Weekly Progress Report

Agrotech Live

2025-04-26

Abstract

In an ongoing effort to achieve food sovereignty, Wiggle Labs has developed Agrotech Live to monitor soil health of different plants and crops. This tool collects four data points; Temperature, Moisture, Light and Conductivity from sensors placed near a subject. Training data for this program are ideal conditions for the subject, and performance of the experiment is based on how close collected sensor (testing) data is to the input care training data. Input data is identical in structure to the testing data (collected during a session), except it represents only ideal conditions for a subject.

This report examines relationships between the session and training data features over the past 7 days, and forecasts the next 3 days. Knowing these insights can advise on how to better adjust an environment for a subject during the session. Clustering will be used to prepare experiment data for classifying the analyzed session as "Above," Below" or "Within" and ideal range.

System Understanding

The program collects feature data via BLE (Bluetooth Low Energy) through the sensors mentioned previously. This feature data is used to generate raw session data in sesh.json. It is also saved to individual daily files in /files/read_files.

Using batch-builder.py found in /tools, input parameters for a subjects' ideal environment can be generated. If any input file is loaded to the tools, it can also be auto-inserted with the command batch-builder.py < input-file.txt.

Data Understanding

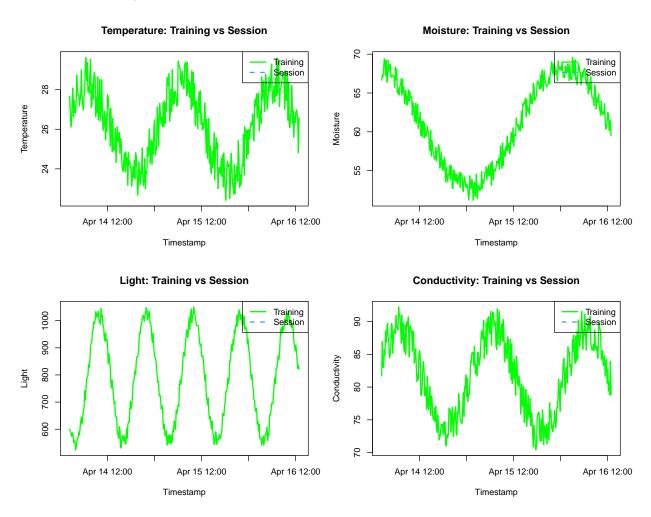
Temperature is measured in Celsius (°C) and includes a tenth decimal (eg. "17.5"). It generally affects soil activity and how nutrients are absorbed. Moisture is measured as a percentage, and depending on the subject's needs, thresholds will vary. Light is collected in lux where 1 = lux is equal to 1 lumen/m^2 . Conductivity is measured in $\mu\text{S/cm}$ which is a electrical conductivity. It is essentially how easily a current passes through the soil.

There are often patterns such as Temperature increasing as light does, or decreasing as Moisture increases. These kinds of relationships are to be expected from the laws of nature In later versions of this report, it is planned to train this analysis to learn these patterns so that insights are more clearly visible.

Stage I: Time Series, Correlation, Covariance and Heatmap

Time Series Comparison

The following graphs represent how the session and training data has changed over time. They are aligned with each other on Timestamp over the past 7 days. Input data determines the shape of training graph in this time series analysis.



Correlation and Covariance Matrices

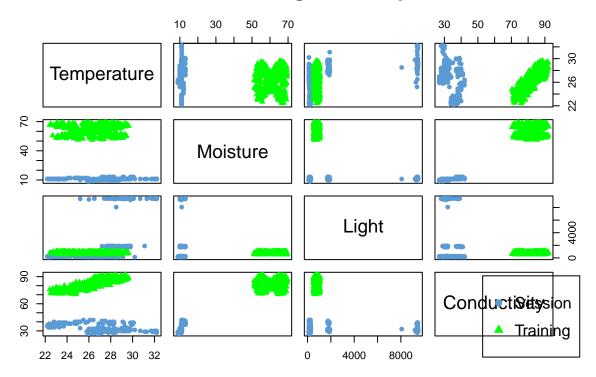
In this correlation matrix, score of 1.0 or -1.0 represents a perfect (positive or negative) self-correlation and values closer to 0 show less to no correlation. The matrix above reflects the same relationships as the covariance matrix.

