PROJECT-2 & 3
CE738 : HYDROMETRY

SUBMITTED BY

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Abstract

This project aims to design and develop a load cell-based IoT system to measure evapotranspiration rates. The objective is to develop an effective, field-ready device that reliably logs data and sends it over Wi-Fi to a remote server. An SD card is used to record data, which is then sent to a database for analysis. Calibration and uncertainty evaluation were conducted to account for environmental variability, providing a dependable solution for real-time field monitoring of evapotranspiration rates.

Introduction

Accurate evapotranspiration measurement is essential for understanding water dynamics, climate impacts, and agricultural irrigation needs. Evapotranspiration rates are a crucial metric in the management of water resources because they show the total amount of water lost as a result of evaporation from soil and plant surfaces. The goal of this project is to design and create an Internet of Things (IoT) system that uses load cells to measure evapotranspiration rates and log data in real time. For the device to withstand the rigorous of outside circumstances and preserve measurement accuracy, the gadget is designed to be sturdy and feild-ready.

The system's data logger captures data with date and time information, which is stored on an SD card for local backup and further analysis. Additionally, data is transmitted via Wi-Fi from an ESP8266 module to a remote server, where it is stored in a PostgreSQL database. The device is powered by a rechargeable battery, ensuring long-term operation in remote field settings.

Sample

Tulsi plant was taken as the sample in a plastic pot of cross section averaged to 16.993 cm diameter and plant of 60 cm height.

Materials

Load Cell - A force is transformed into a measurable electrical signal by a load cell. In this project we deployed load cell to measure weight change associated with water loss, representing evapotranspiration rates.

HX711- is used to amplify the voltage output from load cell as these values are too small and f or digitized from analog to digital converter for Arduino to read this voltage.

RTC (Real Time Clock)- it is a battery powered circuit which keeps track of the current time even when there is no power. RTC is used for datalogging for monitoring the time of data collection.

SD Card Module: Enables interfacing with the SD card for data storage, allowing the system to log data in CSV format for local backup and future analysis.

SD card- One can write or read data on the memory card and communicate with it using the SD and micro-SD card modules.

Battery- A rechargeable lithium battery was used to supply power

Battery Protection Circuit: Protects the lithium battery from overcharging, deep discharge, and short circuits, extending battery life and ensuring safe operation in remote and unattended environments.

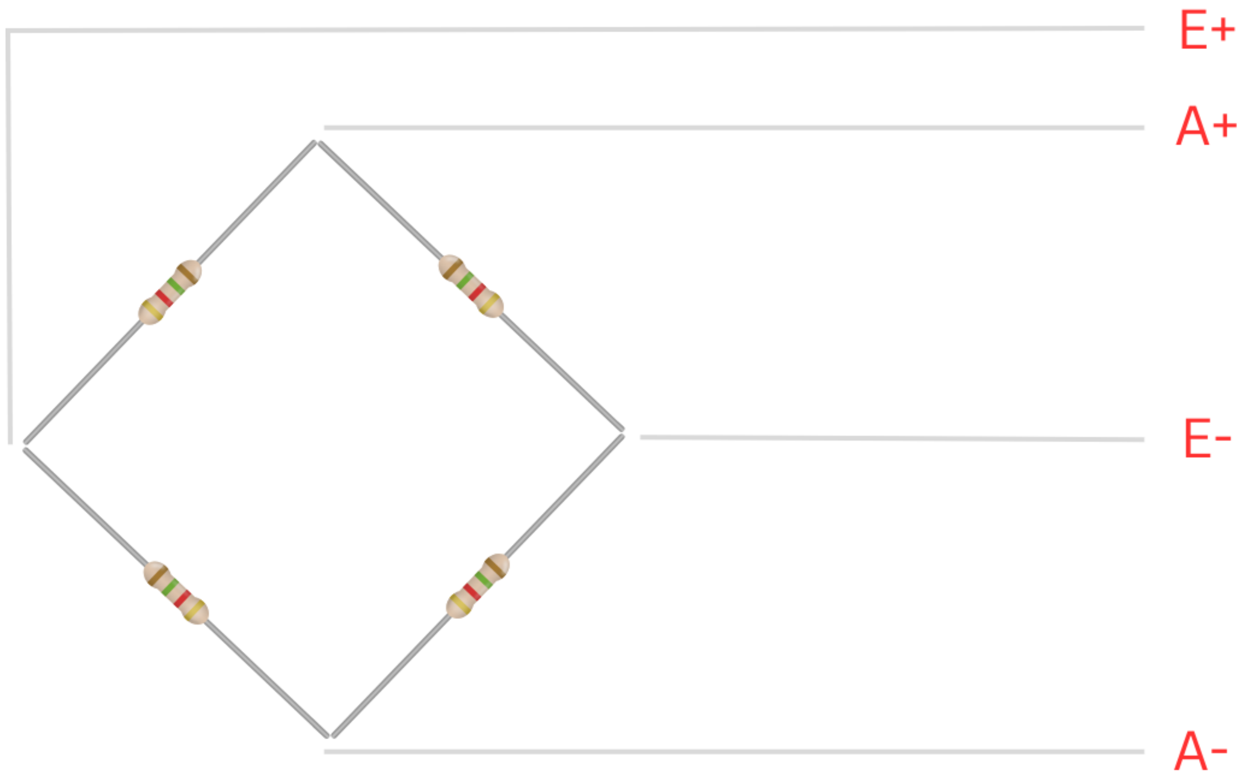
ESP8266: A Wi-Fi module used for wireless data transmission, enabling the system to send logged data to a remote server for analysis and storage.

