that their crops need, reduce expenses, and raise better and healthier crops.

For example, CropX builds IoT soil sensors that measure soil moisture, temperature, and electric conductivity enabling farmers to approach each crop’s unique needs individually. Combined with geospatial data, this technology helps create precise soil maps for each field. Mothive offers similar services, helping farmers reduce waste, improve yields, and increase farm sustainability.

4. Predictive analytics for smart farming

Precision agriculture and predictive data analytics go hand in hand. While IoT and smart sensor technology are a goldmine for highly relevant real-time data, the use of data analytics helps farmers make sense of it and come up with important predictions: crop harvesting time, the risks of diseases and infestations, yield volume, etc. Data analytics tools help make farming, which is inherently highly dependent on weather conditions, more manageable, and predictable.

For example, the Crop Performance platform helps farmers access the volume and quality of yields in advance, as well as their vulnerability to unfavorable weather conditions, such as floods and drought. It also enables farmers to optimize the supply of water and nutrients for each crop and even select yield traits to improve quality. Applied in agriculture, solutions like SoilScout enable farmers to save up to 50% irrigation water, reduce the loss of fertilizers caused by overwatering, and deliver actionable insights regardless of season or weather conditions.

What are the factors that affect crop yield most?

Recently, in view of the constant growth of the world's population, this issue is becoming more and more relevant. However, with the emergence of new challenges for agrarians, there are also new ways and technologies appearing that are called to respond to them. This is what this article is about: what growers can do for increasing crop yield on their farmlands and what new technologies can help farmers in this matter.

What Is Crop Yield And Why Is It Important?

Crop yield is the measure of seeds or grains which is produced from a given land plot. It is usually expressed in kilograms per hectare or in bushels per acre. Such an indicator as the average crop yield per acre serves as the evaluation of a farmer's agricultural output on a particular field over a specified time period. It is considered to be probably the most important measure of each farmer's performance, as it embodies the result of all the efforts and resources invested by agrarians in the development of plants in their fields. Given this, no wonder that most farmers find themselves in a constant quest called "How to increase the average crop yield per acre?".

Let's see what are the main factors that affect crop yield and what are the most efficient and up-to-date solutions and technologies that can help farmers achieve better yields in their fields.

What Are The Ways To Increase Crop Yield?

For centuries, farmers have pondered over and worked on the issue of increasing crop yields. Some of the solutions found were efficient and some were not. Today, in addition to the valuable experience of previous generations of farmers, the agriculture industry can also benefit from the achievements of modern science and technology. Let's now look at the main ways for the farmers to increase crop yields and see how previous experience and advanced technology can be effectively combined to improve agrarians' performance.

Quality Of Seeds

Agricultural productivity depends on the quality of seeds with which farmers sow their fields. Therefore, in order to increase crop yield on their farmlands, agrarians are recommended to sow only certified seeds that have passed all the necessary quality controls. Certified seeds may cost higher than those that do not have certification, but the result will be worth it because the proper quality of seeds is one of the main factors that affect crop yield. Besides that, planting only high-quality seeds represents one of the eco-friendly methods to increase crop yield. If needed, a farmer can check the quality of particular seeds by referring to a relevant seed company and requesting it to conduct special trials on a given land plot.

Apart from this, is it important to remember that the quality of seeds is not something that is permanent and undamageable? Seed grains need protection – seed coating – from the moment they are planted in the ground. Seed coating is the process of protecting seed grains with outer materials in order to improve their characteristics (weight, size) and/or provide them with some active compounds (micronutrients, microbial inoculants, growth regulators, etc.) called to protect them against plant diseases and boost their growth.

Field Productivity Zoning

Before sowing, it is important for a farmer to understand the productivity of the field that is to be sowed and, if applicable, define specific areas where plants grow better. This process is called productivity zoning. In this way, a grower can plant seeds more densely in the areas with greater productivity, potentially getting increased crop yield, and do not waste them much in the zones with low productivity. Also, such zoning allows farmers to properly treat the field areas with lower productivity and take all necessary actions to increase soil fertility and its overall important characteristics to grow a particular plant.

Today’s technologies allow farmers to carry out such productivity zoning of their fields faster and more efficiently than before. For this purpose, many agrarians use the EOS Crop Monitoring software. With its high-precision technology and satellite-driven data, the growers can generate field productivity maps based on the historical data and, thus, clearly identify the areas with the highest and the lowest productivity on given farmland.

Monitoring Crops Growth

From the early stage of development through budding and up to harvesting, it is very important to monitor plant health in order to timely detect any problem that can arise on given farmland (be it related to pest infestations, plant diseases, weeds, etc.) and that can affect the crop yield.

Regular satellite monitoring of land plots, for instance, allows farmers to easily follow the growth status of plants and carry out crop yield estimation using remote sensing. The evolution of plant health status provides key information to decide on possible interventions to the needs of crops.

Even though satellites do not measure the stages of plant growth directly, but with spectral indices. Crop Monitoring also provides data on daily temperatures, analyzes their dynamics in time, and calculates their total sum. Based on this data, the software is capable of detecting growth stages for various types of plants and represents their correlations with other data so that the farmers could make well-weighted decisions.
Apart from this, Crop Monitoring provides agrarians with valuable data about different vegetation indices, such as:

NDVI – Normalized Difference Vegetation Index (recommended during the active stages of crop growth);
MSAVI – Modified Soil Adjusted Vegetation Index (it is best to be used at the early stages of crop growth);
NDRE – Normalized Difference Red Edge Index (recommended to be used together with the NDVI index);
ReCI – Red Edge Chlorophyll (most relevant during early and active growth stages of crop growth).

Accurate Weather Prediction

The average crop yield per acre on a given field is very much conditioned by weather factors. With the same quality of soil and the same species of seeds planted, the climate conditions have a predominant influence on the development of plants and, consequently, on yields. It is especially true when considering how climate change affects agriculture in separate regions and on Earth in general. To work efficiently and cooperatively with such an important but uncontrollable factor as to weather, farmers have an opportunity to refer to the newest technological solutions that help them obtain accurate weather predictions.

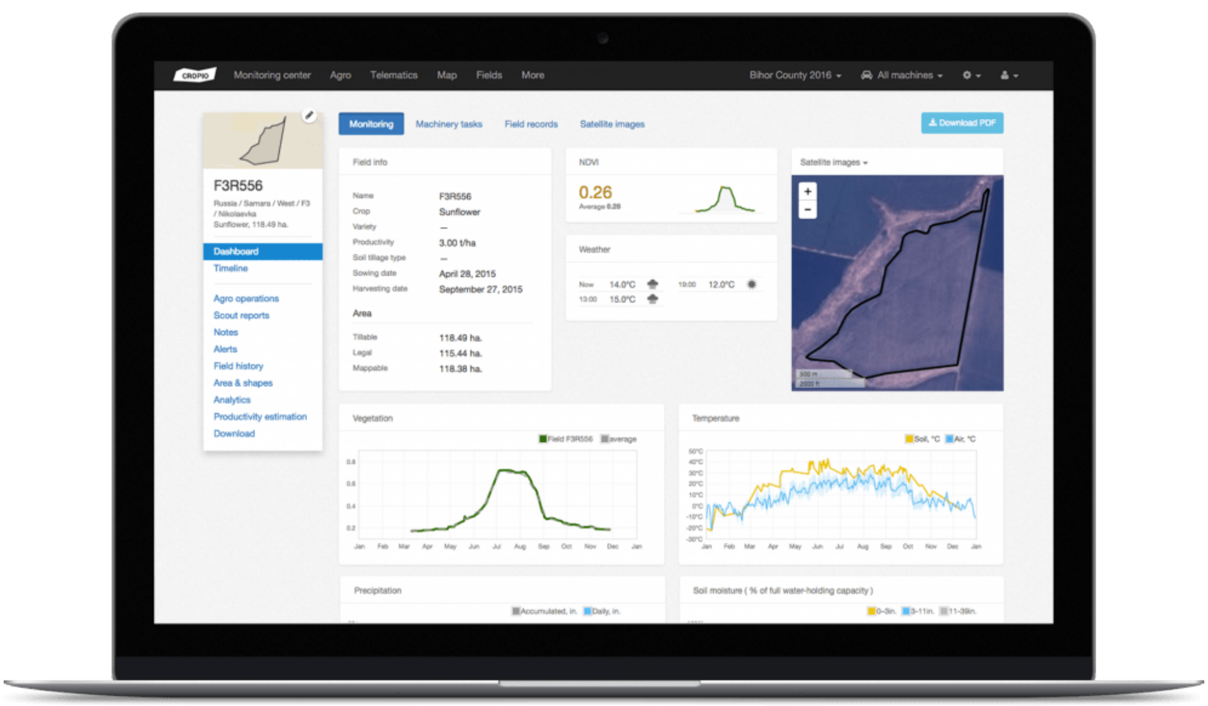
For example, the use of Crop Monitoring software in precision farming gives agrarians the possibility to take preventive measures to protect their crop yield from possible damages caused by weather extremes. High-precision weather forecasts can help growers decide what ag practices they can perform. Given all this, it is worth noting that accurate weather forecasting in precision farming can greatly contribute to increasing crop yields on particular farmland.

