Journal of Informatics
Electrical and Electronics Engineering, 2021,
Vol. 02, Iss. 02, S. No. 007, pp. 1-19
ISSN (Online): 2582-7006

An Integrative Decision Support Model for Smart Agriculture Based on Internet of Things and Machine Learning

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How to cite this paper: S. Saqib, F. Ahmad (2021) An Integrative Decision Support Model for Smart Agriculture Based on Internet of Things and Machine Learning. *Journal of Informatics Electrical and Electronics Engineering, Vol. 02, Iss. 02, S. No. 007, pp. 1-19, 2021*.

https://doi.org/10.54060/JIEEE/002.02.007

Received: 05/04/2021
Accepted: 25/05/2021
Published: 05/06/2021

Abstract

The Internet of Things (IoT) has achieved an upset in a considerable lot of the circles of our current lives, like automobile, medical services offices, home automation, retail, education, manufacturing, and many more. The Agriculture and Farming ventures significantly affect the acquaintance of the IoT with the world. Machine learning (ML) is a part of artificial intelligence (AI) that permits software applications to turn out to be more precise at foreseeing results without being expressly customized to do as such. It uses historical data as input to predict new result values. In the event, a specific industry has sufficient recorded information to help the machine "learn", AI or ML can create outstanding outcomes. Farming is likewise one such important industry profiting and advancing from machine learning at large. ML can possibly add to the total lifecycle of farming, at all phases. This incorporates computer vision, automated irrigation, and harvesting, predicting the soil, weather, temperature, moisture values, and robots for picking off the crude harvest. In this paper, I'll work on a smart agricultural information monitoring framework that gathers the necessary information from the IoT sensors set in the field, measures it, and drives it, from where it streams to store in the cloud space. The information is then shipped off the prediction module where the necessary analysis is done using ML algorithms and afterward sent to the UI for its corresponding application.

Keywords

Internet of Things (IoT), Machine Learning, Smart Agriculture

1. Introduction

Machine learning is an approach to data evaluation that automates analytical system development. It is a department of artificial intelligence-based totally on the concept that systems can study from data, perceive patterns and make choices/decisions/predictions with minimal human intervention. Food Security is one of the most necessary for the developing food needs of an ever-increasing population. Due to the increasing populace, we can't produce meals to meet the requirement of 1.38 billion, and nonetheless increasing the populace will put a large burden on the Indian economy. Around the globe, India is having a massive agricultural hub and the mainstream of the Indian populace is established on the agricultural area for meeting their requirement. Agriculture accounts for a fundamental component of GDP (Gross Domestic Product) now not solely of developing countries. However additionally for many developed nations. Thus, improvising and optimizing the current farming technologies is the want of the hour. It will no longer solely assist in flourishing sustainable improvement of mankind, plant life, and fauna but will additionally assist in dealing with the global crisis such as local weather alternate and epidemics such as draught. Internet of things has upgraded due to convergence of greater than one technology like machine learning, wireless sensors, and embedded systems, real-time analytics. Conventional fields of networking of wireless sensors, embedded systems, automation (including domestic and constructing automation), and many more make contributions to enable the Internet of Things. In the consumer market, IoT technological know-how is most synonymous with product pertaining to the thought of the smart home, gadgets and home equipment (such as lights fixtures, thermostats, domestic protections systems, and cameras, and different domestic appliances) that help one or greater frequent ecosystems, such as smartphones.

The home automation systems are being drastically lookup and developed however, this essential area of Agriculture and especially Smart Agriculture tends to lag at the back of different domains and require pretty a lot of R&D to gain sustainable goals now not solely at the industrial stage, however, at the root degree of this agriculture industry. Automation of traditional irrigation methods can lead to many folds make bigger in crop yield. To form agriculture based on IoT, there are some needs that are to be fulfilled necessarily. In the first place, the particular sensors (e.g., temperature sensors, moisture sensors, pressure sensors, etc.) required for the IoT utility are to be decided smartly. Secondly, the algorithms must be developed maintaining in thinking all the feasible possibilities required for the quality prediction and machine learning to have to be utilized effectively. Seeing next, the sensors are extra likely to get damage in the fields, so pursuits monitoring of these is required timely. Considering that, the framework of the wireless data transmission has to be as per the needs of the devices to join over a precise land region in the field. Lastly and majorly, the safety, security, and privacy of the device must be ascertained through authenticating the setup system, assuring its concealment, candor, and managed admittance. The model proposed here in this paper is about how the Internet of things and machine learning used in the agricultural system. The proposed system may want to be such there will be no compromise between efficiency, security, performance, and safety of the system, and the favored effect has to produce exquisite precision and accuracy.

2. Literature Review

A thorough literature review has been done and a fragment of the effective powerful technologies and algorithms based on literature survey and observations are put forward in this paper for the benefit of smart agriculture. In this current digital time, IoT assumes a huge part in each association just as nation advancement, and horticulture is one of the fields in which most of the things should be automated through IoT devices. This new idea unified on farming data has been known with several different names like Smart Farming, Smart Agriculture, Digital Farming, or Agriculture 4.0, and was born when telematics and information management were combined to the already familiar conception of preciseness Agriculture, up the accuracy of operations [13]. The utilization of new technologies to improve crop profitability are shown by [21]. The utilization of new technologies will be useful to measure and break down the information. To store data identified with soil, the authors are using the Blynk application. The data it will save will be its humidity, moisture, temperature, etc. Its uses are shown by [1]. While applying these new technologies, the test for retrieving information from crops is to come out with something intelligent and important, on the grounds that information themselves are not helpful, simply numbers or pictures. Homesteads that choose to be innovation-driven somehow or another, show significant valuable advantages, such as saving money and work, having an expanded creation or a decrease of expenses with insignificant effort, and delivering quality food with all the more environmentally friendly things. [13] Ç. Ersin, R. Gürbüz, A.K. Yakut, 2016 proposed the micro-controller-based irrigation system which is very efficient and economical compared to different standard strategies, preciseness irrigation approaches are delineate by Liu [20]. [9], [23-34].

A farm vehicle and smart dispatching approach have been researched. [22] provided with associate interconnected approached towards smart agricultural. [J. Kwok, Y. Sun, 2018] work suggested plant detection using deep learning and so supported plant sort its applicable irrigation quantity required. Thus, once thorough study of presently out their literature, that deals with the current farming issues and their various answer, this paper highlights and provides a combined, precise view to the potential solution for smart farming).