DHT 22- Temperature and humidity sensor

Process

Calibration of load cell

Measuring resistance of load cell and form a corresponding Wheatstone bridge



$\frac{R1}{R2} = \frac{R3}{R4}$

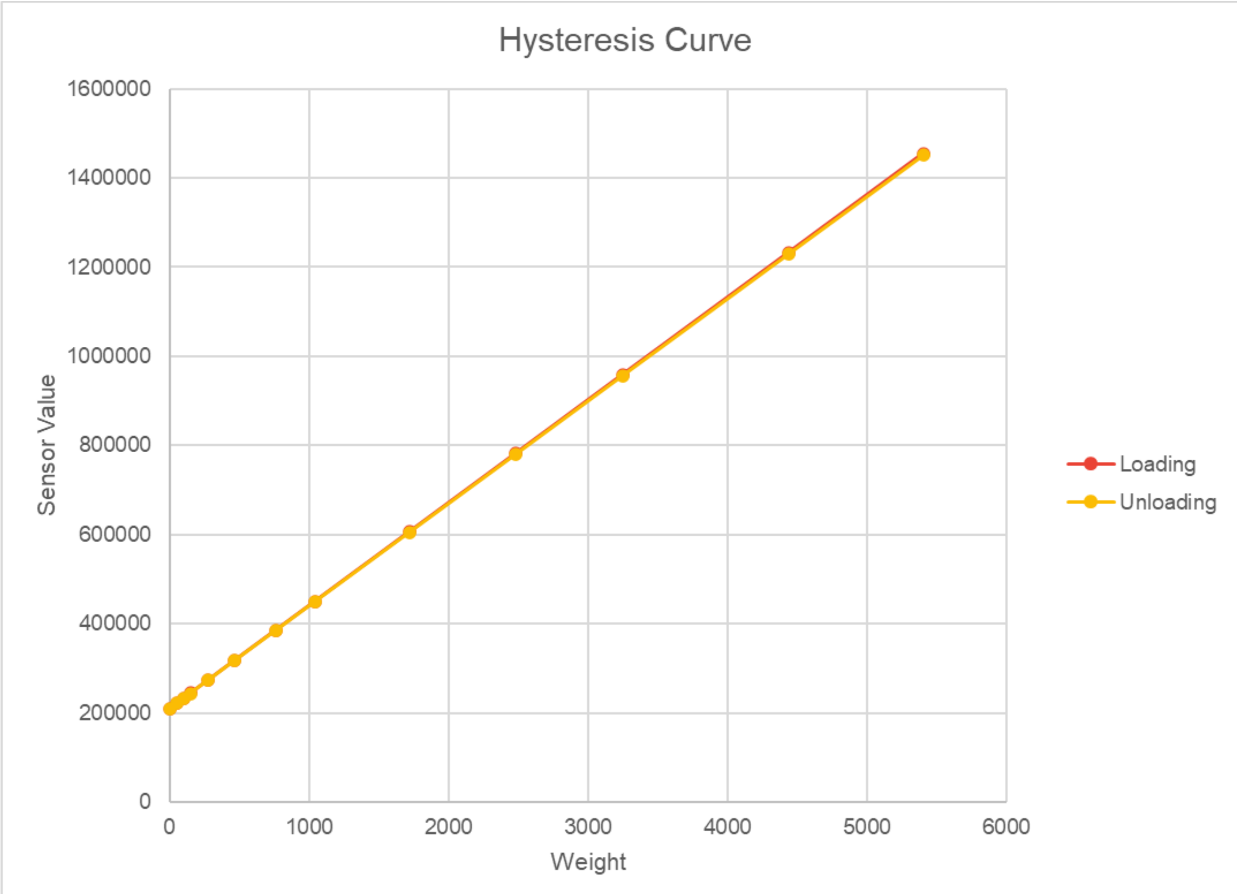
R1 = 924 Ω

R2 = 739 Ω

R3 = 739 Ω

R4 = 591Ω

Load cells need to be carefully calibrated in order to ensure accuracy. Calibration is the process of comparing the load cell's output to known reference weights. This guarantees reliable and precise readings from the load cell throughout its range. Calibration involves placing known weights on the load cell and recording the corresponding electrical outputs. Plotting these outputs and noting any differences results in a calibration curve that can be used as a guide to modify the load cell's output to match the real weight. For our load cells calibration, we took weights 0, 49.232, 99.162, 99.162, 148.394, 278, 468, 760, 1040, 1717, 2480, 3247, 4436, 5402 gm.



Data logging

Data logging to an SD card in over a large period of time allowing data storage and trend analysis for improved management efficiency. It stored the change in weight of the sample in txt format which included the time stamp from RTC and the corresponding weight measurement.SD card stored total of 1.5 MB and 11463 reading in interval of 30 