

Predictive Analysis of Ambient Environment for Urban Cultivation using IoT based Hydroponic System

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Abstract—This paper tells about the best and optimum conditions in which one can grow crops using Hydroponic farming. For this work, we are growing coriander plant in a controlled environment with constant monitoring, the controlled environment being restricted water supply I.e Hydroponic farming. Various parameters like Soil pH, Moisture levels etc. are recorded on daily basis and made into a data set. This data set, then with the help of Supervised Machine Learning algorithms we are going to Co-Relate the data collected via IOT by the help of Regression Models, find the trends within the taken parameters and give an idea as to which conditions give a better yield.

Keywords— Controlled Environment, Hydroponic, Machine Learning Algorithms Supervised, Regression Models

I. INTRODUCTION

In a rapidly developing country like India, which has the world's highest growing GDP Urbanization is being seen in every nook and corner of the country. The difference between the population density of the cities and rural areas are very high. The population of the cities are growing exponentially every year, because of which the agricultural farms in and around the cities are being converted into residential sky scrapers. The need and demand for crops and food is growing up but the area to grow is going down. Due to this alarming scenario, hydroponic agriculture has risen in popularity and practice. It is a form of agriculture in which the plants are grown with restricted water supply.

Agriculture is India's principal employment and the backbone of the Indian economy. Agriculture, in addition to supplying food, gives job possibilities to rural people on a big scale in impoverished and emerging countries. It is the process of producing food, fibre and many other desired products by the cultivation and raising of domestic animals. Agriculture is a primary source of income for more than 58 percent of India's population.

As the population of the city grows significantly the need to feed the city heavily lays on the need of agricultural land. As most of the agriculture lands are dried up due to lack of water the need for starvation increases. Hence cities have to start cultivating crops and the need for automated farming in cities becomes crucial.

Climate changes will have a significant impact on agriculture by increasing water demand and limiting crop productivity in areas where irrigation is most needed. Some of the strategies established to create better crops that may not use water effectively include irrigation systems, rain fed agriculture, and groundwater irrigation. A smart system is intended to use water effectively.. In the system farmers need not make the water flow into fields manually, but the system automatically does that efficiently.

People's traditional practises of water conservation may result in massive water waste. As a result, the notion of robotized farming with a combination of IoT has emerged. Technological developments began to significantly boost manufacturing efficiency, resulting in a dependable system. The understanding of soil qualities causes the water supply to be driven in an intelligent manner. Agriculture practised wisely aids in the acquisition of understanding about soil and temperature conditions. Developing smart agriculture employing IoT-based devices not only boosts output but also reduces water waste.

II. BACKGROUND

Hydroponic farming is heavily dependent upon the water retention. The limited amount of water available will be retained with the help of a special soil mixture provided whose key role is to maintain the water level without losing the soil moisture.

A lot of work has already been done on the aspect of hydroponic farming. We have gone through various papers and found the following drawbacks and concepts.

Feature Selection has not yet been used in the creation of the machine learning model in this study. As a result, the outcome was less than satisfactory. The lettuce was standing straight one day and swaying to the side the next due to the blowing wind. Other errors were influenced by the amount of sunlight and temperature on that particular day. A lot of sunlight causes the plant to wither and unfold. When measured on a day with less sunlight and temperature, the width is smaller than when measured on a day with more sunlight and temperature.[4] Finally, these flaws caused the model to fail to produce a good learning result.

This work focuses on a model which maintains soil moisture level which is optimum for the crop growth.

This level of soil moisture will be maintained constantly for the next 24 hours with no impact and consideration of the weather condition. This work also talks about smart irrigation system which helps in apt water management and provides ideal crop suggestions based on historic soil data.

This work also provides the type and quantity of various minerals needed.[9] This work does not talk about the plant diseases, this can further be extended so as to detect diseases and automated dispersal of pesticides and insecticides.

This work emphasizes on the importance of IoT based technologies in agriculture. This paper works on the use of Low-Power Wide-Area Network(LPWAN) to reduce the power consumption and increasing the wireless range by eliminating the unnecessary dependency of third party and backhaul networks. It also describes the comparisons between Coverage Range, Quality of Service, Battery Life, Latency, Scalability, Payload Length and Development model between LPWAN technologies. The only major drawback of the paper is the maintenance the LPWAN requires to keep it running as the technology used won't have the ideal conditions to run in an agricultural setup even though the batter life and power consumption are ideal.[7]

Multi-Level IOT framework, which uses Application Layer, Internet Layer, Sensor and Actuator Framework along with Distribution middleware and follows MQTT protocol. In the output, the End User Experiences VPS interaction in one aspect and in the other aspect, it uses VPS and Local Server Interaction. This works falls back in implementing limiting factors such as nitrate, nitrate and ammonia via the electronic sensors. Automated data collection can be implemented into this work so that the system can function with better efficiency and maybe it could send alerts to the sender if there is any change or drastic changes in the parameters.[1]

The paper focuses on five main concepts, namely Hydroponics, Need for Automation Control, Climate Statistics, Data Analytics and Cloud, Proposed System. The sensors record analog Data through Hydroponic system with the help of MCP 3008 ADC. This work acts as an eye mainly to farmers but this technology can sometimes act more of an ban than a boon for the farmers. This work is done solely done on the famer end so, it can be implemented in other factors as well[2].

III. SYSTEM ARCHITECTURE

A. Hydroponic Farming

In the present fast pace world, the form of hydroponic farming is taking over. The ongoing research paved new ways and paths for a better and substantial way of farming. Noticing the ways and researching the present trends, mainly followed in metropolitan cities and technologically advanced countries makes lives a lot easier in terms of hydroponic farming.

The work done by us addresses the key issues of automation and IoT integration into the way of sustainable farming in constraints such as limited water supply and space.

B. Necessity for automation

The work being done needs constant monitoring as various sensors are used in an confined and controlled

environment. As pre-processing homo sapiens , we tend to make unavoidable errors in our work. To avoid such mistakes that in other ways cannot be avoided, automation is the way.

With the help of Arduino , ESp 8266 and aurd Spread Sheet the reading from the sensors are directly stored into the spreads sheet with almost no error. The readings are recorded once every 10 minutes which without automation requires a immense amount of man power which intern may lead to loss or errors in recorded results.

C. Climate Maintained

Farming mainly depends on ambient climatic conditions but the city environment is not suitable for the growth of crops in the traditional way.

For our work as we targeted the metropolitan cities we made sure that the temperature rage varied from 28 degree Celsius to 36 degree Celsius. In hydroponic farming, the crops are not exposed to sunlight throughout. Rather than exposing them to sunlight throughout, we made sure that an adequate sunlight was available which in the day reaches approximately 240 candela and in the night for the integrity of the results, we made sure no light from any source was available which resulted in 0 candela.