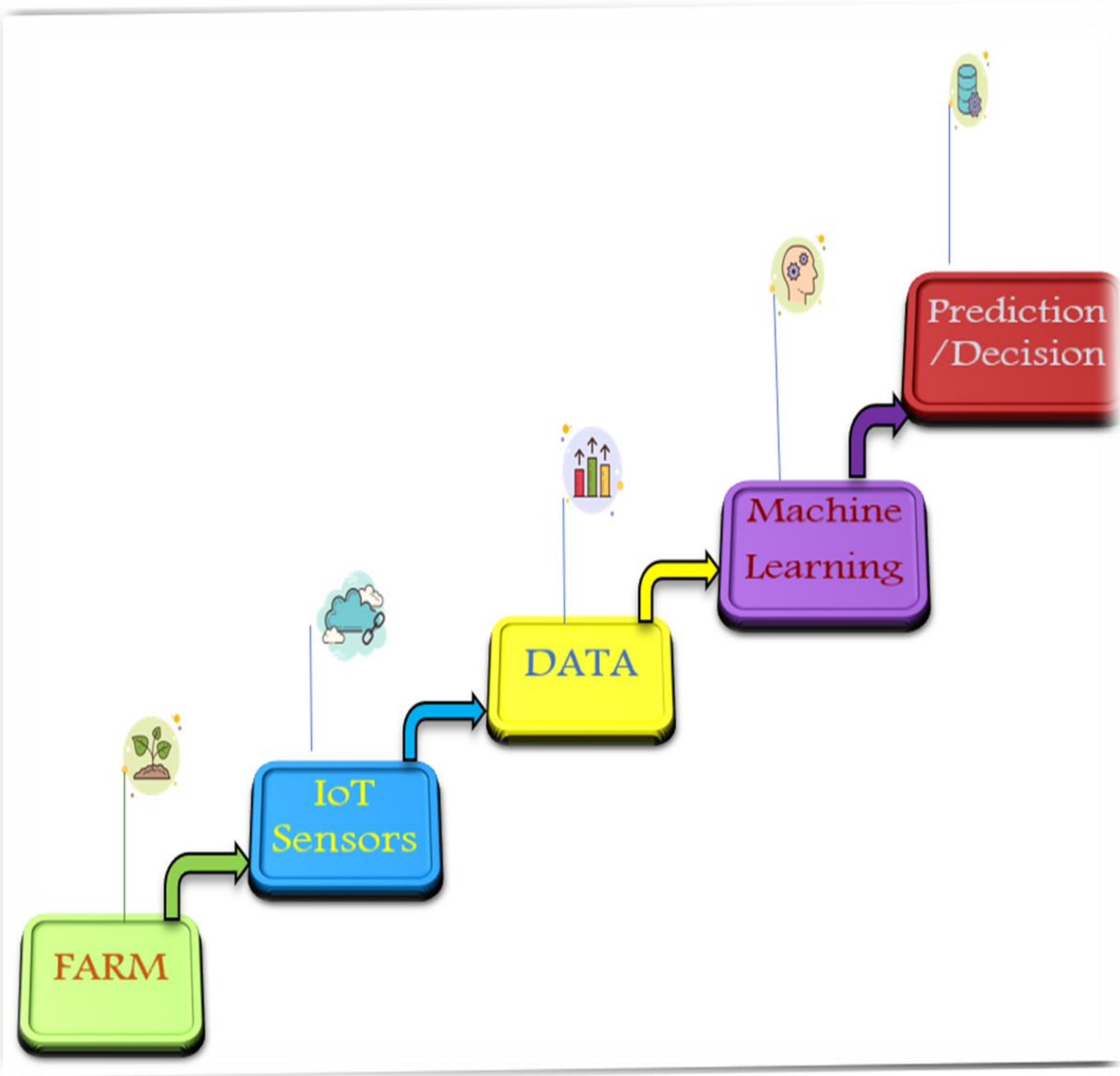

Figure 1. Flow Diagram of proposed work

Table 1. Literature review

Authors	System Design	Findings
[14] Veronica Saiz Rubio (February 2020)	From Smart Farming towards Agriculture 5.0: A Review on Crop Data Management	Optimized cost-effective decisions can be made by farmers while protecting the environment and transforming how food will be produced to match the coming up population growth using IoT and AI.
[7] G.Lavanya, S.Monika ,G.Sandra Karunya, A. Mathan Gopi4 , D. Rajini Girinath, (March2019)	IoT Enabled Assisting Device for Seizures Monitoring	Host Management System (HMS) which is fit for cloud service and checks that stores and controls the MEDIBOX usefulness.
Nikhilesh Wadhwa , Shikhar Tripathi , Chirag Agarwal , Rasika Yeolekar , Ashish Manwatkar (March, 2019)	Web based Intelligent Irrigation System	Methods to solve such problems like identifying crop suitable for which soil, level of water in soil, moisture etc. Mentioned Sensors and electronic devices.
[1] Hemlata Sahu, Prerana Modala , Anjali Jiwankar, Sonal Wagle, (March 2019)	Multidisciplinary Model for Smart Agriculture using IoT	Soil Monitoring for Precision Farming: Monitoring soil conditions is a simple use case but it can lead to a fantastic return on investment for farmers.
[17] Xiaohui Wang, Nannan Liu, (2017)	The Application of Internet of Things in Agricultural means of production supply chain management	Smart agriculture based on IoT and Cloud Computing Use of cloud computing for agriculture utilizing for storing details of agriculture data.
[18] Sanjit Kumar Dash, Subasish Mohapatra, Prasant Kumar Pattnaik, (2017)	A Survey on Applications of Wireless Sensor Network Using Cloud Computing	IoT device can be interfaced to soil and environmental sensors to collect soil properties and current environmental conditions. Analysis of the gathered information for interacting between environment, work and result for high grade work model construction.
[19] S. S. Sarmila (IEEE 2017)	Smart farming: sensing technologies	Model includes smart GPS based remote controlled robot to perform. Controlling of all these operations will be through any remote smart device or computer connected to Internet and operations will be performed by interfacing sensors, Wi-Fi or ZigBee modules, camera, actuators with micro-controller and raspberry.
John R. Dela Cruz (IEEE 2016)	Design of a fuzzy-based automated organic irrigation system for smart farm	Automated organic irrigation system in controlling and properly allocating the available water resources for the irrigation system and pumping water for irrigation on right time and use.