Crop Monitoring provides farmers with weather analytics that include current and historical weather data, as well as forecasts up to two weeks ahead. Also, this software allows agrarians to detect the extreme weather states that can affect crop yields:

- cold stress
- heat stress

Regular Scouting

Scouting is one of the important parts of agribusiness management aimed to ensure the proper development of plants and increase crop yields. Often, when a grower has large fields, it is difficult and non-effective to scout acre by acre, as it is time-consuming and resource-intensive. Crop Monitoring takes advantage here and offers convenient scouting task management. Crop Scouting solution is intended to save time and replace the tedious work of human experts in fields. All that is needed to do is to log into your Crop Scouting app, check for any problem areas on your land plot detected by a satellite, tag these areas on the map, and organize closer scouting of these specific zones. The scouts then proceed to problem investigation on the spot, take pictures, upload them in the application, and enter necessary data in the relevant section. This way, a farmer can create multiple scouting tasks simultaneously, easily managing them and monitoring their completion. Such a time-effective and highly accurate field scouting solution assists agrarians in their daily work and can help increase their yields.



2. Design a solution that will help to have better water management in irrigation

One of the major purposes of the irrigation system is to provide and maintain the ideal environment in terms of temperature and soil moisture for the optimum growth of crops. With the usage of smartphones and computers, users can access the data stored in the cloud. Users can keep track of the crops and are able to control the water, pumps, and fans in the control panel of the user interface.

The primary aim of a smart irrigation system is to provide and maintain the optimum conditions for the crops. Through cultivating in an environment with sufficient water supply and ideal temperature, the growth of plants can be improved, and thus the productivity of the agriculture field will increase as well. Farmers can better use technological systems already installed, adopt extra technologies, enhance their skills in soil and water management, tailor cropping patterns to lower water demand and usage, reduce agrochemical inputs, etc.

By using this technology, we can increase productivity and can feed more people in the future.

Proper Irrigation

Farmers who aim to increase the average crop yield per acre on their fields must have a streamlined irrigation system at hand. Providing the plants with the appropriate amount of water directly affects the development of plants and, consequently, the crop yields. Effective irrigation of farmlands is closely linked to weather forecasts. Today’s technologies – special applications and software for farmers – provide access to hyper-local weather forecasting. It opens the door for precision irrigation and allows agrarians to plan in advance and organize irrigation of their fields in the most accurate and efficient manner.

Smart Application Of Fertilizers

Although fertilizers are intended to nourish the various types of soil, boost plant growth, and increase yields, their use should be balanced and prudent. Using too many fertilizers can negatively affect the soil quality and, therefore, agricultural productivity.

Within one field, different areas may have different needs for soil fertilization, which is why the best solution here is to use fertilizers selectively, depending on the need for them in different field zones. This accurate approach to field fertilization helps keep the soil in good health, which helps increase the average crop yield per acre.

One of the technological solutions in this context is Crop Monitoring software. Based on satellite imagery, it has a field zoning feature that divides farmland into 2-7 zones, identifying the areas that require more care than others. Such precision technology is often used by growers as one of the eco-friendly methods to increase crop yield.

Crop Protection Methods

Agrarians aiming to increase crop yields must take care of their plants throughout their development and up to the end of the growing season. Depending on the problem that may arise, farmers use different substances to diminish the impact of weeds, pests, or diseases on crop yield. Such substances are usually herbicides, insecticides, desiccants, plant growth regulators, fungicides, adjuvants, etc.

In general, there are various crop protection methods. Among the main ones are weed/pest management and plant disease management.

Weed And Pest Management

Weed control and pest management are the biggest challenges for farmers during the growing season. A single plant, for example, can generate over 10 million seeds, and if they are not managed in time, it can substantially decrease the yields on a given field and create problems for years to come. Pest infestations also require a comprehensive management approach from agrarians. As pests are highly adaptable and fast-reproducing organisms that can threaten the yield on particular farmland, farmers must always be ready to respond to the pest infestation issue in a timely manner.

Plant Disease Prevention And Management

Another important threat to a grower's agricultural output is represented by plant diseases. Depending on the type of plants to be grown on a field, farmers can use various plant disease prevention and management methods, like selecting disease-resistant or disease tolerant varieties, treating seeds with fungicides, and applying pesticides, and other similar substances on developing plants. Agrarians should pay special attention to using these or other methods in time so that they have the maximum effect possible.

It is very important to remember that protecting plants in a timely manner is crucial for crop yield per acre indicator – the sooner a problem is identified, the faster and easier it will be solved and the fewer field acres will be affected.

Soil Testing & Its Quality

The quality of soil, i.e. its fertility, is one of the main factors that affect crop yields. Apart from agricultural productivity, the soil quality also influences the cost for a farmer to grow one or another plant, as some of them require certain ratios of specific elements in the soil, like mineral particles, organic matter, water, air, etc. To attain increased crop yields, farmers need to closely monitor soil conditions on their land plots. One of the best ways to maintain the soil in good health is to practice crop rotation, among others. Alternating plants on a given field plot prevent soil exhaustion and breaks pest cycles, which will result in better agricultural output and, therefore, will increase the average crop yield per acre.

Forecasting Crop Yield

Crop yield prediction is very important for the global production of food. Governments all over the world use analytical data concerning crop yield forecasting to take grounded decisions as to their national import/export operations. Companies specialized in seed breeding need to foresee how new hybrids will perform in different climate and soil conditions to plan on further improvement of new variations of seeds. Farmers, in their turn, take advantage of crop yield prediction to make well-weighted agribusiness decisions.

One of the latest trends in industrial agriculture is predicting crop yield with remote sensing satellite data, which has already been proved efficient in different corners of the globe. It is important to note, however, that the accuracy in crop yield estimation using remote sensing depends on multiple factors, such as climate conditions (weather extremes), soil health, pest infestations, etc. Besides that, an important decision-making role in agricultural risk management and crop yield prediction is played by reliable historic records on yields in a given field.

At present time, various machine learning techniques for the prediction of crop yield are used all over the world. Crop yield prediction software requires big amounts of input data, yet may sometimes be not fully accurate due to possible fluctuations in weather conditions.

Smart Combination Of Agricultural Efforts

Taking into account all the above, it could be said that there is no single and universal method of increasing an average crop yield per acre on a farmer’s land plot. In most cases, it is a smart combination of different agricultural efforts that can vary depending on the unique characteristics of a grower’s field. It is yet worth noting that the Crop Monitoring software can be of considerable help for farmers with most of such agricultural efforts, assisting them whether directly or indirectly through accurate monitoring of separate agricultural activities and substantial facilitation of their implementation.

2. PROJECT APPLICATION SCENARIO

Technologies and IoT have the potential to transform agriculture in many aspects. Namely, there are 5 ways IoT can improve agriculture:

- Data, tons of data, collected by smart agriculture sensors, e.g. weather conditions, soil quality, crop's growth progress, or cattle's health. This data can be used to track the state of your business in general as well as staff performance, equipment efficiency, etc.
- Better control over the internal processes and, as a result, lower production risks. The ability to foresee the output of your production allows you to plan for better product distribution. If you know exactly how many crops you are going to harvest, you can make sure your product won't lie around unsold.
- Cost management and waste reduction thanks to the increased control over the production. Being able to see any anomalies in the crop growth or livestock health, you will be able to mitigate the risks of losing your yield.
- Increased business efficiency through process automation. By using smart devices, you can automate multiple processes across your production cycle, e.g. irrigation, fertilizing, or pest control.
- Enhanced product quality and volumes. Achieve better control over the production process and maintain higher standards of crop quality and growth capacity through automation.