Speaking about the soil moisture, for better understating of the impact of moisture retention of the soil we grew the crops in early summer because of which there is humidity in the air than normal. The humidity varied from 40 percent to 80 percent which is the normal range in a coastal city.

TABLE 1
Range of Parameters Full Phase of crop growth

PARAMETER	MAX	MIN
PH	27.13	6.68
LUMINOUS INTENSITY	226	0
HUMIDITY	82.5	47.8
TEMPERATURE	38.6	25.7
SOIL MOISTURE	687	579
WATER LEVEL	731	153

TABLE 2
Range of Parameters Initial Phase of crop growth

PARAMETER	MAX	MIN
PH	27.13	6.68
LUMINOUS INTENSITY	226	0
HUMIDITY	82.5	47.8
TEMPERATURE	38.6	25.7
SOIL MOISTURE	687	579
WATER LEVEL	731	153

TABLE 3
Range of Parameters Growing Phase of crop growth

PARAMETER	MAX	MIN
PH	12.59	0
LUMINOUS INTENSITY	220	0
HUMIDITY	72.7	43.6
TEMPERATURE	36.3	27.7

SOIL MOISTURE	685	676
WATER LEVEL	661	272

TABLE 4

Range of Parameters Harvesting Phase of crop growth

PARAMETER	MAX	MIN
PH	27.13	6.68
LUMINOUS INTENSITY	226	0
HUMIDITY	82.5	47.8
TEMPERATURE	38.6	25.7
SOIL MOISTURE	687	579
WATER LEVEL	731	153

D. Data Analysis

All the information collected from the sensors is stored in the personal systems directly rather than cloud as cloud is heavily dependent upon an uninterrupted internet connection which sometimes may not be possible.

The data collected is stored and processed with the help of python to create results which help in better understanding of the data.

E. Proposed System

An innovative form of hydroponic farming is used. A coco pit is used as an soil replacement as the water retention capacity is much higher in this compared to general soil. The coco pit is connected to water supply which is regulated. Six different sensors are connected to the system. The sensors being, pH sensor which monitors the pH of the water in the coco pit. The water in coco pit pH initially at the time of laying it down was 6.5. The second sensor used is Luminous Intensity Sensor. This sensor monitors the amount of luminescence around the setup. The third sensor is Humidity sensor, this sensor monitors the humidity in the surroundings of the setup. Next sensor used was temperature sensor, this sensor monitors the temperature of the surroundings. The fifth sensor used was soil moisture sensor, this sensor measured the amount of moisture in coco pit throughout the experiment. The final sensor used is water level sensor, this sensor measures the amount of water provided to the system daily. The seeds used were coriander seeds as they take less time to grow which afforded us a chance to cross verify the results by repeating the experiment.

IV. EXPERIMENTAL PROCESS

According to the proposed system, the experiment is designed in such a way that it is a prototypical implementation. The design procedures are explained with a block Diagram.

A. Block Diagram

In the following proposed system, the analogue and digital sensors collect information from the hydrophonic setup. With the help of Arduino Mega 2560 data is send to spreadsheet in a very smooth and effective manner. The data is collected and saved in database using a wifi module. The block figure is represented for the proposed system.

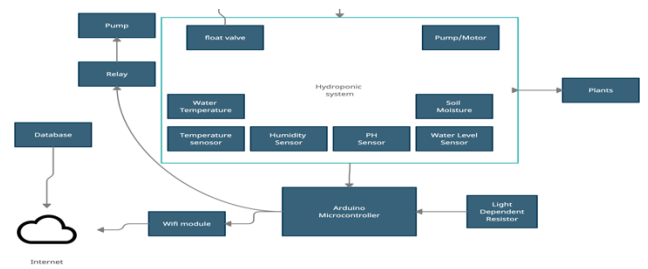


Figure 1. Block diagram of proposed Hydroponic system

Major Steps explained in proposed system is mentioned as flow chart.

B. Circuit diagram and components

The proposed circuit is created in such a way that the cost of components is economical and also the quality the components is not comparamised and also the performance of the components are very good.

The Major components involved in proposed system are:

- Arduino Mega 2560
- Temperature sensor (DHT-22)
- Humidity Sensor (DHT-22)
- Water Level Sensor
- Soil Moisture Sensor
- PH Sensor
- Luminous Intensity Sensor
- WIFI module (ESP 8266)
- Breadboard
- Jumper wires
- Pump
- Water Tube
- 5V motor
- 5V power supply

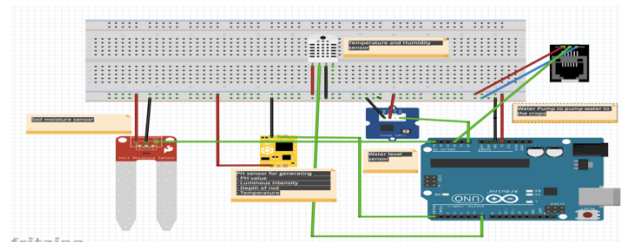


Figure 2: Circuit diagram of proposed Hydroponic System

V. DATASET ANALYSIS

A. Variation of PH with respect to time

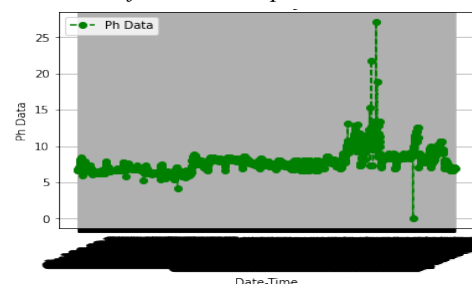


Figure 3. Time series Analysis of PH

Fig: 9 shows the pH values of the water through the experiment. The minimum value recorded is 5.5 on the ph scale and this was recorded during the Initial phase of the experiment. The maximum recorded is 13 and it was recorded during the growth phase due to the addition of mineral water to the water supply, it became more basic. After the growth phase we supplied general water again so, the pH dropped gradually making it more neutral.

B. Variation of Sunlight with respect to time

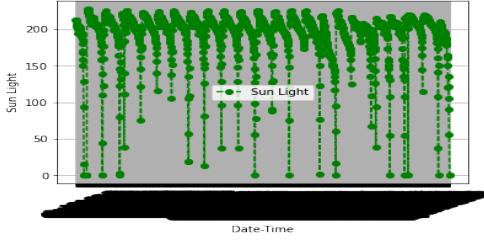


Figure 4. Time series Analysis of Luminous Intensity/ Sunlight for plant

Fig: 10 depicts the Luminous intensity on candle scale over the whole duration of the experiment. The least recorded is Zero as during the night, it is made sure that the experimental setup is not exposed to any form of light energy. The highest value recorded is around 250 candela during the day.