[20] Akshay Atole, Apurva Asmar, Amar Biradar, Nikhil Kothawad (April, 2017)	IoT Based Smart Farming System	Smart Farming System that uses advantages of cutting-edge technologies such as IoT, Wireless Sensor Network and Cloud computing to help farmers enhance the way farming is done.

3. Proposed Work (Framework and Algorithm)

The Internet of Things (IoT) has achieved an upset in a considerable lot of the circles of our current lives, like an automobile, medical services offices, home automation, retail, education, manufacturing, and many more. The Agriculture and Farming ventures significantly affect the acquaintance of the IoT with the world. Machine learning is an approach to data evaluation that automates analytical system development. It is a department of artificial intelligence-based totally In this proposed model IoT and machine learning is combined to create an efficient and effective smart faring model, which will increase the production save time, and resources as well. By the use of different types of sensors, various parameters being monitored for an interval of time best suit irrigation can be done on the farmland, crop management, field conditions management, appropriate use of fertilizers & pesticides all these can be done easily. The figure below gives a brief about the proposed work. It advances the significance and uses in dealing with the agricultural environment for food security. And underlines low energy utilization alternatives for minimal effort or cost and natural maintainability.

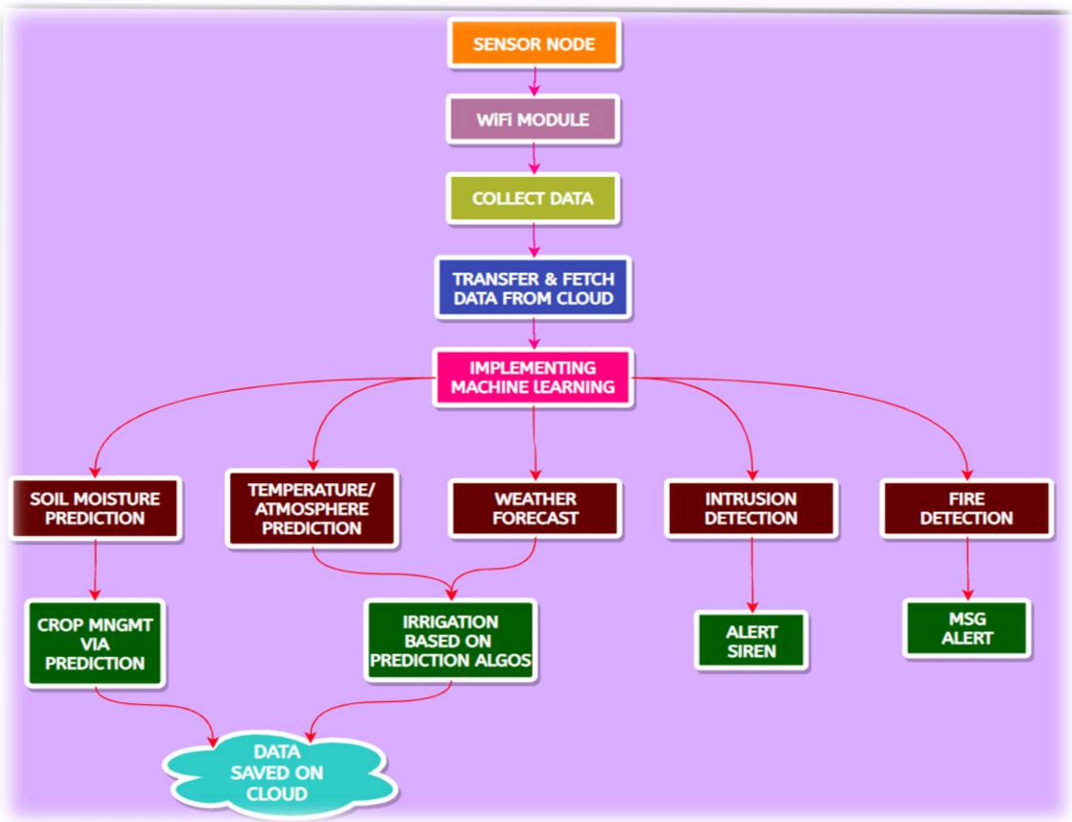

Figure 2. Flowchart for Proposed Work

3.1. Data Processing

As per Second Advance Estimates for 2019-20, complete food grain manufacturing in India is estimated at report 291.95 million tonnes which is greater with the aid of 6.74 million tonnes than the production of food grain of 285.21 million tonnes executed at some stage in 2018-19. However, the manufacturing throughout 2019-20 is greater by way of 26.20 million tonnes than the preceding 5 years (2013-14 to 2017-18) common manufacturing of food grain. To better understand the number of crops cultivated in India and their production volume a study on "Agriculture Production of Crop in India" the dataset is done obtained from the website "Kaggle". The dataset is training dataset. The data analyzation done is for training purpose.

```
plt.figure(figsize = (17, 5))
ax= plt.axes()
ax.set_facecolor("black")
crop_df['Production'].value_counts().head(8).plot(kind='bar'),crop_df['Crop'].value_counts().head(8).plot(kind='bar'
plt.xlabel('CROPS')
plt.ylabel('PRODUCTION')
plt.title("Crop PRODUCTION IN INDIA")
plt.show()
```

Figure 3. Code in python to plot bar graph

The evaluation is done using python language and visualizations are outputs of code executed for the dataset on Google Colab Notebook. This evaluation forms the basis of the importance and needs for automation in the zone to limit cost and enlarge productivity. The bar graph shown is an outcome of the analyzed data. Figure 3 represents the graphical analysis for few crops production. This shows the variety of crops with quantity of their production.