seconds. The readings started on 6th November 10PM till 11 November 7AM which accounted for 105 hours. We also sent data to the server using ESP8266 and we continued monitoring the data on MQTT explorer. The battery and ESP8266 was connected to a power adapter for taking continuous readings.

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2024-11-06 21:30:08 - CE738/Project3/Group5/data: 22:51:48   4/11/2024   Temperature   28.90*C  humidity  56.20% RAW VALUE: 930772.87    MEASURED WEIGHT: 3090.59 g
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2024-11-06 21:48:11 - CE738/Project3/Group5/data: initialization done.
2024-11-06 21:48:14 - CE738/Project3/Group5/data: 21:47:38   6/11/2024   Temperature   28.80*C  humidity  58.80% RAW VALUE: 927598.81    MEASURED WEIGHT: 3078.60 g
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2024-11-06 21:48:36 - CE738/Project3/Group5/data: 21:48:0   6/11/2024   Temperature   28.80*C  humidity  58.10% RAW VALUE: 928956.81    MEASURED WEIGHT: 3083.23 g
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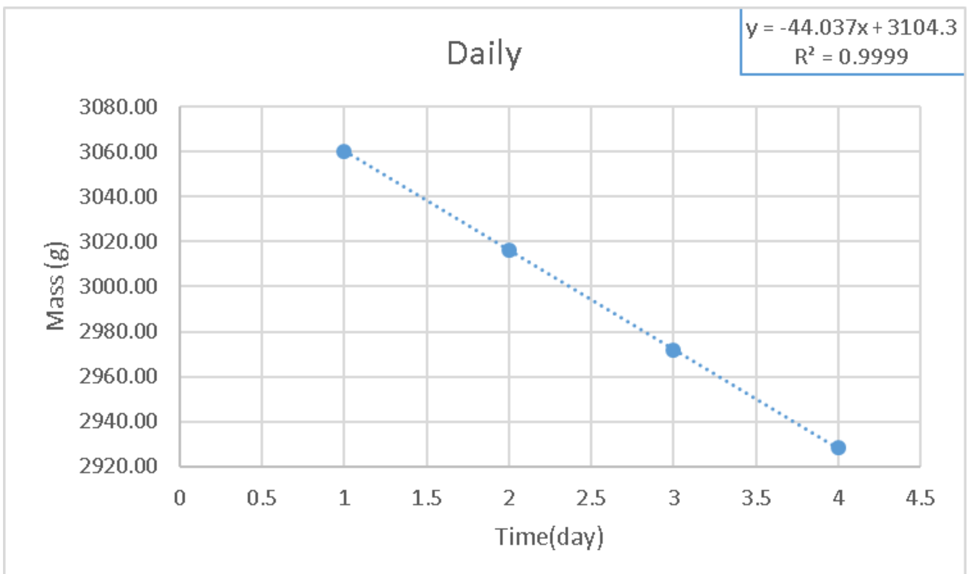


Outlier Detection

We used MAD (Median Absolute Deviation) method for outlier detection. Outlier detection using the MAD method identifies extreme values by measuring deviations from the median.