C. Variation of Humidity with respect to time

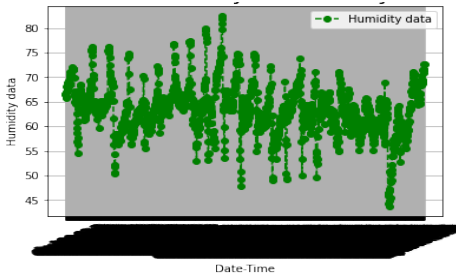


Figure 5. Time series Analysis of Humidity

Fig 11: shows the humidity in the surroundings of the setup. As the experiment setup was in a coastal city, the humidity is relatively high but is under the normal humidity levels for the city. The lowest recoded is 45% and the highest is around 80%. To make sure that the humidity level doesn't go overboard, we conducted the experiment during early summer.

D. Variation of Temperature with respect to time

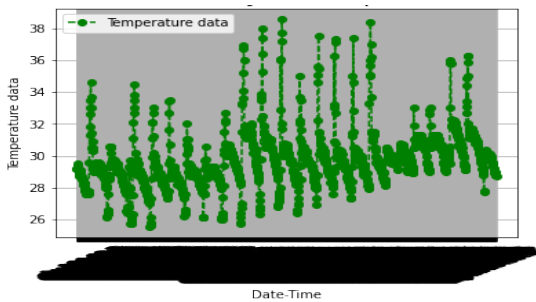


Figure 6. Time series Analysis of Temperature

Fig 12: represents the Temperature of the surroundings throughout the experiment. The temperature kept on raising during the experiment gradually. The lowest recoded temperature was 26degree Celsius and highest was 36degree Celsius. The lowest average temperature was during the initial phase and the highest average was during the harvesting phase.

E. Variation of Soilmoisture with respect to time

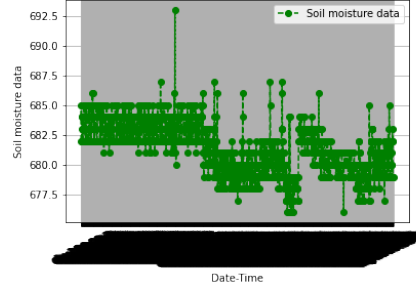


Figure 7. Time series Analysis of Soil Moisture

Fig: 13 shows the moisture in the coco pit during the experiment timeline. During the initial phase the moisture level was between 682-686. The moisture level was highest during the growth phase which ranges between 680-692. The moisture level during the harvest phase is lowest in terms of average, its range varies from 676-680.

F. Variation of Water Level with respect to time

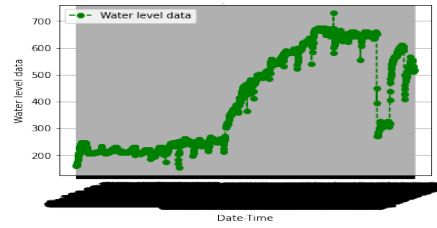


Figure 8. Time series Analysis of Water Level

Fig: 14 depicts the water level in the experiment. The water level gradually increases till the growth phase and decreases there on. The water level during the initial phase was between 160 and 240ml, during growth phase it is between 200ml and 650ml. During the harvest phase, the water level required is low, it ranges from 200-500ml.

VI. RESULT AND DISCUSSION

The main objective of the result is to correlate the various parameters of the experiments with the help of four evaluation parameters, namely

- Mean Absolute Error (MAE)
- Root Mean Square Error (MASE)
- Root Mean Square Log Error (RMSE)
- R Squared(R2)

The lower the value of MAE, the more the parameters are correlated. The R2 specifies the error in the calculations I,e the lesser the value of R2, the better the correlation is.

A. Predictive Analysis of parameters using Linear Regression

TABLE 5

Linear Regression Between Parameters for Initial Phase of Coriander Plant Growth

PARAMETER VS PARAMETER	PH	SUNLIGHT	HUMIDITY	TEMPERATURE	SOILMOISTURE	WATER LEVEL
PH	X	MAE=26.54 MASE=1702.59 RMSE=41.26 R2=0.00288	MAE=3.13 MASE=17.055 RMSE=4.12 R2=0.03718	MAE=0.9522 MASE=2.0584 RMSE=1.43474 R2=0.003785	MAE=0.9161 MASE=1.1950 RMSE=1.0931 R2=0.011836	MAE=11.9423 MASE=233.031 RMSE=15.265 R2=0.0039
SUNLIGHT		X	MAE=2.9133 MASE=16.551 RMSE=4.0683 R2=0.0650	MAE=0.7492 MASE=1.126 RMSE=0.145 R2=0.145	MAE=0.902 MASE=1.160 RMSE=1.077 R2=0.0417	MAE=1.088 MASE=8.1521 RMSE=0.78 R2=0.078
HUMIDITY			X	MAE=0.831 MASE=1.205 RMSE=1.097 R2=0.517	MAE=0.875 MASE=1.06 RMSE=1.033 R2=0.0056	MAE=9.843 MASE=174.68 RMSE=13.2 R2=0.0941
TEMPERATURE				X	MAE=0.9160 MASE=1.190 RMSE=1.090 R2=0.012	MAE=9.714 MASE=168.86 RMSE=12.9 R2=0.087
SOILMOISTURE					X	MAE=11.21 MASE=229.2 RMSE=15.16 R2=0.0049
WATER LEVEL						X

From Table 5, it can be inferred that water level and pH are the most correlated parameters in the initial phase of the experiment as MAE=0.339. This means, with a given Water Level, we can predict the value of pH required for a good yield. The parameters that cannot be correlated are pH and Sunlight as the MAE=26.54, this means that the value of Luminous intensity cannot be predicted with the pH level.