CROSS-COVARIANCE MATRIX (Session vs Training)

```
Temperature
##
                                  Moisture
                                                   Light Conductivity
## Temperature
                   0.8972576
                             4.601141e+00
                                               -23.18137
                                                             3.101182
## Moisture
                   0.2785302 5.939718e-01
                                               -33.98404
                                                             1.130208
## Light
                -764.7418247 -1.476924e+03 -86059.41483 -1717.599071
                                               -72.36139
## Conductivity
                   0.8967236 -2.279202e-03
                                                             3.816446
##
## CROSS-CORRELATION MATRIX (Session vs Training)
##
                Temperature
                                 Moisture
                                                 Light Conductivity
## Temperature
                  0.1916101
                             0.3291864465 -0.05321397
                                                         0.20418588
## Moisture
                             0.1338242652 -0.24567112
                                                         0.23434161
                  0.1873123
## Light
                 -0.1135511 -0.0734699499 -0.13735996
                                                        -0.07863132
## Conductivity
                  0.1407232 -0.0001198299 -0.12206725
                                                         0.18465599
```

Plotting variables against each other.

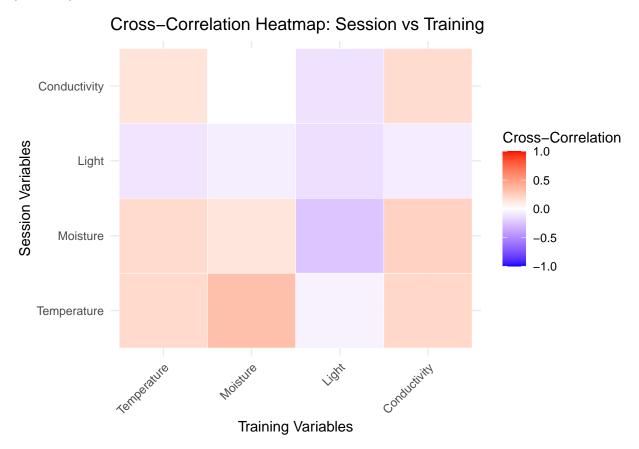
Session vs Training Data Comparison



Up until this point (excluding the matrices) we have been treating the session and training data as independent data sets for comparison purposes. In the next stage, instead of running similarity algorithms within each variable, both the independent (session_data) and the dependent (training_data) must be used together in order to produce valuable insights about their relationship.

Cross Correlation Heat Map

The heatmap below shows cross-correlations between session variables (y-axis) and training variables (x-axis). The color scale represents correlation strength, with red indicating positive correlation (up to +1.0), blue indicating negative correlation (down to -1.0), and white/pale colors representing weak or no correlation (around 0).



Stage II: Similarities and RSME

In this stage the goal is to measure the similarities and differences between our session and training data. From there, we'll b3 able to classify and label the features for K means clustering in Stage 3.

Preprocessing

library(data.table)

```
##
## Attaching package: 'data.table'
## The following objects are masked from 'package:reshape2':
##
## dcast, melt

## The following objects are masked from 'package:dplyr':
##
## between, first, last

library(dplyr)

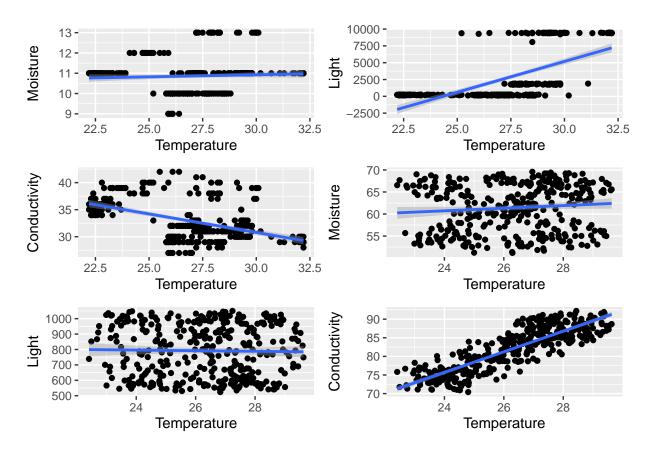
training_dt <- as.data.table(training_data)
session_dt <- as.data.table(session_data)
# head()</pre>
```

Cleaning the Data

To clean up the data, we'll do some indexing by setting up keys. Then to organize it, we put the fields we want to use for our analysis into their own data frames. Converting Temperature, Moisture, Light and Conductivitry to numeric will ensure no problems when plotting.