As a result, all of these factors can eventually lead to higher revenue.

HARDWARE

1. **THE ARDUINO UNO**

The Arduino Uno is a microcontroller card that supports the ATmega328. All sensors are integrated into the Arduino Uno. These sensors provide information about the ambient conditions for the Arduino Uno. Arduino Uno makes the necessary decisions/actions and uses cloud computing to inform farmers about sensor readings and necessary actions. And also send them a message with the help of GSM.

2. **SOIL MOISTURE SENSOR**

It detects soil moisture. The sensor has both analog and digital output input and operates according to the principle of open short circuits. The LED output indicates more or less the output in this system. When the ground is dry, the electricity stops flowing and acts as an open circuit. If the ground is wet, the current passes and the circuit is short and the output is zero. Sensor information is indicated by levels. It is corrosion-resistant so the sensor has a long time to handle the cost of the farmer at a minimal cost.

3. **TEMPERATURE AND HUMIDITY SENSOR**

It is used to measure temperature and humidity. This system displays information about how well it worked. Suppose the threshold is exceeded, the LED starts flashing and the values are immediately displayed on the web page and the farmer can check Them.

4. **ACOUSTIC SENSORS**

These offer various uses in managing the farms, which include cultivation of the soil, weeding, and harvesting. The major advantage of Using this sensor is its quick response and low cost, mainly while making an allowance for portable equipment. These types of sensors work by measuring the alterations in the noise. These sensors are mainly used for monitoring pests and their detection, a variety of seeds are classified as well by using these sensors.

5. **OPTICAL SENSORS**

Optical sensors use a phenomenon called light reflectance, which measures the organic substances in soil, moisture, minerals, color, and composition, etc. The ability of soil to reflect light depends upon the various parts of the electromagnetic spectrum tested by these sensors. Variation in the soil density is indicated by the alteration that occurred in the reflection of waves.

By implementing the latest sensing and IoT technologies in agriculture practices, every aspect of traditional farming methods can be fundamentally changed. Currently, seamless integration of wireless sensors and the IoT in smart agriculture can raise agriculture to levels that were previously unimaginable. By following the practices of smart agriculture, IoT can help to improve the solutions of many traditional farming issues, like drought response, yield optimization, land suitability, irrigation, and pest control. We list a hierarchy of major applications,

services, and wireless sensors being used for smart agriculture applications. While major instances in which the advanced technologies are helping at various stages to enhance overall efficiency are discussed below.

A. SOIL SAMPLING AND MAPPING

Soil is the stomach of plants, and its sampling is the first step of examination to obtain field-specific information, which is then further used to make various critical decisions at different stages. The main objective of soil analysis is to determine the nutrient status of a field so that measures can be taken accordingly when nutrient deficiencies are found. Comprehensive soil tests are recommended on an annual basis, ideally in Spring; however, based on soil conditions and weather consents, they may be done in Fall or Winter.

The factors that are critical to analyzing the soil nutrient levels include soil type, cropping history, fertilizer application, irrigation level, topography, etc. These factors give insight regarding the chemical, physical, and biological statuses of soil to identify the limiting factors such that the crops can be dealt with accordingly. Soil mapping opens the door to sowing different crop varieties in a specific field to better match soil properties accordingly, like seed suitability, time to sow, and even the planting depth, as some are deep-rooted and others less.

Furthermore, growing multiple crops together could also lead to smarter use of agriculture, simply making the best use of resources. Currently, manufacturers are providing a wide range of toolkits and sensors that can assist farmers to track the soil quality and, based on this data, recommend remedies to avoid its degradation. These systems allow for the monitoring of soil properties, such as texture, water-holding capacity, and absorption rate, which ultimately help to minimize erosion, densification, salinization, acidification, and pollution (by avoiding excessive use of fertilizer).

Drought is a major concern that limits the productivity of crop yield. Most of the regions around the globe face this issue with various intensities. To deal with this issue, especially in very rural areas, remote sensing is being used to obtain frequent soil moisture data which helps to analyze the agricultural drought in far regions.

For this purpose, the Soil Moisture and Ocean Salinity (SMOS) satellite was launched in 2009 which provides global soil moisture maps every, one to two days. In this effort, they followed different approaches to obtain the soil water parameters in order to compare with the SWDI acquired from in situ data. They used the moderate resolution imaging spectroradiometer (MODIS) sensor to map various soil functional properties to estimate the land degradation risk for sub-Saharan Africa. The soil maps and field survey data, which covered all major climate zones on the continent, were used to develop the prediction models. Sensors and vision-based technologies are helpful to decide the distance and depth for sowing the seed efficiently. Sensor and vision-based autonomous robots called Agribot are developed for sowing seeds.

The robot can perform on any agricultural lands on which the global and local maps are generated from Global Positioning System (GPS) while the on-board vision system is paired with a personal computer. Advancing further, various non-contact sensing methods are proposed to determine the seed flow rate where the sensors are equipped with LEDs; consisting of infrared, visible light, and laser-LED as well as an element as a radiation receiver. The output voltage varies based on the movement of the seeds through the sensor and band of light rays and the falling of shades on the elements of the receiver. The signal information, linked to the passing seeds, is used to measure the seed flow rate.

B. IRRIGATION

Water is held by oceans and seas, and only the remaining 3% is freshwater, more than two-thirds of which is frozen in the forms of glaciers and polar ice caps. Only 0.5% of the unfrozen freshwater is above the ground or in the air, as the rest lies underground. In short, humanity relies on this 0.5% to fulfill all its requirements and to maintain the ecosystem, as enough freshwater must be kept in rivers, lakes, and other similar reservoirs to sustain it. It is worth mentioning that solely the agriculture industry uses approximately 70% of this accessible freshwater. In many countries, the situation rises to 75% e.g. Brazil, further in some underdeveloped countries, even exceeds 80%. The main reason for this high water consumption is the monitoring procedure as even in 2013, crops visual inspection for irrigation decision-making was very common, as nearly 80% of farms in the United States were observed by this. According to the UN Convention to Combat Desertification (UNCCD) estimates in 2013 show that there were 168 countries affected by desertification and by 2030, almost half of the world population will be living in areas with high water shortages. Considering the figures of water crises around the globe, same time its increasing demands in agriculture and many other industries, it should be provided to places only where it is needed, most importantly, in required quantities. For this purpose, increased awareness has been implemented to conserve the existing under-stress water resources by employing more efficient irrigation systems.

Various controlled irrigation methods, like drip irrigation and sprinkler irrigation, is being promoted to tackle the water wastage issues, which were also found in traditional methods like flood irrigation and furrow irrigation. Both the crop quality and quantity are badly affected when facing water shortage, as irregular irrigation, even excess leads to reduced soil nutrients and provokes different microbial infections. It is not a simple task to accurately estimate the water demand of crops, where factors like crop type, irrigation method, soil type, precipitation, crop needs, and soil moisture retention are involved. Considering this fact, a precise soil and air moisture control system using wireless sensors not only makes optimal use of water but also leads to better crop health. The current situation of irrigation methods is expected to be changed by adopting the emerging IoT technologies.

A significant increase in crop efficiency is expected with the use of IoT-based techniques, such as crop water stress index (CWSI)-based irrigation management. For this, attaining crop canopy at different periods and air temperatures is needed for the calculation of CWSI. A wireless sensors-based monitoring system where all the field sensors are connected to collect the mentioned measurements, further transmitted to a processing center where corresponding intelligent software applications are used to analyze the farm data. Not only this but information from other sources including weather data and satellite imaging is applied to CWSI models for water need assessment, and finally, a specific irrigation index value is produced for each site. A prominent example is VRI (Variable Rate Irrigation) optimization by CropMetrics, which works according to topography or soil variability, ultimately improves the water use efficiency.

C. FERTILIZER

A fertilizer is a natural or chemical substance that can provide important nutrients for the growth and fertility of plants. Plants mainly need three key macronutrients: nitrogen (N) for leaf growth; phosphorus (P) for root, flowers, and fruit development; potassium (K) for stem growth and water movement. Any sort of nutrient deficiency or applying them improperly can be seriously harmful to plant health. More importantly, excessive use of fertilizer not only results in financial losses but also creates harmful impacts to the soil and environment by depleting the soil quality, poisoning groundwater, and contributing to global climate changes. Overall, crops absorb less than half the nitrogen applied as fertilizer, while the remaining are either emitted to the atmosphere or lost as runoff. Unbalanced use of fertilizer leads to an imbalance in both soil nutrient levels and global climate as, reportedly, around 80% of the world's deforestation has occurred due to agricultural practices alone.