TABLE 6

Linear Regression Between Parameters for Growing Phase of Coriander Plant Growth

PARAMETER VS PARAMETER	PH	SUNLIGHT	HUMIDITY	TEMPERATURE	SOILMOISTURE	WATER LEVEL
PH	X	MAE=21.157 MASE=1228.4 RMSE=35.04 R2=0.0048	MAE=3.400 MASE=21.32 RMSE=4.618 R2=0.0108	MAE=1.155 MASE=3.1804 RMSE=1.783 R2=0.0061	MAE=1.6315 MASE=3.9975 RMSE=1.999 R2=0.0096	MAE=136.46 MASE=23789.17 RMSE=154.2 R2=0.1199
SUNLIGHT		X	MAE=3.309 MASE=20.457 RMSE=4.522 R2=0.194	MAE=1.010 MASE=2.544 RMSE=1.595 R2=0.1704	MAE=1.556 MASE=3.836 RMSE=1.917 R2=0.0247	MAE=1.562 MASE=3.678 RMSE=1.917 R2=0.033
HUMIDITY			X	MAE=0.943 MASE=1.686 RMSE=1.298 R2=0.5603	MAE=1.6009 MASE=3.845 RMSE=1.96 R2=0.00245	MAE=134.715 MASE=24155.87 RMSE=155.42 R2=0.1037
TEMPERATURE				X	MAE=1.780 MASE=4.511 RMSE=2.123 R2=0.0042	MAE=142.16 MASE=25289.25 RMSE=159.02 R2=0.0057
SOILMOISTURE					X	MAE=130.00 MASE=23137.31 RMSE=152.109 R2=0.0110
WATER LEVEL						X

From Table 6, it can be inferred that temperature and pH are the most correlated parameters in the growth phase of the experiment as MAE=0.8932. This means, with a given

temperature, we can predict the value of pH required for a good yield. The parameters that cannot be correlated are temperature and water level as the MAE=142.16, this means that the value of Water level cannot be predicted with a given temperature.

TABLE 7

Linear Regression Between Parameters for Harvesting Phase of Coriander Plant Growth

PARAMETER VS PARAMETER	PH	SUNLIGHT	HUMIDITY	TEMPERATURE	SOILMOISTURE	WATER LEVEL
PH	X	MAE=22.68 MASE=102.7818 RMSE=32.0 R2=0.020	MAE=4.58 MASE=33.367 RMSE=5.7 R2=0.154	MAE=0.906 MASE=1.835 RMSE=1.36 R2=0.0653	MAE=1.1328 MASE=1.821 RMSE=1.349 R2=0.032	MAE=100.54 MASE=15723.309 RMSE=125.392 R2=0.05177
SUNLIGHT		X	MAE=0.9 MASE=731 MASE=1.421 RMSE=1.192 R2=0.0967	MAE=0.7630 MASE=1.645 MASE=1.282 RMSE=0.2184	MAE=0.945 MASE=1.470 RMSE=1.212 R2=0.0047	MAE=1.0651 MASE=1.972 RMSE=1.404 R2=0.00676
HUMIDITY			X	MAE=0.725 MASE=1.277 RMSE=1.130 R2=0.290	MAE=1.008 MASE=1.796 RMSE=1.340 R2=0.01474	MAE=108.25 MASE=14820.36 RMSE=121.738 R2=0.207
TEMPERATURE				X	MAE=1.130 MASE=2.060 RMSE=1.435 R2=0.00103	MAE=111.24 MASE=16898.54 RMSE=129.99 R2=0.02605
SOILMOISTURE					X	MAE=105.00 MASE=16357.032 RMSE=127.894 R2=0.004
WATER LEVEL						X

From Table 7, it can be inferred that humidity and temperature are the most correlated parameters in the harvesting phase of the experiment as MAE=0.723. This means, with a given humidity level, we can predict the temperature required for a good yield. The parameters that cannot be correlated are temperature and water level as the MAE=111.24, this means that the value of Water level cannot be predicted with a given temperature.

TABLE 8

Linear Regression Between Parameters for Full Phase of Coriander Plant Growth

PARAMETER VS PARAMETER	PH	SUNLIGHT	HUMIDITY	TEMPERATURE	SOILMOISTURE	WATER LEVEL
PH	X	MAE=23.313 MASE=1591.0 RMSE=39.88 R2=0.00118	MAE=3.9601 MASE=27.93 RMSE=5.285 R2=0.00598	MAE=1.210 MASE=3.0650 RMSE=1.750 R2=0.0599	MAE=1.8210 MASE=4.899 RMSE=2.213 R2=0.0378	MAE=137.684 MASE=22732.459 RMSE=150.772 R2=0.2893
SUNLIGHT		X	MAE=1.036 MASE=2.128 RMSE=1.459 R2=0.000246	MAE=1.147 MASE=2.604 RMSE=1.613 R2=0.185	MAE=1.921 MASE=5.188 RMSE=2.277 R2=0.0118	MAE=1.8404 MASE=4.6457 RMSE=2.155 R2=0.0026
HUMIDITY			X	MAE=0.929 MASE=1.478 RMSE=1.216 R2=0.375	MAE=1.811 MASE=4.672 RMSE=2.161 R2=0.023	MAE=165.664 MASE=31591.99 RMSE=159.9199 R2=0.02649
TEMPERATURE				X	MAE=1.658 MASE=4.024 RMSE=2.006 R2=0.0590	MAE=166.6700 MASE=31745.51 RMSE=176.172 R2=0.0422
SOILMOISTURE					X	MAE=125.65 MASE=22858.07 RMSE=151.18 R2=0.288

WATER LEVEL	MAE= 0.850 8 RMSE=1.23 R2=0.2719	MAE= 23.489 MASE= 1536.91 RMSE= 39.20 R2= 0.0056	MAE= 3.864 MASE= 28.33 RMSE= 5.322 R2= 0.0916	MAE=1.185 MASE=2.916 RMSE=1.707 R2=0.0823	MAE=1.451 MASE=3.329 RMSE= 1.824 R2= 0.3089	X
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From Table 8, it can be inferred that water level and pH are the most correlated parameters in the full phase analysis of the experiment as MAE=0.850. This means, with a given water level, we can predict the pH required for a good yield. The parameters that cannot be correlated are temperature and water level as the MAE=166.67, this means that the value of Water level cannot be predicted with a given temperature.

B. Predictive Analysis of parameters using Support Vector Regression

TABLE 9

Support Vector Regression Between Parameters for Initial Phase of Coriander Plant Growth