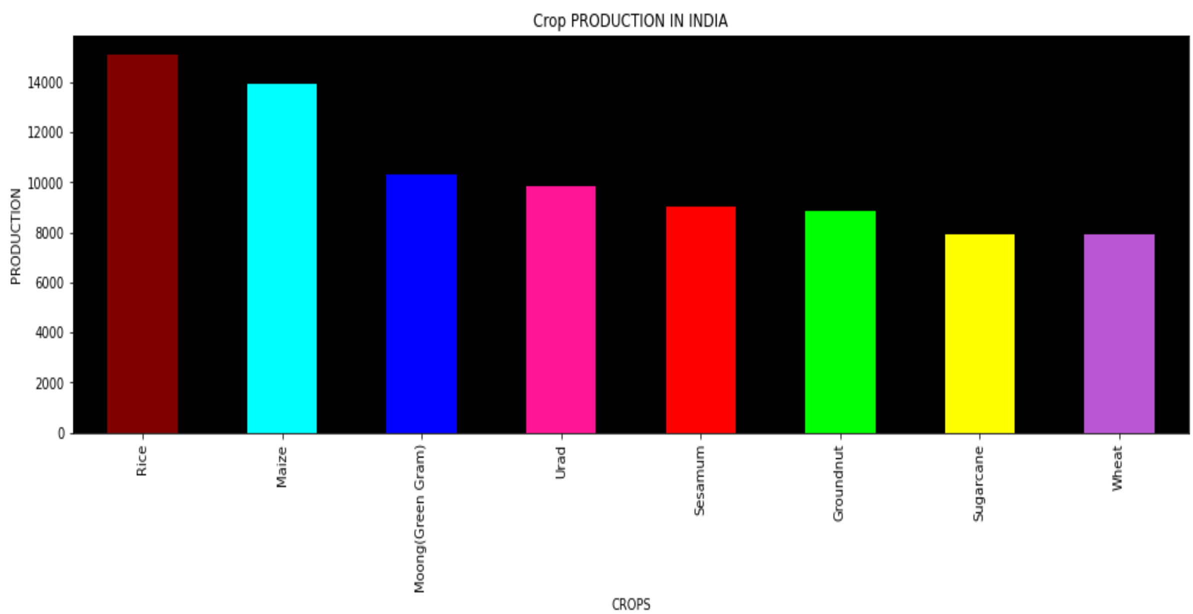

Figure 4. Production of different crops in India

```
[ ]
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
rice_df= pd.read_csv('/content/rice - Sheet1 (1).csv')
```

```
rice_df
```

	State_Name	Rice
0	Andhra Pradesh	165064
1	Assam	262347
2	Bihar	18112
3	Chhattisgarh	456491
4	Jammu and Kashmir	23727
5	Karnataka	176688
6	Telangana	418097
7	Uttar Pradesh	14515
8	West Bengal	780861

Figure 5. Rice Production data frame

```
plt.figure(figsize = (17, 5))
ax= plt.axes()
ax.set_facecolor("black")
rice_df['Rice'].plot(kind='bar',color=['maroon', 'cyan', 'blue', 'deeppink', 'red','lime','yellow','grey','mediumorchid' ]),rice_df['State_Name'].value_counts().plot(kind='
plt.xlabel('STATES')
plt.ylabel('RICE PRODUCTION')
plt.title("RICE PRODUCTION IN INDIA")
plt.show()
```

Figure 6. Code for plotting bar graph Rice Production Vs States of India

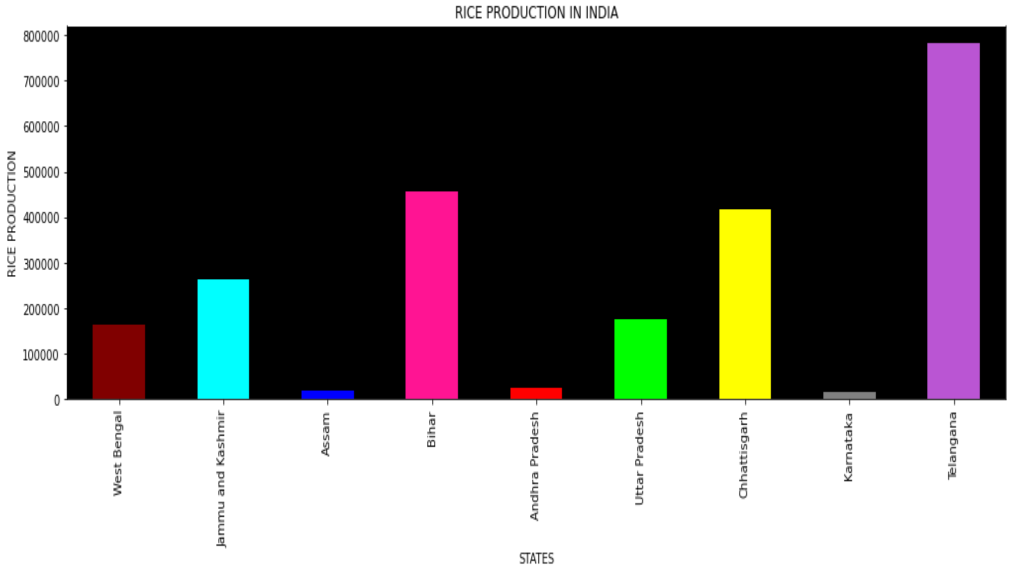

Figure 7. Bar graph for Rice Production in India

4. Implementation

The Internet of Things (IoT) portrays the network of physical connected smart devices that are embedded with sensors, other applied sciences technologies for the motive for interfacing and supplanting realities with various units and designs over the web. This proposed model is based on a farming land, each region consists of different kinds of sensors which will explore it's close by climate by which farmers will be able to act accordingly and the necessities can be executed as soon as possible.