Fertilization under smart agriculture helps to precisely estimate the required dose of nutrients, ultimately minimizing their negative effects on the environment. Fertilization requires site-specific soil nutrient level measurements based on various factors, such as crop type, soil type, soil absorption capability, product yield, fertility type and utilization rate, weather condition, etc. The reason is that The measurement of soil nutrient level is not only expensive but also time-consuming, as, typically, investigations of soil samples at each location are required. To better depict this discussion, figure 4, summarizes the major inputs, processes and resultant outputs of smart agriculture. New IoT-based fertilizing approaches help to estimate the spatial patterns of nutrient requirements with higher accuracy and minimum labor requirements. For example, the Normalized Difference Vegetation Index (NDVI) uses aerial/satellite images to monitor crop nutrient status. Basically, NDVI is based on the reflection of visible and near-infrared light from vegetation and is used to estimate crop health, vegetation vigor, and density, further contributing to assessing the soil nutrient level. Such precise implementation can significantly improve fertilizer efficiency, simultaneously reducing the side effects on the environment. Many recent enabling technologies, like GPS accuracy, geo-mapping, Variable Rate Technology (VRT), and autonomous vehicles, are strongly contributing to IoT-based smart fertilization. Other than precision fertilization, fertigation and chemigation are other benefits of IoT. In these methods, water-soluble matters, such as fertilizers, soil amendments, and pesticides, can be applied through the irrigation system. Although these methods are not new to agriculture and have been applied over the last three decades, their precise use with real results has been witnessed only with IoT integration. Based on recent outcomes, fertigation is considered as the best management practice to improve the effectiveness of many agriculture matters; most importantly, it can be integrated with IoT-based smart farming infrastructure seamlessly.

D. CROP DISEASE AND PEST MANAGEMENT

The Great Famine, also known as the Irish Potato Famine, in which approximately one million Irish people died around 1950, resulted due to crop failure and yield. Even today, corn growers in the US and southern Canada are facing an economic loss of approximately one billion USD. The Food and the Agriculture Organization (FAO) estimates that 2040% of global crop yields are lost annually due to pests and diseases. To control such vast production losses, pesticides and other agrochemicals became an important component of the agriculture industry during the last century.

It is estimated that each year, around half a million tons of pesticide are used in the US alone, while more than two million tons are used globally. Most of these pesticides are harmful to human and animal health, leaving a severe, even irreversible, impact on the environment, ultimately causing significant contamination to entire ecosystems. Recent IoT-based intelligent devices, such as wireless sensors, robots, and drones are allowing the growers to slash pesticide uses significantly by precisely spotting crop enemies. Compared to the traditional calendar or prescription-based pest control procedures, modern IoT-based pest management provides real-time monitoring, modeling, disease forecasting, hence proving more effective. Generally, the reliability of crop disease monitoring and pest management depends on three aspects: sensing, evaluating, and treatment.

The advanced disease and pest recognition approaches are based on image processing in which raw images are acquired throughout the crop area using field sensors, UAVs, or remote sensing satellites. Usually, remote sensing imagery covers large areas and, hence, offers higher efficiency with lower cost. On the other hand, field sensors are capable to support more functions in collecting data, like environment sampling, plant health, and pest situations, in every corner throughout the crop cycle. For example, IoT-based automated traps can capture, count, and even characterize insect types, further uploading data to the Cloud for detailed analysis, which is not possible through remote sensing. Approaches like vehicle precise spray and automatic VRT chemigation, commonly used under smart fertilization, can also be utilized for disease treatment and other pesticide applications. Moreover, the advancement of robotic technology offers new solutions. When equipping an agricultural robot with multispectral sensing devices and precision spraying nozzles, it can locate and deal with pest problems more precisely under the manipulation of a remote IoT disease management system.

This IoT-based pest management system has many advantages, as it can reduce the overall expenditures while, at the same time, support the restoration of the natural climate. For example, recently, it has been found that yields of many crop types are facing severe threats due to the lack of pollination. In fact, the pollination is being affected due to bee colony collapse disorder resulting from the uncontrolled pesticides.

E. YIELD MONITORING, FORECASTING, AND HARVESTING

Yield monitoring is the mechanism used to analyze various aspects corresponding to agricultural yield, like grain mass flow, moisture content, and harvested grain quantity. It helps to accurately assess by recording the crop yield and moisture level to estimate how well the crop performed and what to do next. Yield monitoring is considered an essential part of precision farming not only at the time of harvest but even before that, as monitoring the yield quality plays a crucial role. Yield quality depends on many factors, e.g. sufficient pollination with good quality pollen especially when predicting seed yields under changing environmental conditions. Currently, when we are dealing with more open markets, buyers around the world become more particular about fruit quality; hence, effective production depends on the right fruit size to the right market at the right time.

Crop forecasting is an art to predict the yield and production (tons/ha) before the harvest takes place. This forecasting helps the farmer for near-future planning and decision making. Furthermore, analyzing the yield quality and its maturity is another critical factor which enables the determination of the right time for harvesting. This monitoring covers various development stages and uses fruit conditions like its color, size, etc., for this purpose.

Predicting the right harvesting time not only helps to maximize the crop quality and production but also provides an opportunity to adjust the management strategy. Although harvesting is the last stage of this process, proper scheduling can make a clear difference. To obtain the real benefits from crops, farmers need to know when these crops are actually ready to harvest.

3. Methodology

Wireless sensors placed strategically around fields are providing farmers with up-to-date information in real-time, allowing them to adapt the care that the crops need, which results in higher food production with less waste.

Wireless sensor networks (WSNs) are also being used to inform farmers about nearly all aspects of their crop growth as well helping in preventing loss of crop as well as enhancing the readiness of the equipment which cultivates it.

WSNs with GPS capability are helping tractors in compensating for uneven terrain and optimizing land preparation for growing crops. Recently, advances in image recognition and digital signal processing gave even more capabilities to WSN to accurately determine crop quality and health.

In order to make agriculture sustainable, the use of the IoT will be at the center and forefront in agricultural operations.

This includes everything from water and power usage, crop transportation, farm machinery operation and maintenance alerts, and market price updates. The IoT has the capability to make these tasks streamlined and more predictable by proved a breakthrough and is further going to change the
we look at various agriculture activities by providing the farmer control over their land and assets in an unprecedented way, thus, maximizing their effectiveness and efficiency.

Further, the future of the IoT can be shaped by the phenomenal advances in WSNs and the fifth generation (5G) of cellular mobile communication technologies to provide farmers with real-time data and information anytime and everywhere their land is. Based on recent success, it is estimated that more than 75 million IoT-based devices will be operating in the agriculture industry by 2020. Further, the average farm is expecting to generate 4.1 million data points on a daily basis by 2050.

Real success of IoT in agriculture largely depends on advances in connectivity. From telecom's perspective, providing mainly connectivity and other value-added services has an immense potential and can influence the entire chain greatly. Most of the telecom operators around the globe offer connectivity services, but such services only represent a tiny amount of the entire smart agriculture market. Considering its worth, especially in rural areas, the cellular operators have to offer a new range fact that most of the community belong to this industry are not highly educated and mostly unaware of new technologies, hence the operator should provide end-to-end solutions other than just providing the connectivity. If so, then it will certainly help to increase the market share of mobile and telecom operators. Further, these operators need partnerships with the investors to provide end-to-end solutions, which demands higher investment, even before advantages can be seen.

The results of success when inviting the investors depend on the nature of the partnership and the involved bodies, like device manufacturers, solution providers, non-cellular connectivity service providers, system integrators, etc. On one side, the outcome of this partnership would help operators to enter deeper into the industry, ultimately boosting their market share.

At the same time, this opportunity can create strong relationships among the organizations and farmers to help to educate them about the benefits of smart agriculture. The success of cellular technology is only possible when service providers leverage its real benefits like portability, flexibility and luxury of two way communication to offer low cost but customized solutions. They must provide what the farmer is in need, at the place they choose. Furthermore, to provide fast penetration in the agriculture industry, policy changes are required in order to provide access to reliable and quality inputs. The research conducted in which considers 23 studies where mostly belong to developing countries, concludes that the cellular services and smartphone technology carry a promising future for smallholder farmers being capable to improve their yields.