PARAMETER VS PARAMETER	PH	SUNLIGHT	HUMIDITY	TEMPERATURE	SOILMOISTURE	WATER LEVEL
PH	X	MAE=22.10 2 MASE=2351.64 RMSE=48.4 93 R2=0.0852	MAE=2.9432 MASE=15.3 63 RMSE=3.91 9 R2=0.2227	MAE=0.8280 2 MASE=1.598 RMSE=1.264 2 R2=0.0446	MAE=0.8612 MASE=1.423 RMSE=1.193 R2=0.174	MAE=10.6116 MASE=218.732 RMSE=14.789 R2=0.0377
SUNLIGHT	MAE=0.346 0 MASE=0.227 RMSE=0.4766 R2= -0.0458	X	MAE=2.836 MASE=13.7 70 RMSE=3.710 9 R2=0.294	MAE=0.518 MASE=0.825 RMSE=0.933 R2=0.450	MAE=0.8686 MASE=1.627 RMSE=1.167 R2=0.120	MAE=0.989 MASE=169.0 RMSE=1.275 R2=0.225
HUMIDITY	MAE=0.310 MASE=0.174 RMSE=0.417 R2=0.275	MAE=17.27 MASE=1259.47 RMSE=35.48 R2=0.0078	X	MAE=0.683 MASE=0.825 RMSE=0.933 R2=0.3423	MAE=0.833 MASE=1.378 RMSE=1.174 R2= -0.057	MAE=9.329 MASE=13.00 RMSE=31 R2=0.0302
TEMPERATURE	MAE=0.396 MASE=0.3 17 RMSE=0.563 R2=0.0075	MAE=13.68 MASE=1172.59 RMSE=34.2 4 R2=0.2142	MAE=2.742 MASE=11.7 37 RMSE=3.42 5 R2=0.466	X	MAE=0.842 MASE=1.325 RMSE=1.151 R2=0.1610	MAE=7.9547 MASE=137.1 81 RMSE=11.71 3 R2=0.25006
SOILMOISTURE	MAE=0.348 MASE=0.199 RMSE=0.4461 R2= -0.0110	MAE=20.96 2 MASE=2052.051 RMSE=45.299 R2=0.0695	MAE=3.7415 MASE=23.2 97 RMSE=4.82 67 R2=0.0293	MAE=0.886 MASE=1.852 RMSE=1.361 R2=0.1329	X	MAE=8.9695 MASE=161.8 012 RMSE=12.701 R2= -0.00836
WATER LEVEL	MAE=0.359 MASE=0.2 667 4 R2=0.0892	MAE=23.2524 MASE=2417.059 RMSE=49.1636 R2=0.0059	MAE=2.9750 MASE=16.4 40 RMSE=4.05 465 R2=0.02438	MAE=1.0000 6 MASE=2.702 94 RMSE=1.644 0 R2=0.1164	MAE=0.7492 MASE=1.080 1.0396 R2= -0.1662	X

From Table 9, it can be inferred that humidity and pH are the most correlated parameters in the initial phase of the experiment as MAE=0.310. This means, with a given humidity level, we can predict the pH required for a good yield. The parameters that cannot be correlated are water level and sunlight as the MAE=23.025, this means that the value of Water level cannot be predicted with a given luminous intensity.

TABLE 10

Support Vector Regression Between Parameters for Growing Phase of Coriander Plant Growth

PARAMETER VS PARAMETER	PH	SUNLIGHT	HUMIDITY	TEMPERATURE	SOILMOISTURE	WATER LEVEL
PH	X	MAE=17.013 MASE=1014.28 RMSE=31.8 4 R2=0.0743	MAE=3.800 3 MASE=25.3 6 RMSE=5.03 61 R2=0.0470	MAE=0.995 MASE=2.330 RMSE=1.526 6 R2=0.1112	MAE=1.638 MASE=4.429 RMSE=2.104 6 R2=0.0109	MAE=120.94 MASE=24176.55 RMSE=155.48 R2=0.026
SUNLIGHT	MAE=1.00 5 MASE=4.719 RMSE=2.172 R2= -0.0719	X	MAE=3.602 MASE=23.9 74 RMSE=5.89 6 R2=0.1506	MAE=0.802 MASE=1.444 RMSE=1.201 9 R2=0.430	MAE=1.8199 MASE=4.053 6 RMSE=2.013 R2=0.0220	MAE=139.69 8 MASE=29287.10 RMSE=29.71 34 R2=0.1414
HUMIDITY	MAE=0.82 2 MASE=1.8 79 RMSE=1.370 R2=0.0892	MAE=17.210 MASE=1090.04 RMSE=33.0 15 R2=0.0421	X	MAE=0.745 MASE=0.988 RMSE=0.979 R2=0.7400	MAE=1.749 MASE=4.602 RMSE=2.145 3 R2=0.0295	MAE=134.73 9 MASE=2457.95 RMSE=156.7 09 R2=0.0675
TEMPERATURE	MAE=0.83 9 MASE=1.9	MAE=18.473 MASE=1451.83	MAE=2.618 MASE=11.7 8	X	MAE=1.564 MASE=3.69	MAE=139.68 MASE=26889.48

	34 RMSE=1.3 91 R2= -0.0447	RMSE=38.1 02 R2=0.1318	RMSE=3.43 R2=0.572		RMSE=1.922 R2=0.0255	RMSE=163.9 80 R2=0.00359
SOILMOISTURE	MAE=0.886 MASE=2.831 RMSE=1.6 82 R2= -0.037	MAE=18.183 MASE=1149.82 RMSE=33.909 R2=0.0549	MAE=4.1329 MASE=30.3 2 RMSE=5.5005 R2=0.0070	MAE=1.1566 MASE=3.419 RMSE=1.84 R2=0.0083	X	MAE=136.77 5 MASE=24782.89 RMSE=157.4 2 R2=0.0698
WATER LEVEL	MAE=0.58 68 MASE=1.5 42 RMSE=1.2 41 R2=0.3133	MAE=17.654 MASE=1008 RMSE=31.7 50 R2=0.04008	MAE=3.581 MASE=24.3 RMSE=4.93 0 R2=0.1196	MAE=1.176 MASE=3.361 RMSE=1.83 R2=0.0380	MAE=1.2847 MASE=2.611 RMSE=1.616 R2=0.368	X

From Table 10, it can be inferred that water level and pH are the most correlated parameters in the growth phase of the experiment as MAE=0.586. This means, with a given water level, we can predict the pH required for a good yield. The parameters that cannot be correlated are temperature and water level as the MAE=139.68, this means that the value of Water level cannot be predicted with a given temperature.

TABLE 11

Support Vector Regression Between Parameters for Harvesting Phase of Coriander Plant Growth