4.1. 4-Layer Architecture

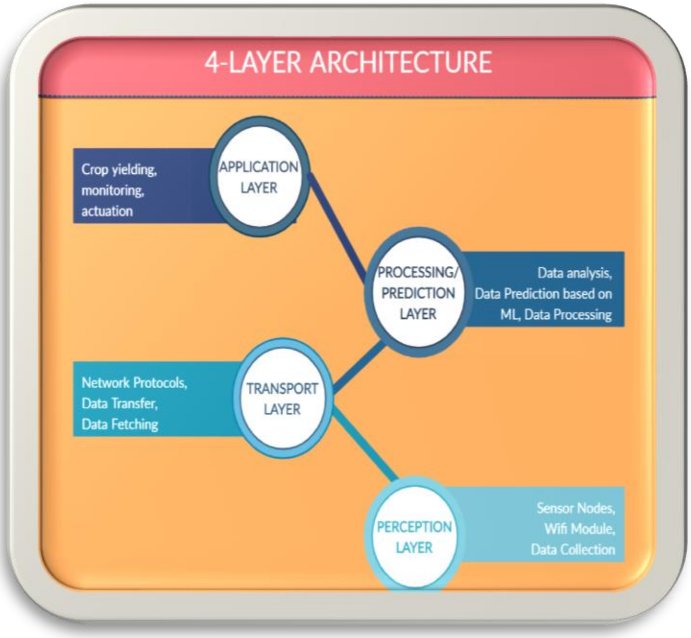

Figure 8. Four Layer Architecture of proposed model

The perception layer represents physical layer which has smart IoT devices. It identifies some physical parameters in the environment and how they communicate with one another and with the second layer transport layer. The IoT objects are responsible for gathering information/data, enabling the interaction between smart devices. This should be possible by utilizing sensor nodes or devices embedded with sensors, unmanned aerial vehicle and microcontrollers like Raspberry-Pi, Arduino to create sensor nodes and transmission gateways. Sensors are used to monitor soil moisture, atmospheric pressure, temperature, water level, fire detection, humidity, intrusion detection. The transport layer relates to network layer which is responsible for interconnecting other smart IoT devices, network devices, and servers. It is also used for processing of sensor data and transmitting it. The processing/prediction layer contains information storage, prediction, and visualizing assets. In this specific circumstance, big data helps store data in huge amounts and information handling, extraction of data in the briefest conceivable time. Such data are utilized as models by machine learning that is a data handling strategy through various algorithms to identify patterns and connections among perplexing and irrelevant information for the improvement of choices and decisions and automation of crop management, irrigation management, soil management, plant diseases monitoring. The application layer consists of Internet of things and machine learning applications with help and provided data from other previous layers, it lets farmers do management of production process in a very effective and efficient manner.

4.2. Interacting IoT

Basic Components:

Some major components for model:

1. Identification (ID): A unique technique for object identification strategy is needed. An ID can be allotted to an object dependent on examples like Internet Protocols (IPv6) id, machine address, a unique product code, or some other random technique.
2. Metadata: Alongside a unique ID, we need some meta data about the object depicts its structure and activity. This is needed to build up proper associations with the object and furthermore suitably place it in together.
3. Security: This is about controls on devices. A proprietor of a gadget may put limitations on the sorts of gadgets that can interface with it. He can decide settings and privacy of the device controlling.
4. Service: such sort of a framework resembles cloud service. A dedicated space should be committed for devices giving particular sorts of administrations. It turns out to be vital to stay up with the latest to such an extent that gadgets.
5. Interconnection- It is like relationship management between various devices. It additionally stores the kinds of gadgets that a given gadget should attempt to associate with dependent on the sort of administrations gave Headings, or heads, are organizational devices that guide the reader through your paper. There are two types: component heads and text heads.

IoT Structure:

1. Water Sprinkler supply water in the farm and water Level Monitor measures the level of the water if level of the water is high then Sprinkler turns OFF and Water Drain start working.
2. Temperature Monitor and Humidity Monitor measures the temperature, humidity present in the environment.
3. Atmospheric Pressure is placed which measured the pressure in the atmosphere.
4. Fire Monitor detected the fire in the farm when it detects fire Alarm turns ON.
5. Trip Sensor senses when any animal or thief try to enter in the farm then Siren starts.

6. Soil moisture sensor records the moisture of soil and it is sent on cloud and then fetched and applied machine learning algorithms for predictions.