Furthermore, licensed LPWA (low-power wide-area) technology is expected to be a game-changer for smart agriculture. Due to its characteristics and supported services including low power consumption and efficient coverage
are well suited to the geography and economics of agriculture hence expected to play a critical role in future smart farming. Consequently, narrowband IoT (NB-IoT) got strong industry support and became an effectively global standard for LPWA connectivity. It has the potential to provide major connectivity changes in the agriculture industry by changing the perceptions about Internet capabilities. Believing in its future success, it is expected that leading cellular operators with strong IoT ambitions can generate significant revenues by providing smart agriculture services when collaborating with LPWA technology providers. In order to achieve long-term success of these short, mid and long-range communication.

4. Literature survey

Crop Yield Estimation

- Zhou Zhongwei's method to picture the items in an inventory network in a rural setting.[2]
- LiSanbo and at Alcentre for programming the process control of the water design framework and engineering around the equipment.
- Smash and Atal for how to properly direct water in the fields in the rural setting.[3]
- BoYifan and Atal for horticulture and range services using a web of things and distributed computing.[4]
- M.V. Latte and Atal for identifying the many dependencies and shortcomings in the growing of paddy using pictures of the leaf using shading and example investigation.[5]

Water management in irrigation

1. **Pani Panchayat: Orissa Water Resource Consolidation Project[11]**

- The success stories published in the quarterly journal "Krushak Bandhu Arnapurna" helps in the exchange of knowledge with a larger audience.
- The bottom-up institutional framework helps in sustained and effective management of the resource.
- Capacity developm ent helps in the continual improvement of the office bearers

2. **Micro-irrigation in Gujarat[12]**

- This model sets a benchmark that could be implemented across nations.
- Strict monitoring and dedicated agencies played a crucial role in making the program a success.
- Effective storage and management of water is equally important as is the availability.

3. **Participatory Irrigation Management (PIM) - Waghad, Maharashtra[13]**

- A participatory approach can help is the judicious use of resources.
- Representation of an equitable percentage of women in the formation and working of WUA's is highly important.
- Tail-to-head distribution of resources helps in achieving equity.
- Capital and labor contribution in building an institutional structure gives a sense of ownership to the beneficiaries.

4. **Mission Kakatiya, Telangana[14]**

- Public participation will lead to ownership and help in the long-term sustainability of the interventions.
- Restoration and maintenance of water resources should be a continual process and local people should be trained to manage their resources

Existing Problem:

Horticulture is the foundation of our Nation. In the past, agriculturists used to figure out the ripeness of soil and influenced presumptions to develop which kind of product.

They didn't think about the dampness, level of water, and especially climate conditions which are more horrifying to an agriculturist.

They utilize pesticides in view of a few suspicions which lead to a genuine impact on the yield if the supposition isn't right. The profitability relies upon the last phase of the harvest on which agriculturists depend.

Proposed Solution:

To improve the efficiency of the product thereby supporting both rancher and country we need to utilize the innovation which appraises the nature of harvest and gives recommendations.

The Internet of things (IoT) is revamping agribusiness, engaging the farmers by the broad assortment of techniques, for instance, accuracy and conservative cultivation to go up against challenges in the field. In this project, on a farm, management can monitor different environmental parameters effectively using sensor devices such as temperature sensors, relative humidity sensors, and soil moisture sensors.

Periodically (30 seconds) the sensors are collecting information of the agriculture field area and are being logged and stored online using cloud computing and the Internet of Things.

By using wireless transmission, the sensed data is forwarded to the webserver database. If irrigation is automated, then that means if the moisture and temperature fields fall below the potential range.
The user can monitor and control the system remotely with the help of an application that provides a web interface to the user.

5. Finding the business partner in the industrial scenario

We would need to find the business partners according to the following services.

- Value Chain Studies
- Crop Surveys- Sowing Intention, Acreage and Yield estimation
- Crop Cutting Experiments (CCEs) and Monitoring
- Impact & Evaluation Studies
- Farmer’s training & capacity building
- Advisory and Consulting on commodities
- Customize research Reports
- Irrigation Patterns in different seasons
- Market assessment and entry strategy

Some of the Potential Industry Clients:

(Farming in general - No need to change in irrigation, have added some stakeholders only for irrigation)

Corporates –

- Ruchi Soya,
- ICICI LOMBARD
- RELIANCE GENERAL INSURANCE
- CHOLA MS
- TATA AIG
- AGRICULTURE INSURANCE COMPANY
- BAJAJ ALLIANZ and IFFCO TOKIO
- Hindustan Gum
- Cargill
- P&G
- Nestle
- ITC
- Godrej, Mitsubishi Corp
- Future Retail
- General Mills
- Gujarat Ambuja
- Britannia
- Coromandal
- Kohinoor
- Vishal Megamart
- NCDEX
- MCX
- Edelweiss
- ICICI Direct.com

Governments –

- FCI
- Ministry of Agriculture

- USDA
- STC
- PEC
- SFAC
- AIC
- Ministry of Consumer Affairs
- Food & Public distribution
- Horticulture Board
- Ministry of Rural Development
- APEDA
- Ministry of Food Processing

Development organizations –

- FAO
- GIZ
- World Bank
- DFID
- USDA
- Sir Dorabji Tata Trust

6. Work done status report 1 with output

We have done data comparison analytics by comparing different parameters that might affect crop yield prediction and coding on our web application. All the data and data sets present here are verified from goverment websites or reputed organization.

Crop Yield Prediction through different Machine Learning Algorithm

We first decided to check the different machine learning algorithms for crop yield estimation in a Jupyter Notebook to see how the predictions were fair. Here are the results.

Data Source and Datasets

The acquisition of datasets in the Indian sub-terrain is a tad difficult as there is no official compilation of the required datasets but scattered datasets are available which upon merging can be used to provide the desired yield.

The following data sets were used throughout the project:

1. **Temperature and Rainfall**: These datasets were collected from the Indian Water Portal (www.indianwaterportal.org). They consist of 100 years of temperature/rainfall data per month for each district in India as follows :

District	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
adilabad	1912	6.725	10.488	23.288	35.56	23.119	115.546	294.119	276.865	181.615	47.31	1.339	0
adilabad	1913	0.42	0	0.388	6.07	3.331	45.96	233.973	167.971	198.177	26.447	35.083	11.222
adilabad	1914	6.643	1.956	0.173	4.551	33.348	132.078	436.611	334.544	226.037	138.818	14.095	8.823
adilabad	1915	0.054	0.121	11.446	0.017	16.9	131.048	160.694	81.865	251.577	110.391	0.146	0.13
adilabad	1916	0.589	2.293	8.252	35.02	17.569	79.937	96.331	313.522	361.697	4.95	0.146	0
adilabad	1917	4.369	1.967	9.703	0.326	2.983	221.619	279.633	189.606	132.764	11.557	23.836	6.166
adilabad	1918	0.921	2.758	2.275	27.166	0.537	141.804	221.362	301.701	83.428	0.735	4.585	3.344
adilabad	1919	2.478	5.536	3.84	3.644	8.194	100.301	271.8	333.651	364.372	0.715	0.146	0.036
adilabad	1920	0.265	2.163	3.161	42.729	4.311	134.261	284.987	174.845	121.895	1.791	0.146	7.174

Rainfall Data

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	District
1912	22.965	24.17	28.024	31.609	33	31.1	27.18	25.999	27.661	26.686	23.167	21.096	Adilabad
1913	23.233	24.964	29.675	32.378	35.101	32.33	28.376	27.853	26.852	26.614	22.351	21.26	Adilabad
1914	22.708	24.058	28.554	32.16	32.434	32.286	27.008	26.479	26.762	25.25	21.657	20.216	Adilabad
1915	22.413	24.189	28.269	32.898	33.69	29.975	27.588	27.1	26.565	26.117	22.051	20.894	Adilabad
1916	21.963	22.996	28.156	30.432	34.193	32.5	27.96	26.899	26.491	26.089	23.558	20.526	Adilabad
1917	22.599	24.932	27.901	32.973	35.192	30.038	27.404	26.833	26.482	25.864	23.249	21.637	Adilabad
1918	22.171	24.722	27.891	29.792	32.966	30.733	27.861	25.406	27.432	27.157	24.343	20.63	Adilabad
1919	21.402	24.856	27.817	33.023	34.671	31.838	26.92	25.992	26.707	25.976	22.181	19.461	Adilabad
1920	23.312	25.207	29.182	29.945	33.747	29.65	26.531	27.075	26.535	26.098	23.249	22.181	Adilabad
1921	22.401	24.173	28.672	32.754	34.235	30.022	27.908	26.924	26.327	25.628	21.175	20.16	Adilabad

Temperature Data

2. **Crop Yield Data:** This dataset is available on the Open Government Data (OGD) Platform of India (www.data.gov.in). This consists of data points of 17 years that are categorized based on, districts, crops, seasons, and area.