Linear Regression Model & Errors

```
## 'geom_smooth()' using formula = 'y ~ x'
```



This plot is nice, but can only tell us so much about the data. Running a summary() will give us more information.

Session Summaries

AGT session data

```
##
## Call:
## lm(formula = training_data$Moisture ~ session_data$Moisture)
##
##
  Residuals:
##
       Min
                1Q
                    Median
                                3Q
                                       Max
##
   -10.358
           -5.308
                     1.520
                             4.688
                                     8.052
##
##
  Coefficients:
##
                         Estimate Std. Error t value Pr(>|t|)
## (Intercept)
                          51.9214
                                       3.7672
                                               13.783
                                                        <2e-16 ***
  session_data$Moisture
                           0.8733
                                      0.3457
                                                2.526
                                                         0.012 *
                   0 '*** 0.001 '** 0.01 '* 0.05 '.' 0.1 ' 1
## Signif. codes:
##
## Residual standard error: 5.341 on 350 degrees of freedom
## Multiple R-squared: 0.01791,
                                    Adjusted R-squared: 0.0151
## F-statistic: 6.382 on 1 and 350 DF, p-value: 0.01197
```

Residual Standard Error

Residuals represent the differences between the actual and predicted values of our dependent (response) variable. A high RSE indicates a weak model for this prediction.

Multiple R

Multiple R, also called the correlation coefficient, measures the strength and direction of a relationship between variables. On a scale of -1 to +1, values closer to -1 or +1 represent perfect negative or positive correlation. 0 means no correlation at all.

Multiple R2 Error

R squared tells us the proportion for variance in the dependent variable explained by the predictor variable. It can be on a scale of 0 to 1. A value closer to 1 represents greater variance, while closer to 0 represents less variance. Returning a whole 0 or 1 means none or perfect variance respectively.

Adjusted R2 Error

This error is a modified version of the above R-squared error that is able to accommodate for multiple predictors in a regression model.

Stage III: Modeling, Classification and Metrics

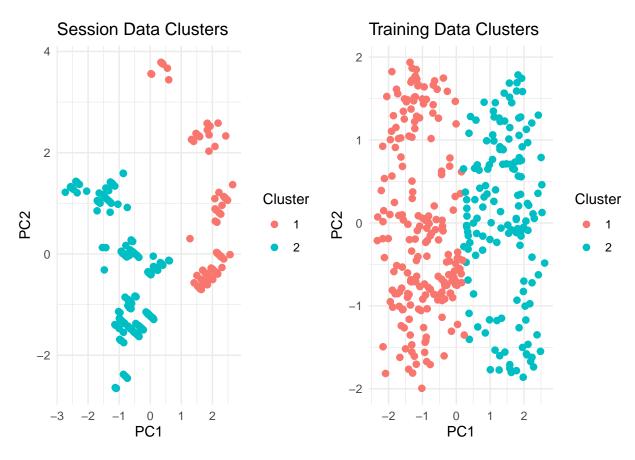
In this next section, we will use the KNN algorithm to find the best K for a label. As this is a placeholder for future use, a good question to use this for is:

How can we classify a subjects health by having thresholds of poor, unsatisfactory, neutral, satisfactory or excellent?

To measure this hypothetical threshold, we would use how closely or different the training data is from testing. This was explored in the previous stage, and is required to be able to have a label to predict for in KNN.

```
## Session Cluster Distribution (%):
##
## 1 2
## 30.39773 69.60227
##
## Training Cluster Distribution (%):
##
## 1 2
## 57.95455 42.04545
##
## Session Cluster Centers (scaled):
```

```
##
     Temperature
                   Moisture
                                  Light Conductivity
##
      -0.9817638
                  0.9211749 -0.3721474
                                            1.3242057
  1
       0.4287703 -0.4023090
##
                              0.1625297
                                          -0.5783266
##
## Training Cluster Centers (scaled):
##
     Temperature
                   Moisture
                                    Light Conductivity
##
       0.7088745
                  0.1466714
                              0.004021424
                                              0.7317423
      -0.9770973 -0.2021687 -0.005543043
                                             -1.0086177
##
  Attaching package: 'gridExtra'
   The following object is masked from 'package:dplyr':
##
##
       combine
```



In order to begin preprocessing and find the right k, we will only keep the relevant features and label the cluster. This analysis uses the session data as testing data and the generated ideal conditions as the training data.

We will use two approaches. First with the built in K nearest neighbor functions with R and then manually calculating the accuracy of each K values.