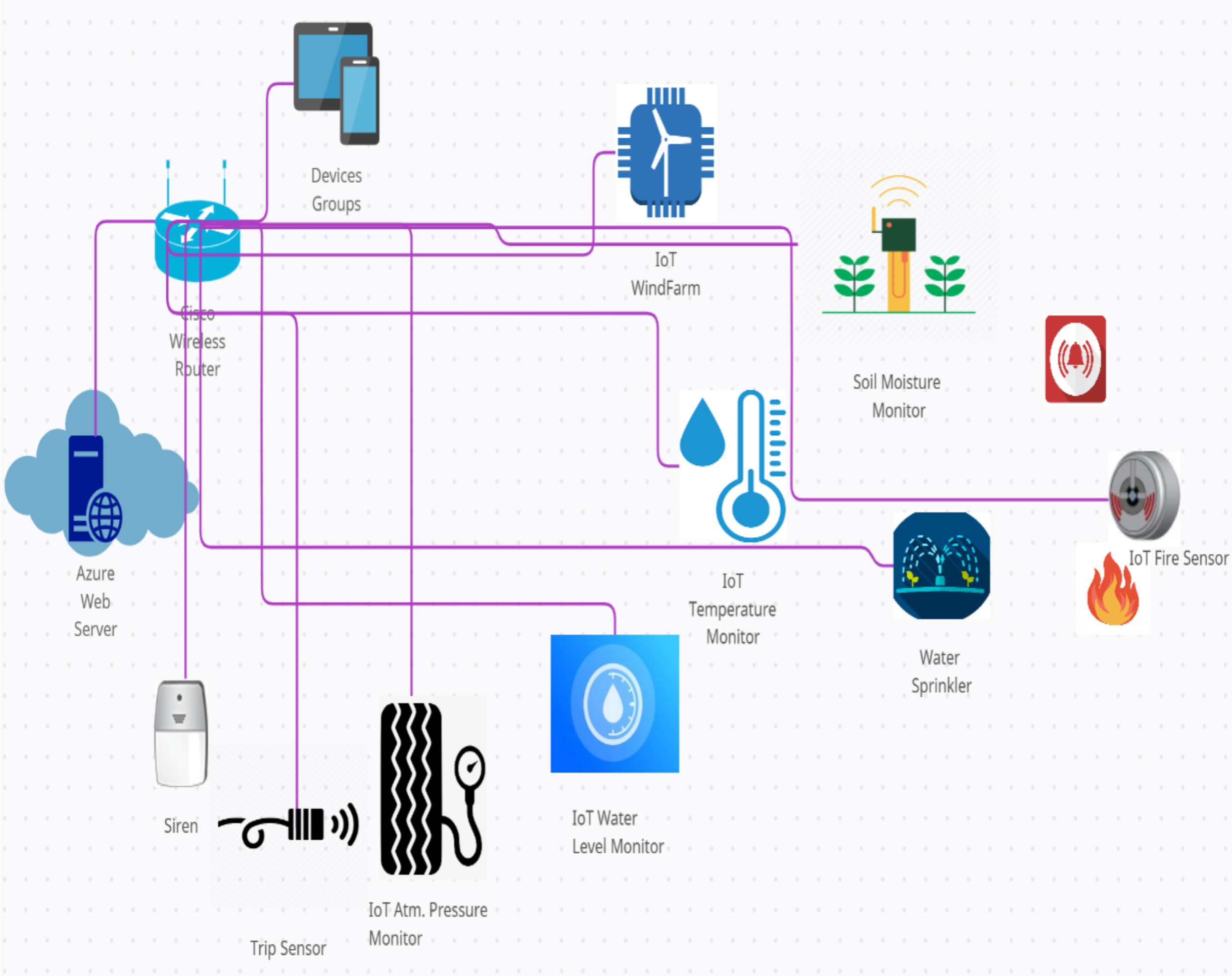

Figure 8. IoT framework in the farm field

4.3. Machine Learning Approach

Machine learning is an approach to data evaluation that automates analytical system development. It is a department of artificial intelligence-based totally on the concept that systems can study from data, perceive patterns and make choices/decisions/predictions with minimal human intervention. Successful farming comes down to recognizing the most powerful sections of land and harvests on a specific day. The present yield forecast advancements don't put together decisions exclusive with respect to chronicled information yet in addition use of computer software programming vision combined with shrewd climate investigation to meet the consistently developing farming interest. ML colossally affects the adequacy of yield arrangement and quality. IoT can be combined with machine learning algorithms to give effective results. Machine Learning algorithms like SVM (Support Vector Machine) and SVR (Support Vector Regression) with Radial basis function kernel, Random forest classifier and regression helps in predicting and classifying quantitative results for crop type, amount of water required for irrigation, soil type for variety of crops.

- **Support Vector Regression Algorithm:**

  Support Vector Regression is a supervised learning algorithm that is utilized to anticipate distinct values. Support Vector Regression utilizes a similar rule as the Support Vector Machines. The essential thought behind SVR is to locate the best fit line. In SVR, the befitting line is the hyperplane that has the most extreme number of points. Dissimilar to other Regression models that attempt to limit the blunder between the actual and predicted values, the SVR attempts to fit the most effective line inside a threshold value. The threshold value is the interval between the hyperplane and borderline. The analysis of Soil Moisture training dataset taken from kaggle is done and Support Vector Regression is applied on it to get the predicted values. The comparative study of various algorithms suggests that Support Vector Regression gives the accuracy approximately of 90.6%. Support Vector Regression is the correlation of SVM for regression problems. SVR recognizes the existence of non-linearity in the data and anticipates a effective prediction model. Smart farming with this machine learning algorithm will provide smooth flow of work for all kinds of different scales of farming. First soil moisture data will be collected from sensor then this algorithm will be applied on that provided data.

- **Implementing Support Vector Regression**

  Support Vector Regression (SVR) is implemented in python using Google Colab Notebook

```python
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
```

Figure10. Step 1: Importing the libraries

```python
dataset = pd.read_csv('/content/soil_moisture - Sheet1.csv')
X = dataset.iloc[:, 4].values
y = dataset.iloc[:, 5].values
y = np.array(y).reshape(-1,1)
```

Figure11. Step 2: Reading the dataset

```
from sklearn.preprocessing import StandardScaler
sc_X = StandardScaler()
sc_y = StandardScaler()
X = sc_X.fit_transform(X.reshape(-1,1))
y = sc_y.fit_transform(y.reshape(-1,1))
```

Figure12. Step 3: Feature Scaling

```
from sklearn.svm import SVR
regressor = SVR(kernel = 'rbf')
regressor.fit(X_train.reshape(-1,1), y_train.reshape(-1,1))
```

Figure13. Step 4: Fitting SVR to the dataset

```
y_pred = regressor.predict(X_test)
y_pred = sc_y.inverse_transform(y_pred)
y_pred

df = pd.DataFrame({'Real Values':sc_y.inverse_transform(y_test.reshape(-1)), 'Predicted Values':y_pred})
df
```

Figure14. Step 5. Predicting a new result

```
# Visualising the SVR results (for higher resolution and smoother curve)
X_grid = np.arange(min(X), max(X), 0.1)
X_grid = X_grid.reshape((len(X_grid), 1))
plt.scatter(sc_X.inverse_transform(X_test), sc_y.inverse_transform(y_test.reshape(-1)), color = 'cyan')
plt.scatter(sc_X.inverse_transform(X_test), y_pred, color = 'yellow')
ax= plt.axes()
ax.set_facecolor("black")
plt.title('SVR Regression For Soil Moisture')
plt.xlabel('MINUTES')
plt.ylabel('MOISTURE')
plt.show()

plt.plot(X_grid, regressor.predict(X_grid), color = 'deeppink')
ax= plt.axes()
ax.set_facecolor("black")
plt.title('SVR Regression For Soil Moisture')
plt.xlabel('MINUTES')
plt.ylabel('MOISTURE')
plt.show()
```

Figure15. Step 6. Visualizing the SVR results

- Random Forest Regression

  Random Forest Regression is a supervised learning algorithm that utilizes an ensemble-based learning paradigm for the regression approach. Ensemble learning is a technique that combines multiple several ML algorithms predictions to get extra precise predictions compared to any other single model. Random forest regression in order to obtain the result uses multiple Decision Trees. The comparative study of various algorithms suggests that Support Vector Regression gives the accuracy of approximately 92.49%.

  It follows the following steps:

  Step 1. Picking random K data points from the training set.

  Step 2. Put up a decision tree with respect to these K data points.

  Step 3. Select the number of trees needed to be created and then repeat the above steps.

  Step 4. For a new data point, make each of the selected number of trees to predict the values of the dependent variable for the provided inputs and assign that new point to the average value of the predicted values to the actual final result.

Smart agriculture with this machine learning algorithm will provide smooth progression of work to all sorts of various sizes of farming. First temperature data will be gathered from sensor then this calculation will be applied on Random Forest Regression algorithm for accurate predictions.