State_Name	District_Nam	Crop_Year	Season	Crop	Area	Production
Andaman an	NICOBARS	2000	Kharif	Arecanut	1254	2000
Andaman an	NICOBARS	2000	Kharif	Other Kharif	2	1
Andaman an	NICOBARS	2000	Kharif	Rice	102	321
Andaman an	NICOBARS	2000	Whole Year	Banana	176	641
Andaman an	NICOBARS	2000	Whole Year	Cashewnut	720	165
Andaman an	NICOBARS	2000	Whole Year	Coconut	18168	65100000
Andaman an	NICOBARS	2000	Whole Year	Dry ginger	36	100
Andaman an	NICOBARS	2000	Whole Year	Sugarcane	1	2
Andaman an	NICOBARS	2000	Whole Year	Sweet potatc	5	15
Andaman an	NICOBARS	2000	Whole Year	Tapioca	40	169
Andaman an	NICOBARS	2001	Kharif	Arecanut	1254	2061
Andaman an	NICOBARS	2001	Kharif	Other Kharif	2	1
Andaman an	NICOBARS	2001	Kharif	Rice	83	300
Andaman an	NICOBARS	2001	Whole Year	Cashewnut	719	192

3. **The Final Dataset**: This data set is made by merging the temperature, rainfall, and production into the final .csv file. The predictions were made on this final data set to get the required results.

State	District	Year	Season	Crop	Area	Production	emperature	Rainfall
Andhra Pra	anantapur	1997	Kharif	Arhar/Tur	21400	2600	25.52133	68.57033
Andhra Pra	anantapur	1997	Kharif	Bajra	1400	500	25.52133	68.57033
Andhra Pra	anantapur	1997	Kharif	Castor seec	1000	100	25.52133	68.57033
Andhra Pra	anantapur	1997	Kharif	Cotton(lint)	7300	9400	25.52133	68.57033
Andhra Pra	anantapur	1997	Kharif	Dry chillies	3700	7100	25.52133	68.57033
Andhra Pra	anantapur	1997	Kharif	Groundnut	650800	228400	25.52133	68.57033
Andhra Pra	anantapur	1997	Kharif	Horse-gram	3300	1000	25.52133	68.57033
Andhra Pra	anantapur	1997	Kharif	Jowar	10100	10200	25.52133	68.57033
Andhra Pra	anantapur	1997	Kharif	Korra	2200	700	25.52133	68.57033
Andhra Pra	anantapur	1997	Kharif	Maize	2800	4900	25.52133	68.57033
Andhra Pra	anantapur	1997	Kharif	Moong(Gre	1300	500	25.52133	68.57033
Andhra Pra	anantapur	1997	Kharif	Other Khari	800	100	25.52133	68.57033
Andhra Pra	anantapur	1997	Kharif	Ragi	6700	11800	25.52133	68.57033

Algorithms Applied

- **Rainfall and Temperature:**

  The data was sequential thus time series analysis algorithms were used:

1. **LSTM**: LSTM networks are well-suited to classifying, processing, and making predictions based on time series data since there can be lags of unknown duration between important events in a time series.
2. **Simple RNN**: A recurrent neural network (RNN) is a class of artificial neural networks where connections between nodes form a directed graph along a sequence. This allows it to exhibit temporal dynamic behavior for a time sequence.
3. **Linear Regression**: Forecasting by minimizing the errors in prediction in past.

- **Final Dataset** :

  Regression Analysis and Classification Analysis were both applied to this data set.

1. KNN Regressor and classification
2. Artificial Neural Net
3. Linear Regression
4. SGD Regressor and classification

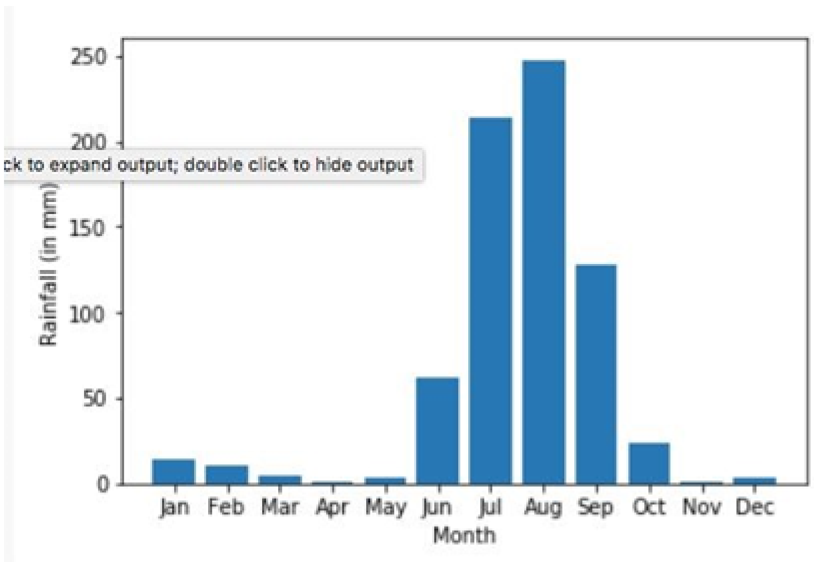
5. Random Forest Regressor and classification

Comprehensive Analysis of the Algorithms Applied

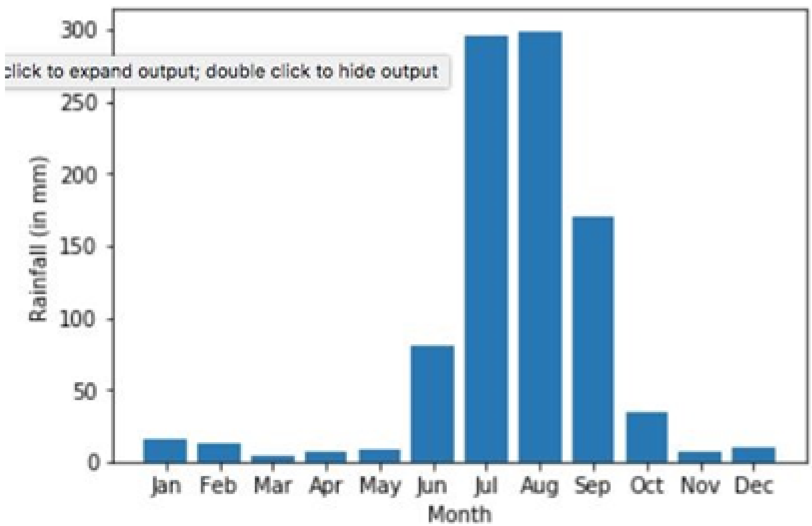
Rainfall Prediction:

We have taken a look back of 10 years and thus predicting the rainfall for the 11th year for training data

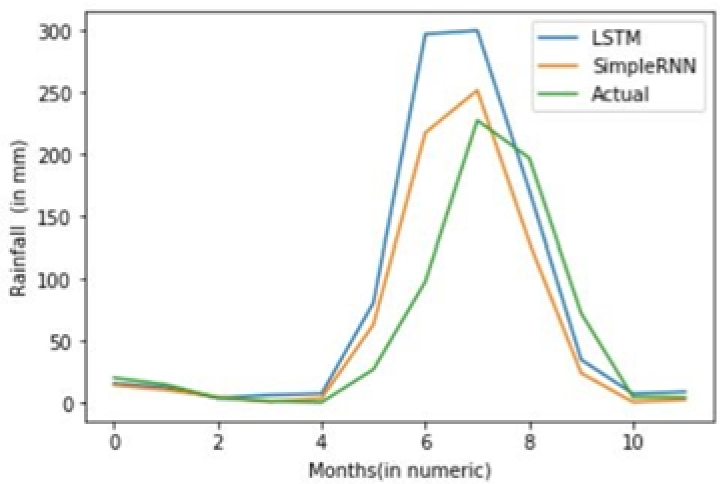
1. Simple RNN



2. LSTM



Comparison of the two models:

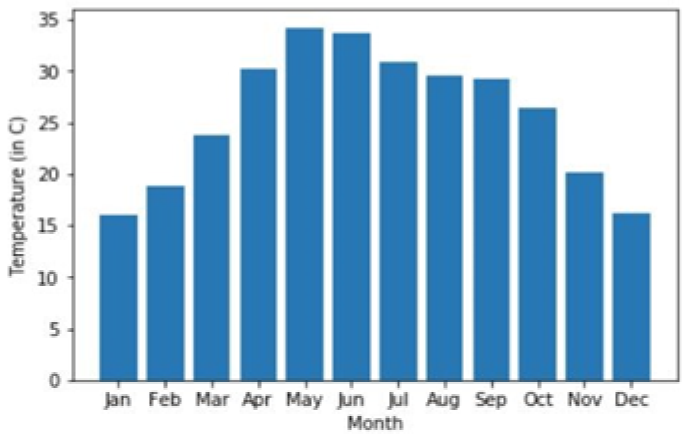


Model	Mean Absolute Error
Simple RNN	22.17
LSTM	34.14

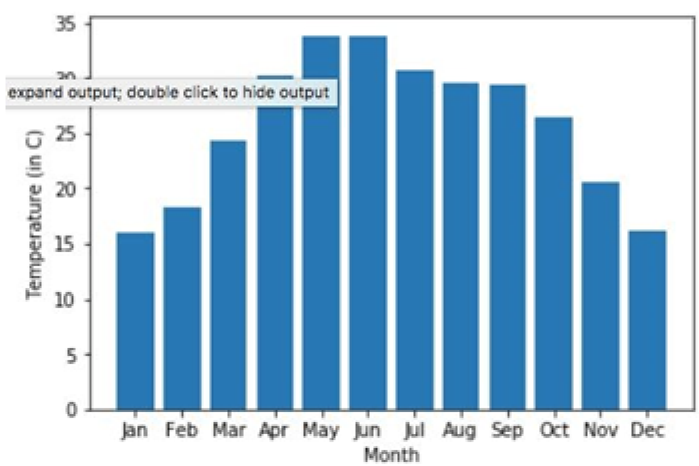
Temperature Prediction:

We have taken a look back of 10 years and thus predicting the temperature for the 11th year for training data.

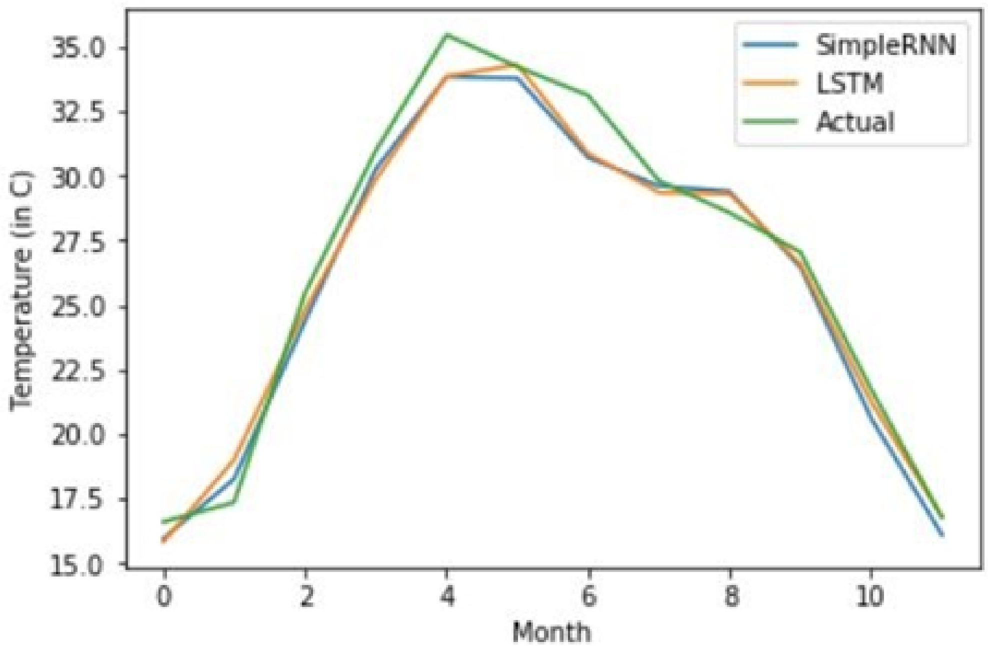
1. Simple RNN



2. LSTM



Comparison of the two models:

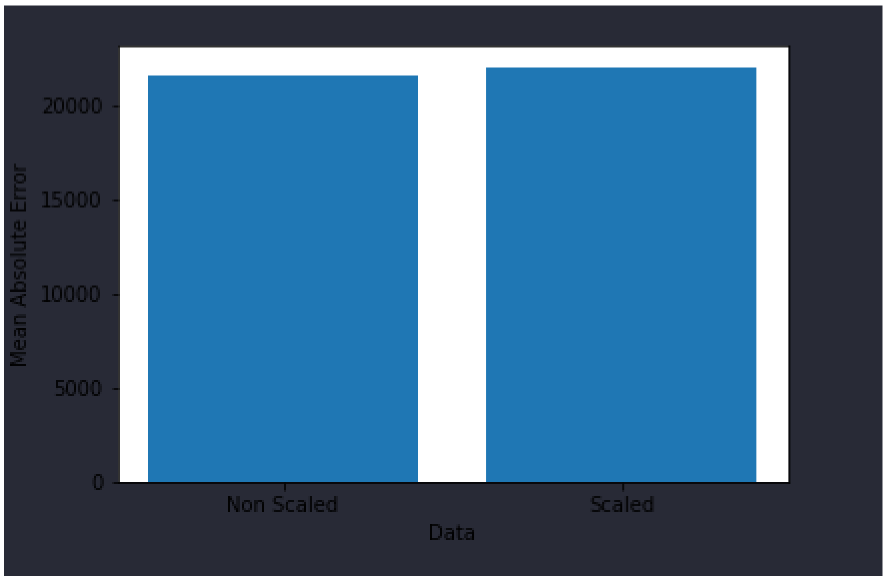


Model	Mean Absolute Error
Simple RNN	0.92016
LSTM	0.8137

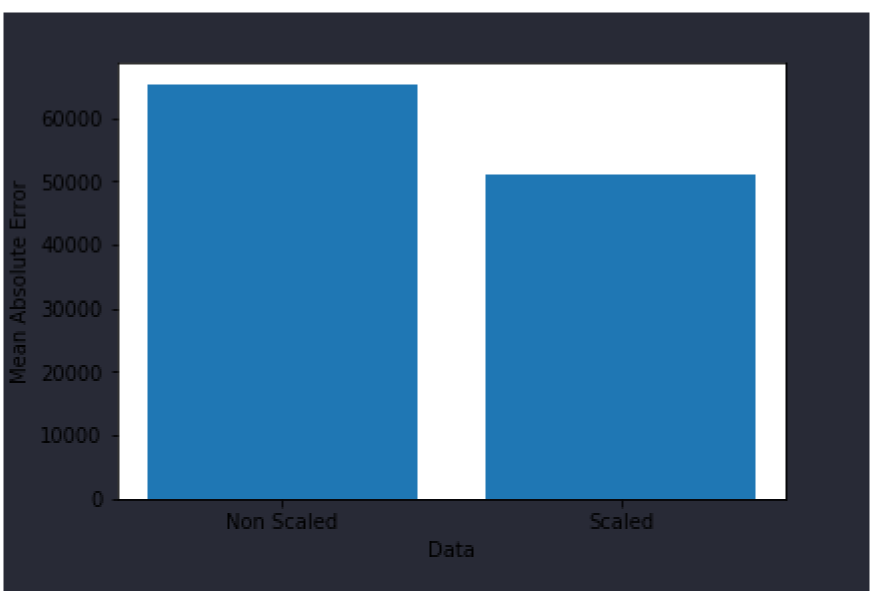
Yield Prediction:

We are predicting the value of prediction and then dividing it by the area of the chosen district thus in turn predicting the crop name.