PARAMETER VS PARAMETER	PH	SUNLIGHT	HUMIDITY	TEMPERATURE	SOILMOISTURE	WATER LEVEL
PH	X	MAE=14.519 MASE=1121.40 RMSE=33.48 7 R2=0.055	MAE=3.75 0 MASE=23.179 RMSE=4.8 14 R2=0.2572	MAE=0.8486 MASE=1.720 9 RMSE=1.311 R2=0.0536	MAE=1.2121 MASE=2.518 RMSE=1.586 R2=0.0438	MAE=109.77 MASE=21901.17 RMSE=147.99 R2=0.1792
SUNLIGHT	MAE=0.975 MASE=1.782 RMSE=1.334 R2=0.0502	X	MAE=3.642 MASE=23.84 RMSE=4.883 R2=0.2922	MAE=0.5587 MASE=0.9602 RMSE=0.979 R2=0.537	MAE=1.033 MASE=1.731 RMSE=1.315 R2=0.109	MAE=110.02 MASE=21459.37 RMSE=146.49 R2=0.334
HUMIDITY	MAE=0.733 MASE=1.0 997 RMSE=1.0 487 R2=0.1170	MAE=15.693 MASE=1416.608 RMSE=37.63 7 R2=0.1004	X	MAE=0.6907 MASE=1.549 RMSE=1.244 R2=0.144	MAE=1.197 MASE=2.227 RMSE=1.492 R2= -0.087	MAE=112.208 MASE=21545.41 RMSE=146.78 3 R2=0.1230
TEMPERATURE	MAE=0.848 MASE=1.3 07 RMSE=1.143 R2=0.0404	MAE=7.830 MASE=209.7 4 RMSE=14.48 2 R2=0.491	MAE=2.66 4 MASE=13.02 RMSE=3.6 R2=0.3560	X	MAE=0.9160 MASE=1.190 RMSE=1.090 R2=0.012	MAE=103.405 MASE=18617.395 RMSE=136.44 5 R2=0.0513
SOILMOISTURE	MAE=0.908 MASE=1.5 76 RMSE=1.2 55 R2=0.0711	MAE=14.502 MASE=1074.906 RMSE=32.78 5 R2=0.0437	MAE=4.89 2 MASE=38.307 RMSE=6.1 89 R2=0.0917	MAE=1.027 MASE=2.190 RMSE=1.480 R2=0.0648	X	MAE=117.428 MASE=22258.28 RMSE=149.19 2 R2=0.1749
WATER LEVEL	MAE=0.868 MASE=2.4 79 RMSE=1.5 74 R2=0.069	MAE=13.670 MASE=525.3 105 RMSE=22.91 9 R2= -0.1050	MAE=3.9546 MASE=25.5 84 RMSE=4.79 42 R2=0.0380	MAE=0.785 MASE=1.084 RMSE=1.041 R2=0.011	MAE=0.9191 MASE=1.329 RMSE=1.041 1.152 R2=0.298	X

From Table 11, it can be inferred that sunlight and temperature are the most correlated parameters in the harvesting phase of the experiment as MAE=0.558. This means, with a given luminous intensity, we can predict the temperature required for a good yield. The parameters that cannot be correlated are soil moisture and water level as the MAE=117.428, this means that the value of Water level cannot be predicted with a soil moisture.

TABLE 12

Support Vector Regression Between Parameters for Full Phase of Coriander Plant Growth

PARAMETER VS PARAMETER	PH	SUNLIGHT	HUMIDITY	TEMPERATURE	SOILMOISTURE	WATER LEVEL
PH	X	MAE=18.38 MASE=1347.984 RMSE=36.71 R2= -0.0432	MAE=3.538 MASE=22.9 84 RMSE=4.79 42 R2=0.0380	MAE=1.002 MASE=2.368 RMSE=1.539 R2=0.189	MAE=1.506 MASE=3.971 RMSE=1.992 R2=0.1733	MAE=127.77 MASE=22839.3 RMSE=151.12 R2=0.298
SUNLIGHT	MAE=0.943 0 MASE=2.927 RMSE=1.7 11 R2= -0.00975	X	MAE=3.621 MASE=23.651 RMSE=4.8632 R2=0.21483	MAE=1.111 MASE=2.539 RMSE=1.593 R2=0.3130	MAE=1.9406 MASE=5.305 RMSE=2.303 R2=0.0322	MAE=162.01 3 MASE=31499.0 RMSE=177.4 79 R2=0.0218
HUMIDITY	MAE=0.903 9 MASE=1.6 890 RMSE=1.2 98 R2=0.0062	MAE=18.206 6 MASE=1258.105 RMSE=35.46 9 R2=0.0738	X	MAE=0.974 MASE=1.814 RMSE=1.3470 R2=0.486	MAE=1.715 MASE=4.422 RMSE=2.102 R2=0.0019	MAE=161.61 MASE=3018 1.06 RMSE=173.7 2 R2=0.057

TEMPERATURE	MAE=0.898 MASE=2.7 85 RMSE=1.668 R2=0.0656	MAE=18.518 MASE=1583. 68 RMSE=39.10 9 R2=0.115	MAE=2.86 MASE=13.6 1 RMSE=3.68 9 R2=0.4670	X	MAE=1.609 MASE=4.139 RMSE=2.034 R2=0.0995	MAE=136.56 7 MASE=2616 9.03 RMSE=161.7 6 R2=0.148
SOILMOISTURE	MAE=0.806 8 MASE=1.7 44 RMSE=1.3 20 R2=0.0942	MAE=20.280 MASE=1555. 61 RMSE=39.443 R2=0.055	MAE=3.8521 RMSE=27.5 794 RMSE=5.251 R2=0.0213	MAE=1.179 MASE=3.128 RMSE=1.768 R2=0.0436	X	MAE=110.41 6 MASE=2195 1.64 RMSE=148.1 60 R2=0.312
WATER LEVEL	MAE=0.682 MASE=1.3 31 RMSE=1.1 53 R2=0.388	MAE=19.253 MASE=1462.55 RMSE=38.243 R2=0.0474	MAE=3.608 MASE=25.0 69 RMSE=5.00 69 R2=0.00369	MAE=1.0911 MASE=2.581 RMSE=1.609 R2=0.1359	MAE=1.237 MASE=2.696 RMSE=1.642 R2=0.4985	X

From Table 12, it can be inferred that water level and pH are the most correlated parameters in the full phase analysis of the experiment as MAE=0.682. This means, with a given water level, we can predict the pH required for a good yield. The parameters that cannot be correlated are sunlight and water level as the MAE=162.013, this means that the value of Water level cannot be predicted with a given luminous intensity.