- Implementing Random Forest Regression

  Random Forest Regression is implemented in python using google colab notebook

```
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
```

Figure 16. Step 1: Importing the libraries

```
dataset = pd.read_csv('/content/temperature.csv')
X = dataset['Temperature'].values
y = dataset['Day'].values

dataset.head(8)
```

Figure 17. Step 2: Reading the dataset

```
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 0.6)

```

Figure18. Step 3: Split the dataset into the Training set and Test set

```
# Fitting Random Forest Regression to the dataset
from sklearn.ensemble import RandomForestRegressor
regressor = RandomForestRegressor(n_estimators = 10, random_state = 0)
regressor.fit(X_train.reshape(-1,1), y_train.reshape(-1,1))

```

Figure 19. Step 4: Fitting the Random Forest Regression to the dataset

```
y_pred = regressor.predict(X_test.reshape(-1,1))
y_pred

df = pd.DataFrame({'Real Values':y_test.reshape(-1), 'Predicted Values':y_pred.reshape(-1)})
df
```

Figure 20. Step 5: Predicting the Test set results

```
# # Visualising the Random Forest Regression Results
X_grid = np.arange(min(X), max(X), 0.01)
X_grid = X_grid.reshape((len(X_grid), 1))
plt.scatter(X_test, y_test, color = 'yellow')
plt.scatter(X_test, y_pred, color = 'red')
ax= plt.axes()
ax.set_facecolor("black")
plt.title('Random Forest Regression')
plt.xlabel('Temperature')
plt.ylabel('Day')
plt.show()

plt.plot(X_grid, regressor.predict(X_grid))
ax= plt.axes()
ax.set_facecolor("black")
plt.title('Random Forest Regression')
plt.xlabel('Temperature')
plt.ylabel('Day')
plt.show()
```

Figure 21. Step 6. Visualizing the results

5. Result

An intelligence-based farm monitoring model is developed in this proposed work which will provide precise and sustaining solutions to various epidemics like food shortage, economic crisis, food security etc. Internet of Things and Machine Learning algorithms such as SVM (Support Vector Machine) and SVR (Support Vector Regression) with Radial basis function kernel, Random Forest Regression provides in predicting, classifying of water level, atmosphere pressure, soil moisture, weather forecast, irrigation system. The analysis is done on training datasets obtained from "Kaggle" for Indian Agriculture production about farming information such as crop production in various states, particular crop rice production in Indian states, soil moisture, temperature. The Support Vector Regression algorithm is applied on the soil moisture data as follows are the results:

	Real Values	Predicted Values
0	0.52	0.682535
1	0.56	0.598449
2	0.84	0.674151
3	0.83	0.743037
4	0.51	0.627465
5	0.51	0.749360
6	0.54	0.560640

Figure 22. Data Frame of real and predicted values of SVR

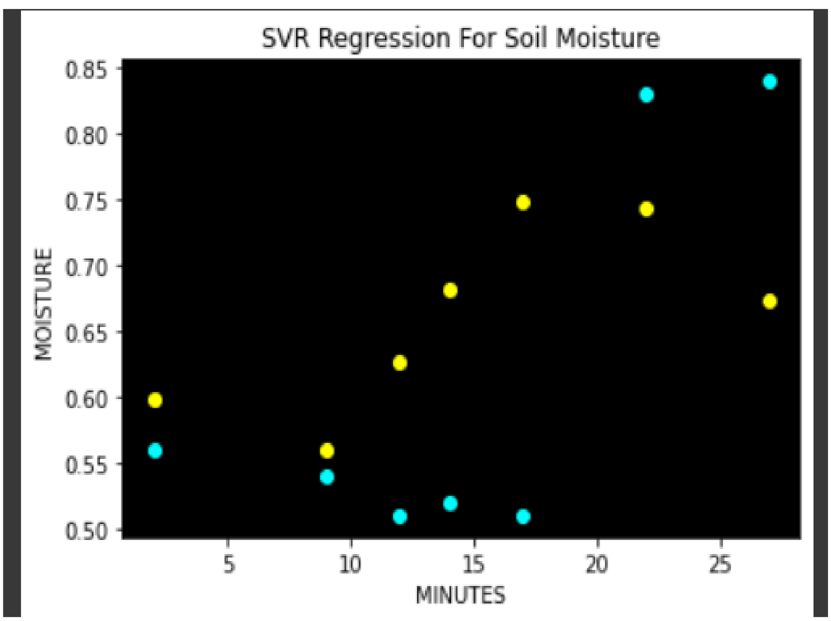

Figure 23. Cyan points are real values and yellow are predicted values

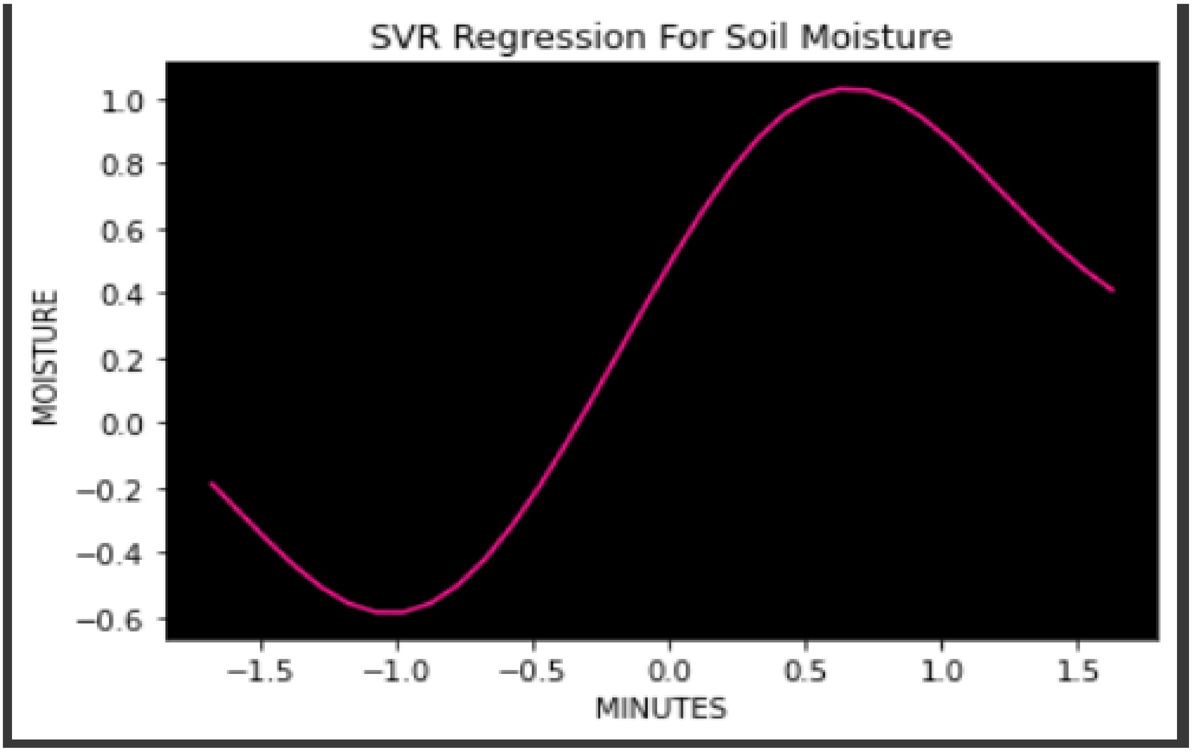

Figure 24. SVR curve

The Random Forest Regression algorithm is applied on the temperature dataset as follows are the results:

	Real Values	Predicted Values
0	23	25.9
1	20	22.4
2	21	22.4
3	18	22.4
4	25	25.9

Figure 24. Data Frame of real and predicted values of Random Forest Regression

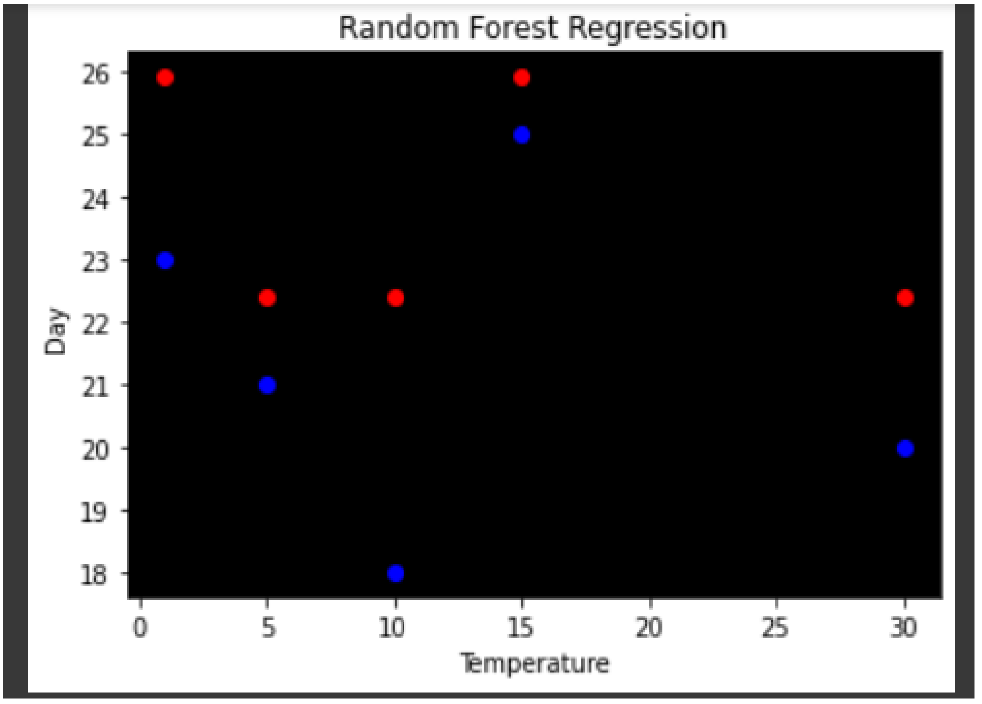

Figure 26. Blue points are real values and red are predicted values

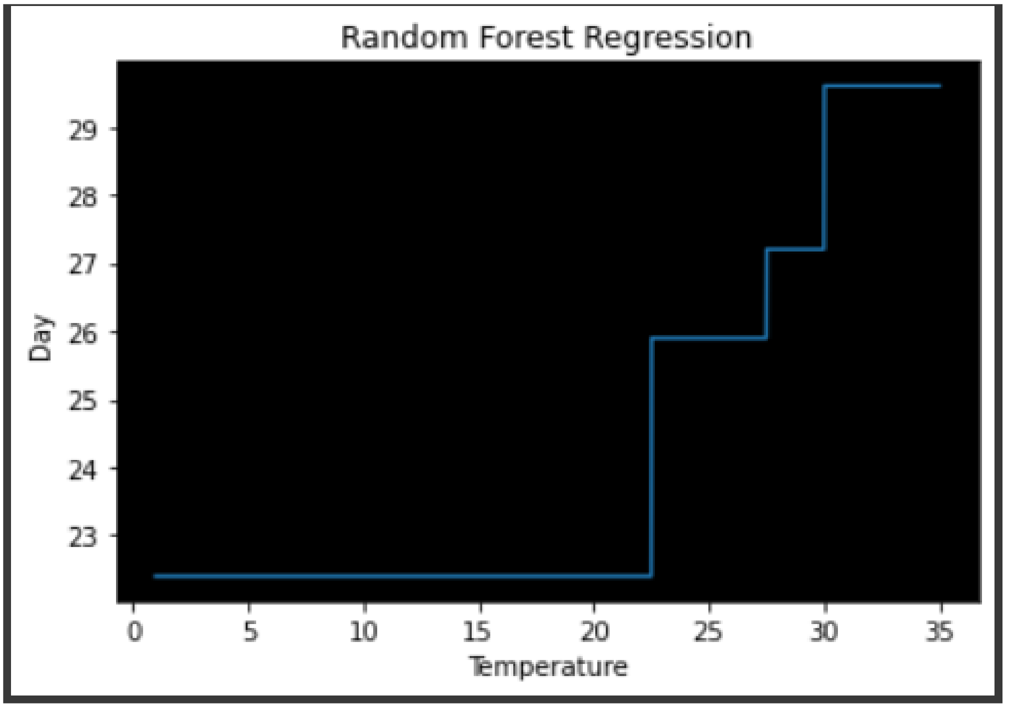

Figure 27. Random Forest Regression curve

6. Conclusion

This paper represents an economically efficient approach towards successful and powerful automated agriculture, or we can say agriculture 5.0, Smart Farming, Smart agriculture. It utilizes the Internet of Things and a Machine Learning-based approach to obtain the best effective outcomes of farming production. Sensor nodes are interconnected with each other to monitor the fields completely. Then the data is being collected and transferred to the cloud. From the cloud, the data is fetched, and then machine learning algorithms like SVM (Support Vector Machine) and SVR (Support Vector Regression) with Radial basis function kernel, Random Forest Regression are applied to predict and make accurate decisions for farm fields. Which results in very effective and efficient outcomes of farming. Therefore, smart agriculture is conceivable to convey a more profitable, sustainable, and manageable type of farming productions, based on ensemble learning giving more exact precise, and resource-efficient methodology.

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