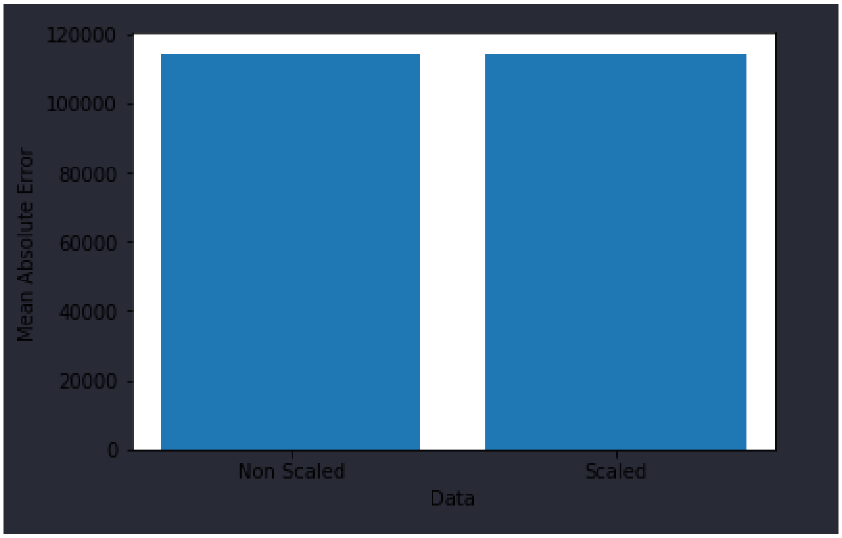
1. Artificial Neural Net



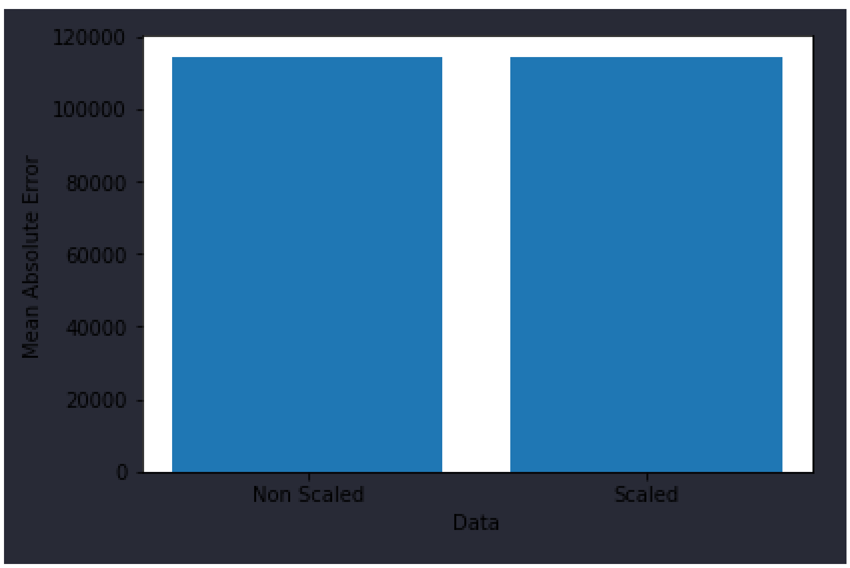
2. Linear Regression



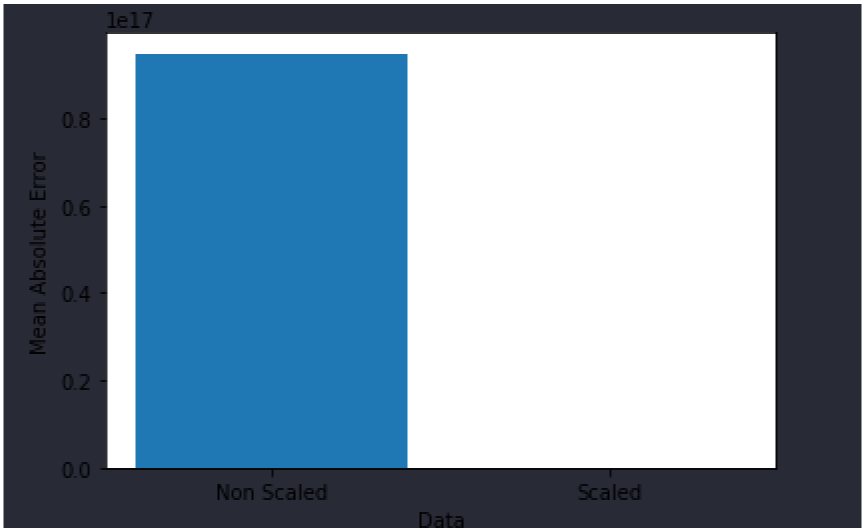
3. Random Forest Regressor



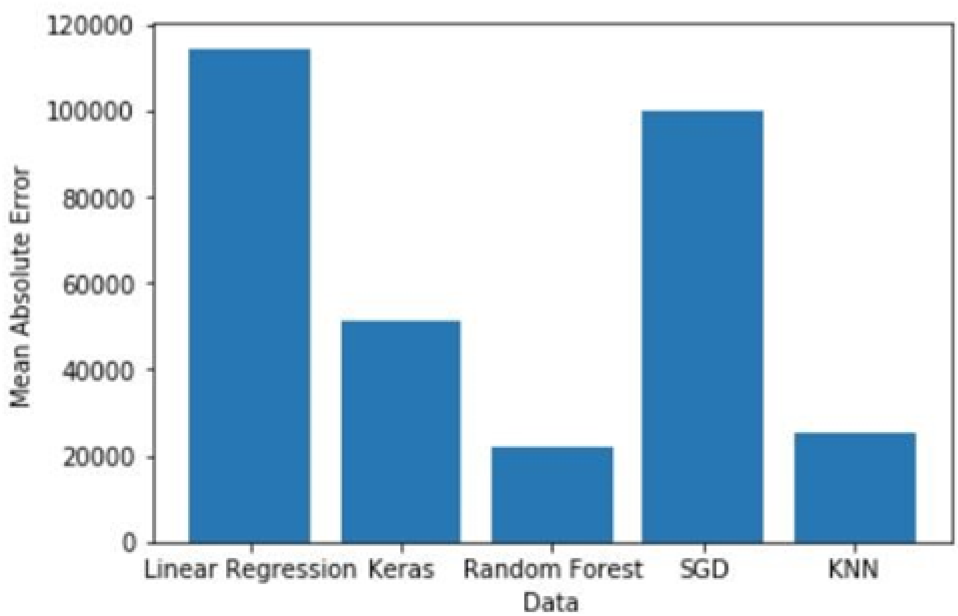
4. KNN Regressor



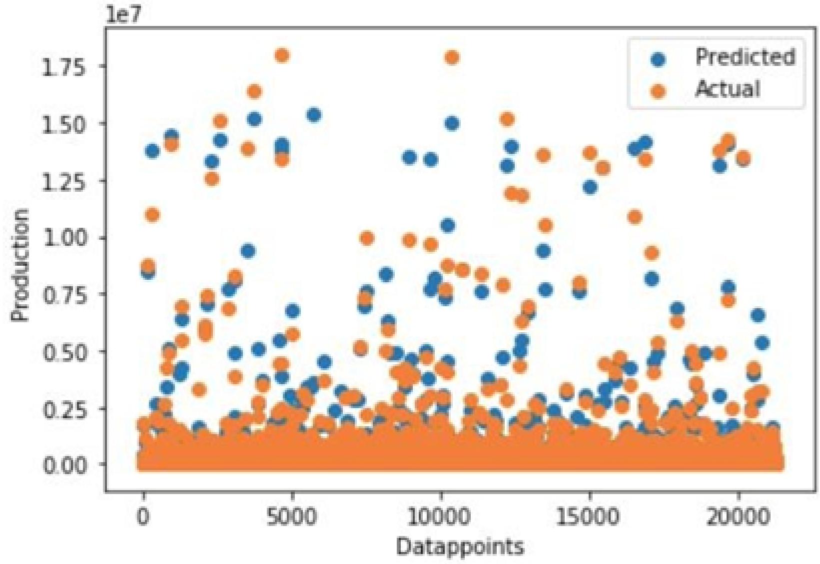
5. SDG



Comparison of various techniques



Predicted vs Actual Production Value for Random Forest Regressor



Result Analysis

- The dataset size is around 1 lakh.
- The best technique for rainfall is SimpleRNN with a mean absolute error of 22.14mm • The best technique for temperature is LSTM with a mean absolute error of 0.8137 degrees.
- After applying various techniques we found out that in Crop Yield annd Crop Name Random Forest yields the best result with minimum mean absolute error.

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