C. Predictive Analysis of parameters using Decision Tree Regression

TABLE 13

Decision Tree Regression Between Parameters for Initial Phase of Coriander Plant Growth

PARAMETER VS PARAMETER	PH	SUNLIGHT	HUMIDITY	TEMPERATURE	SOILMOISTURE	WATER LEVEL
PH	X	MAE=25.117 MASE=1570. 68 RMSE=39.631 R2=0.0493	MAE=3.498 9 MASE=21.0 RMSE=4.58 4 R2=0.262	MAE=1.085 MASE=2.704 RMSE=1.171 R2=0.415	MAE=0.952 0 MASE=266. 11 RMSE=16.312 R2=0.1289	MAE=11.33 0 MASE=266. 11 RMSE=16.312 R2=0.1289
SUNLIGHT	MAE=0.421 3 MASE=0.329 RMSE=0.57 3 R2=0.227	X	MAE=0.637 MASE=1.028 RMSE=1.014 9 R2=0.0655	MAE=1.126 MASE=2.266 RMSE=1.505 1.248 R2=0.3035	MAE=0.996 0 MASE=1.55 8 RMSE=1.248 R2=0.3035	MAE=0.996 0 MASE=1.55 8 RMSE=1.248 R2=0.3035
HUMIDITY	MAE=0.408 MASE=0.29 2 RMSE=0.54 1 R2=0.365	MAE=36.44 MASE=4653. 88 RMSE=68.219 R2=0.3042	X	MAE=0.9103 MASE=1.477 RMSE=1.517 R2=0.174	MAE=1.0399 MASE=2.304 RMSE=1.363 R2=0.2165	MAE=11.83 3 MASE=332. 31 RMSE=18.2 2 R2=0.10522
TEMPERATURE	MAE=0.389 MASE=0.28 0 RMSE=0.529 R2=0.0033	MAE=23.802 MASE=2150. 406 RMSE=46.37 R2=0.322	MAE=2.903 MASE=11.8 80 RMSE=3.44 6 R2=0.410	X	MAE=1.1320 MASE=1.858 RMSE=1.363 R2=0.433	MAE=8.271 MASE=122. 69 RMSE=11.33 7 R2=0.303
SOILMOISTURE	MAE=0.406 MASE=0.29 4 RMSE=0.542 R2=0.0160	MAE=28.44 MASE=2407.91 RMSE=49.070 R2=0.0055	MAE=3.018 MASE=16.7 RMSE=4.09 3 R2=0.020	MAE=0.7735 MASE=1.104 RMSE=1.050 R2=0.0059	X	MAE=11.34 1 MASE=217. 46 RMSE=14.7 4 R2=0.205
WATER LEVEL	MAE=0.334 MASE=0.21 8 RMSE=0.46 72 R2=0.129	MAE=21.03 MASE=1526. 93 RMSE=39.075 R2=0.2402	MAE=3.323 MASE=18.8 34 RMSE=4.33 9 R2=0.05843	MAE=0.919 MASE=2.70294 RMSE=1.5006 R2=0.0072	MAE=1.0835 MASE=1.879 RMSE=1.3707 R2=0.5531	X

From Table 13, it can be inferred that water level and pH are the most correlated parameters in the initial phase of the experiment as MAE=0.334. This means, with a given water level, we can predict the pH required for a good yield. The parameters that cannot be correlated are water level and humidity as the MAE=11.833, this means that the value of Water level cannot be predicted with a given humidity.

TABLE 14

Decision Tree Regression Between Parameters for Growing Phase of Coriander Plant Growth

PARAMETER VS PARAMETER	PH	SUNLIGHT	HUMIDITY	TEMPERATURE	SOILMOISTURE	WATER LEVEL
PH	X	MAE=23.487 MASE=1556. 330 RMSE=39.45 0 R2=0.133	MAE=4.444 0 MASE=33.5 18 RMSE=5.78 9 R2=0.066	MAE=1.067 MASE=2.294 RMSE=1.514 R2=0.0555	MAE=1.662 MASE=4.845 RMSE=2.201 R2=0.0173	MAE=86.23 MASE=14214. 92 RMSE=119.22 R2=0.422
SUNLIGHT	MAE=1.21 0 MASE=5.2 87 RMSE=2.2 99 R2=0.220	X	MAE=2.764 MASE=24.7 75 RMSE=4.97 7 R2=0.1022	MAE=0.902 MASE=2.036 RMSE=2.036 R2=0.3970	MAE=1.852 MASE=5.100 RMSE=2.258 R2=0.126	MAE=140.63 58 MASE=28070 58 RMSE=167.5 4 R2=0.131
HUMIDITY	MAE=1.08 5 MASE=2.4 75 RMSE=1.57 R2=0.264	MAE=19.74 MASE=1099.71 RMSE=32.55 R2=0.2786	X	MAE=0.9107 MASE=1.569 RMSE=1.252 R2=0.438	MAE=1.816 MASE=5.153 RMSE=2.270 R2=0.4041	MAE=142.94 4 MASE=32162 22 RMSE=179.3 38 R2=0.161

TEMPERATURE	MAE=0.94 7 MASE=1.7 23 RMSE=1.3 12 R2=0.142	MAE=15.279 MASE=791.1 6 RMSE=28.12 7 R2=0.2953	MAE=2.512 MASE=11.0 47 RMSE=3.32 3 R2=0.475	X	MAE=1.775 MASE=4.988 RMSE=2.233 R2=0.105	MAE=134.80 MASE=25756 83 RMSE=160.4 8 R2=0.010
SOILMOISTURE	MAE=1.02 63 MASE=4.3 60 RMSE=2.0 88 R2=0.0082	MAE=21.63 MASE=1319.71 60 RMSE=36.32 R2=0.0284	MAE=3.285 MASE=19.0 59 RMSE=4.36 5 R2=0.0023	MAE=1.063 MASE=2.231 RMSE=1.493 R2=0.0132	X	MAE=121.68 MASE=22438 58 RMSE=149.7 9 R2=0.1508
WATER LEVEL	MAE=0.698 MASE=1.3 71 RMSE=1.1 71 R2=0.0699	MAE=22.549 MASE=1676. 62 RMSE=40.94 R2=0.261	MAE=3.063 MASE=20.0 44 RMSE=4.47 7 R2=0.2023	MAE=1.067 MASE=3.0071 RMSE=1.724 R2=0.09765	MAE=1.528 MASE=3.8184 RMSE=1.9540 R2=0.0723	X

From Table 14, it can be inferred that water level and pH are the most correlated parameters in the growth phase of the experiment as MAE=0.698. This means, with a given water level, we can predict the pH required for a good yield. The parameters that cannot be correlated are water level and humidity as the MAE=142.944, this means that the value of Water level cannot be predicted with a given humidity.