Method 1: Built in knn() Function

```
# Select numeric features and the cluster label
features_train <- training_data[, c("Temperature", "Moisture", "Light", "Conductivity")]
labels_train <- as.factor(training_data$Cluster)

test_features <- session_data[, c("Temperature", "Moisture", "Light", "Conductivity")]
labels_test <- as.factor(session_data$Cluster)</pre>
```

Normalizing the data will help scale larger values down to a comparable size.

```
# Normalize (scale) the features
features_train_scaled <- as.data.frame(scale(features_train))
test_features_scaled <- as.data.frame(scale(test_features))</pre>
```

For our train/test split,

```
train_features <- features_train_scaled
train_labels <- labels_train</pre>
```

Now we'll proceed with modeling KNN and evaluating its performance. Before we start though, this cross correlation data needs to be fitted a bit more in order to pass through the KNN model.

```
# Make sure train and test sets have the same number of rows as their respective labels
min_train_rows <- min(nrow(train_features), length(train_labels))
min_test_rows <- min(nrow(test_features), length(labels_test))

# Trim all data to match
train_features <- train_features[1:min_train_rows, ]
train_labels <- train_labels[1:min_train_rows]
test_features <- test_features[1:min_test_rows, ]
labels_test <- labels_test[1:min_test_rows]

# Convert labels to factors after trimming
train_labels <- as.factor(train_labels)
labels_test <- as.factor(labels_test)</pre>
```

```
library(class)

# Training the KNN model
k_value <- 3  # You can experiment with different values of k
knn_model <- knn(train_features, test_features, train_labels, k = k_value)
# Evaluate the model
confusion_matrix <- table(Predicted = knn_model, Actual = labels_test)
accuracy <- sum(diag(confusion_matrix)) / sum(confusion_matrix)

cat("Accuracy on Session Data (Test Data):", accuracy)</pre>
```

Accuracy on Session Data (Test Data): 0.3039773

Method 2: Manual K Value Accuracy Computation

K Nearest Neighbor (KNN) works by computing the Euclidean distance between the test and training points. Then after selecting the proper k that is the shortest distance, it assigns those closest neighbors most common label to the test point.

Using knn() the class package automatically computes the Euclidean Distance between two points. We will adjust in the input parameters to ingest the train and test data we have already prepared.

```
# Inputs for manual model
train_data <- features_train_scaled
test_data <- test_features_scaled
train_labels <- as.numeric(labels_train)
test_labels <- as.numeric(labels_test)

euc_dis <- function(p1, p2) {
    sqrt(sum((p1 - p2)^2))
}</pre>
```

In this next section we're implementing the KNN Classifier manually to train the target data. At this stage, the classifier logic is being defined below.

Here is where we'll compute accuracy for the session data using manual KNN.

k = 7 , Accuracy = 54.83 %
k = 9 , Accuracy = 57.1 %
k = 11 , Accuracy = 52.56 %
k = 13 , Accuracy = 53.12 %
k = 15 , Accuracy = 51.7 %

```
k_values <- seq(1, 15, 2) # or however many k's you want

cat("Train samples:", nrow(train_data), "Label count:", length(train_labels), "\n")

## Train samples: 352 Label count: 352

accuracy_results <- c()

for (k in k_values) {
    predictions <- knn(train = train_data, test = test_data, cl = train_labels, k = k)
    acc <- mean(predictions == test_labels)
    accuracy_results <- c(accuracy_results, acc)
    cat("k =", k, ", Accuracy =", round(acc * 100, 2), "%\n")
}

## k = 1 , Accuracy = 54.26 %

## k = 3 , Accuracy = 53.12 %

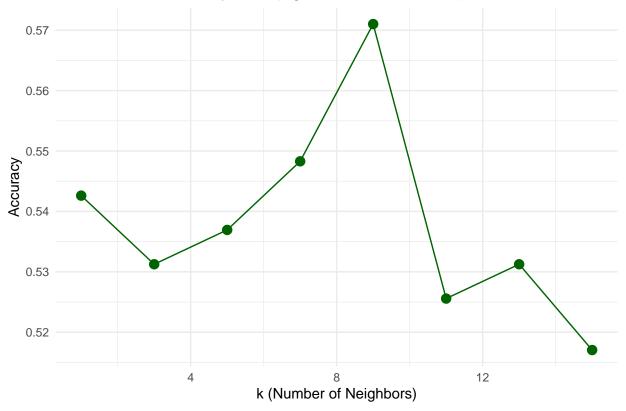
## k = 5 , Accuracy = 53.69 %</pre>
```