TABLE 15

Decision Tree Regression Between Parameters for Harvesting Phase of Coriander Plant Growth

PARAMETER VS PARAMETER	PH	SUNLIGHT	HUMIDITY	TEMPERATURE	SOILMOISTURE	WATER LEVEL
PH	X	MAE=22.732 MASE=2045. 76 RMSE=45.23 0 R2=0.0708	MAE=4.569 MASE=45.1 41 RMSE=6.71 8 R2=0.4999	MAE=0.882 MASE=2.502 RMSE=1.581 R2=0.225	MAE=1.471 MASE=2.0333 RMSE=0.8793 R2=0.0793	MAE=83.55 MASE=18340.29 RMSE=135.4 2 R2=0.069
SUNLIGHT	MAE=1.14 6 MASE=2.7 43 RMSE=1.6 56 R2=0.0261	X	MAE=3.395 MASE=21.5 54 RMSE=4.64 2 R2=0.414	MAE=0.6377 MASE=1.307 RMSE=1.143 R2=0.498	MAE=1.5740 MASE=1.959 RMSE=0.953 R2=0.453	MAE=129.51 MASE=25884. 24 RMSE=160.8 85 R2=0.4367
HUMIDITY	MAE=1.06 MASE=2.1 86 RMSE=1.4 78 R2=0.724	MAE=15.92 MASE=505.1 41 RMSE=22.47 R2=0.59	X	MAE=0.841 MASE=2.206 RMSE=1.485 R2=0.262	MAE=1.522 MASE=3.722 RMSE=1.959 R2=0.4325	MAE=87.022 MASE=15484 RMSE=124.4 3 R2=0.135
TEMPERATURE	MAE=0.72 3 MASE=0.9 85 RMSE=0.9 92 R2=0.4802	MAE=7.183 MASE=198.8 6 RMSE=14.10 2 R2=0.787	MAE=3.359 MASE=23.2 51 RMSE=4.82 2 R2=0.342	X	MAE=1.123 MASE=1.954 RMSE=1.397 R2=0.4325	MAE=93.27 MASE=15132 8 RMSE=123.0 1 R2=0.0495
SOILMOISTURE	MAE=1.04 MASE=1.7 81 RMSE=1.33 R2=0.018	MAE=28.62 MASE=2623. 48 RMSE=51.22 0 R2=0.0750	MAE=4.297 MASE=195.7 72 RMSE=5.45 6 R2=0.109	MAE=1.060 MASE=1.380 RMSE=1.380 R2=0.3879	X	MAE=117.64 MASE=21402. 11 RMSE=148.6 6 R2=0.1676
WATER LEVEL	MAE=0.7400 MASE=1.4 44 RMSE=1.2 01 R2=0.158	MAE=18.43 MASE=39.67 464 RMSE=42.93 5 R2=0.616	MAE=4.103 MASE=32.0 56 RMSE=5.66 R2=0.0454	MAE=1.00740 MASE=2.8656 RMSE=1.6928 R2=0.9196	MAE=1.197 MASE=2.6819 RMSE=1.6376 R2=0.33059	X

From Table 15, it can be inferred that sunlight and temperature are the most correlated parameters in the harvesting phase of the experiment as MAE=0.6377. This means, with a given temperature, we can predict the luminous intensity required for a good yield. The parameters that cannot be correlated are water level and sunlight as the MAE=129.51, this means that the value of Water level cannot be predicted with a given sunlight.

TABLE 16

Decision Tree Regression Between Parameters for Full Phase of Coriander Plant Growth

PARAMETER VS PARAMETER	PH	SUNLIGHT	HUMIDITY	TEMPERATURE	SOILMOISTURE	WATER LEVEL
PH	X	MAE=23.667 MASE=1574. 28 RMSE=39.67 R2=0.0871	MAE=3.77 MASE=26.1 97 RMSE=5.11 8 R2=0.0070	MAE=1.162 MASE=3.117 RMSE=1.764 R2=0.0277	MAE=1.375 MASE=3.4744 RMSE=1.863 R2=0.2968	MAE=70.152 MASE=13362. 83 RMSE=115.5 97 R2=0.589
SUNLIGHT	MAE=1.019 0 MASE=2.46 9 RMSE=1.57 1 R2=0.1476	X	MAE=3.674 MASE=2.46 30 RMSE=4.79 R2=0.171	MAE=1.0661 MASE=1.494 RMSE=1.2434 R2=0.2434	MAE=1.857 MASE=3.874 RMSE=1.6376 R2=0.155	MAE=163.11 MASE=34396 27 RMSE=185.4 6 R2=0.0659
HUMIDITY	MAE=1.032 MASE=1.95 6 RMSE=1.39 8 R2=0.219	MAE=22.217 MASE=1540. 602 RMSE=39.25 0 R2=0.1037	X	MAE=0.961 MASE=1.620 RMSE=1.272 R2=0.3378	MAE=1.906 MASE=5.624 RMSE=2.371 R2=0.1596	MAE=162.59 MASE=36533 3 RMSE=191.1 3 R2=0.152
TEMPERATURE	MAE=0.911 MASE=1.70 3 RMSE=1.30 R2=0.11710	MAE=17.664 MASE=1005. 81 RMSE=31.71 4 R2=0.0440	MAE=3.067 MASE=16.2 38 RMSE=4.02 5 R2=0.3001	X	MAE=1.650 MASE=4.224 RMSE=2.055 R2=0.0587	MAE=147.26 9 MASE=29019 5 RMSE=170.3 51 R2=0.1299

SOIL MOISTURE	MAE=0.975 MASE=2.74 47 RMSE=1.65 6 R2=0.0873	MAE=20.854 MASE=1216. 04 RMSE=34.87 R2=0.00587	MAE=3.995 MASE=28.3 18 RMSE=5.32 1 R2=-0.0553	MAE=1.0834 MASE=2.619 RMSE=1.618 R2=0.109	X	MAE=112.74 MASE=20885. 92 RMSE=144.5 19 R2=0.3583
WATER LEVEL	MAE=0.706 MASE=1.32 8 RMSE=1.15 2 R2=0.210	MAE=23.019 MASE=1913. 38 RMSE=43.74 R2=0.0553	MAE=3.665 MASE=25.9 72 RMSE=5.09 6 R2=0.0735	MAE=1.1366 MASE=3.302 RMSE=1.8172 R2=-0.2404	MAE=1.253 MASE=2.836 RMSE=1.684 R2=0.4258	X

From Table 16, it can be inferred that water level and pH are the most correlated parameters in the full phase analysis of the experiment as MAE=0.706. This means, with a given water level, we can predict the pH required for a good yield. The parameters that cannot be correlated are water level and sunlight as the MAE=163.11, this means that the value of Water level cannot be predicted with a given luminous intensity.

VII. CONCLUSION AND FUTURE WORKS

In conclusion, our whole work can be split into two main part. The first one being the growth of plants and creation of data set, in this we have grown the crops and taken the data with the help of sensors. In this aspect, there is minimal automation. The dataset is then created by taking the data and cleaning it to make sure that the anomalies are removed. With the help of this data set, we then move onto the second phase of the work. The second phase of this work is processing of the data set created and correlating the data to establish the best scenario for plant growth and good yield. With the help of Linear Regression, Support vector regression and Decision Tree Regression, we have established the parameters which are best correlated.

For the work that can be done to further the progress done by us is to fully automate the system. With the correlation achieved by us, the parameters can be used to know the ambient conditions required when a certain parameter is fixed and cannot be altered in any way possible especially in the city environment in countries like India.

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