The accuracy of this model varies based in the k value used. Plotting them will provide a better idea of which to use to get the best accuracy.

```
accuracy_data <- data.frame(
   k_values = k_values,
   accuracy = accuracy_results,
   dataset = "Session/Training"
)

ggplot(accuracy_data, aes(x = k_values, y = accuracy)) +
   geom_line(color = "darkgreen") +
   geom_point(size = 3, color = "darkgreen") +
   labs(title = "Manual KNN Accuracy vs. k (Agrotech Session Data)",
        x = "k (Number of Neighbors)", y = "Accuracy") +
   theme_minimal()</pre>
```

Manual KNN Accuracy vs. k (Agrotech Session Data)



Stage IV: Forecasting

Time Series Analysis and Forecasting

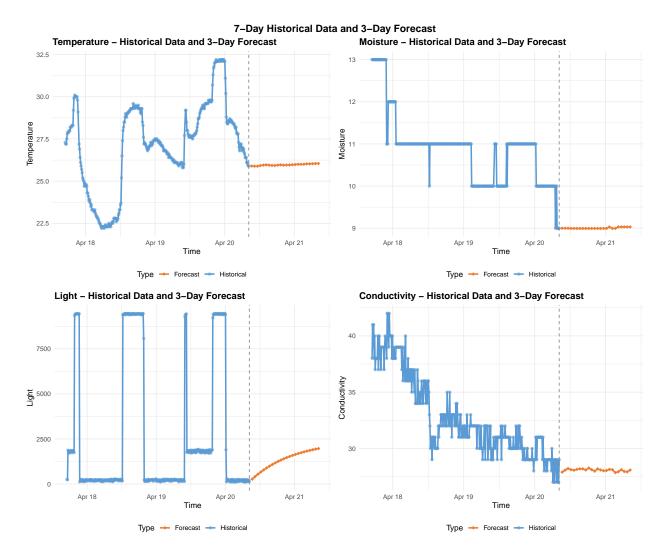
```
## Number of unique days in dataset: 4
## Date range: 20195 to 20198
## Average observations per day: 88
```

Creating Forecast Models

For each sensor variable, we'll use an appropriate time series forecasting method. We'll evaluate ARIMA, ETS (Exponential Smoothing), and Prophet models to find the best approach for our data.

Visualization of Historical Data and Forecasts

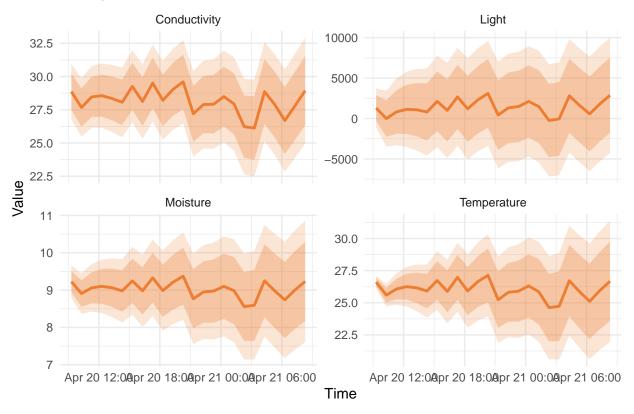
```
## Warning: 'aes_string()' was deprecated in ggplot2 3.0.0.
## i Please use tidy evaluation idioms with 'aes()'.
## i See also 'vignette("ggplot2-in-packages")' for more information.
## This warning is displayed once every 8 hours.
## Call 'lifecycle::last_lifecycle_warnings()' to see where this warning was ## generated.
## Warning: Using 'size' aesthetic for lines was deprecated in ggplot2 3.4.0.
## i Please use 'linewidth' instead.
## This warning is displayed once every 8 hours.
## Call 'lifecycle::last_lifecycle_warnings()' to see where this warning was ## generated.
```



Forecast Accuracy and Confidence Intervals

```
##
##
    Temperature Forecast Accuracy Metrics:
                          ME
                                 RMSE
                                             MAE
                                                          MPE
                                                                   MAPE
                                                                              MASE
## Training set -0.001780191 0.243637 0.1470391 -0.007378328 0.5407512 0.07155614
##
                        ACF1
## Training set 0.0008039722
##
##
   Moisture Forecast Accuracy Metrics:
##
                         {\tt ME}
                                 RMSE
                                              MAE
                                                         MPE
                                                                  MAPE
                                                                            MASE
## Training set -0.01537808 0.2197884 0.05411674 -0.1681009 0.5194882 0.1365407
##
                       ACF1
## Training set 0.004310307
##
##
  Light Forecast Accuracy Metrics:
                                                  MPE
                                                          MAPE
                                                                    MASE
##
                      ME
                             RMSE
                                       MAE
## Training set 7.092266 1234.197 381.3237 -79.12131 86.72519 0.1200084
##
## Training set 0.005092738
##
   Conductivity Forecast Accuracy Metrics:
                                                      MPE
                         ME
                               RMSE
                                          MAE
                                                              MAPE
                                                                        MASE
## Training set -0.08063037 1.05766 0.8109361 -0.3285735 2.479315 0.5095537
## Training set -0.04219496
```

3-Day Forecasts with 80% and 95% Confidence Intervals



Forecast Table Summary

Table 1: Daily Forecast Summary for the Next 3 Days

Day	Variable	Min	Mean	Max
1	Temperature	25.88	25.97	26.04
2	Temperature	NA	NA	NA
3	Temperature	NA	NA	NA
1	Moisture	9.00	9.01	9.03
2	Moisture	NA	NA	NA
3	Moisture	NA	NA	NA
1	Light	272.20	1320.93	1965.26
2	Light	NA	NA	NA
3	Light	NA	NA	NA
1	Conductivity	27.85	28.07	28.26
2	Conductivity	NA	NA	NA
3	Conductivity	NA	NA	NA

Comparison to Training (Ideal) Data

Below are four plots showing the session data features compared to the ideal training data. The dotted line is a threshold which influences the status.

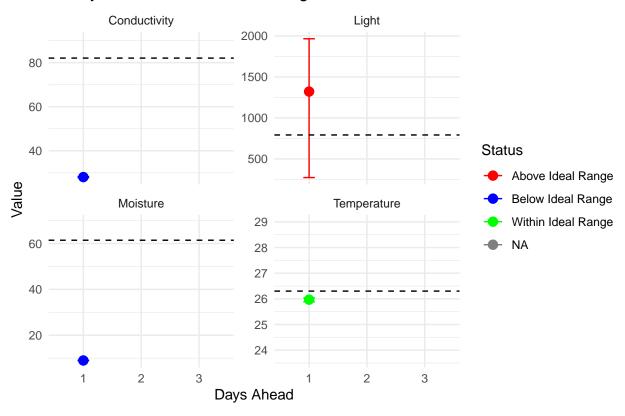
```
##
   Temperature
                    Moisture
                                    Light Conductivity
       26.30136
                    61.41136
                                791.69855
                                              82.06389
##
         Variable Ideal_Mean Ideal_Min Ideal_Max
##
## 1
     Temperature
                    26.30136
                                    NA
                                              NA
## 2
         Moisture
                    61.41136
                                    NA
                                              NA
## 3
            Light 791.69855
                                    NA
                                              NA
## 4 Conductivity
                    82.06389
                                    NA
                                              NA
## Ideal Conditions (from Training Data):
##
         Variable Ideal_Mean Ideal_Min Ideal_Max
                                         29.00596
## 1
     Temperature
                    26.30136 23.59677
## 2
         Moisture
                    61.41136 53.33851
                                         69.48422
## 3
            Light 791.69855 540.09470 1043.30240
## 4 Conductivity
                    82.06389 73.29176
                                         90.83603
```

Table 2: Forecast Comparison to Ideal Conditions

Variable	Day	Mean	Ideal_Mean	Status
Conductivity	1	28.07	82.06	Below Ideal Range
Conductivity	2	NA	82.06	NA
Conductivity	3	NA	82.06	NA
Light	1	1320.93	791.70	Above Ideal Range
Light	2	NA	791.70	NA
Light	3	NA	791.70	NA
Moisture	1	9.01	61.41	Below Ideal Range
Moisture	2	NA	61.41	NA
Moisture	3	NA	61.41	NA
Temperature	1	25.97	26.30	Within Ideal Range
Temperature	2	NA	26.30	NA
Temperature	3	NA	26.30	NA

^{##} Warning: Removed 8 rows containing missing values or values outside the scale range
('geom_point()').

3-Day Forecast vs. Ideal Growing Conditions



Stage V: Discussion