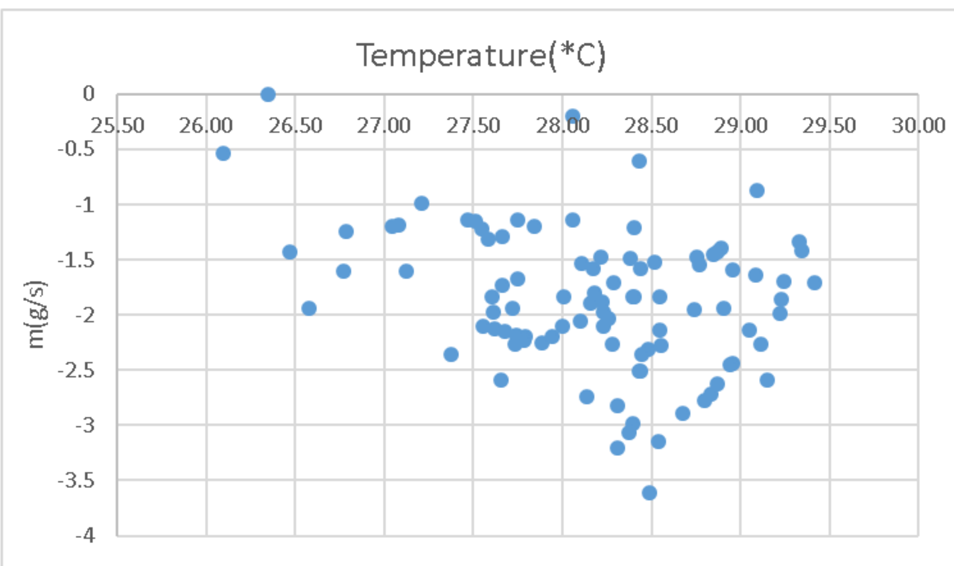
The MAD method is robust to outliers and works well for skewed or non-normal distributions. It's widely used for detecting anomalies in datasets while minimizing the influence of extreme values.

Uncertainties

In scientific and technical measurements, evaluating uncertainty is a crucial step. It entails measuring the extent to which different influencing factors may cause a measured value to diverge from the true value. Understanding and controlling uncertainties is crucial for obtaining dependable results in many applications. Some factors due to which uncertainty can occur are :

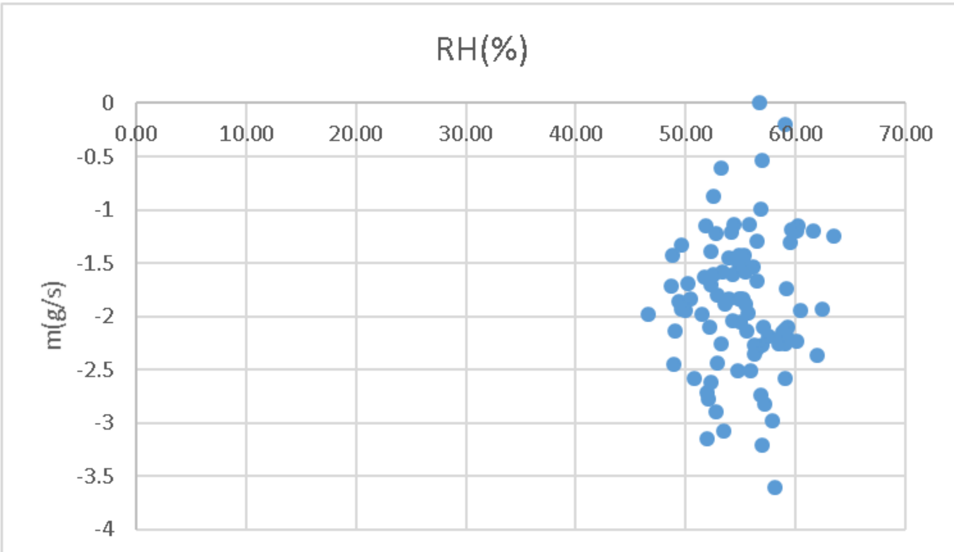
Load cell Sensitivity-Variations in temperature, changes in material properties, electrical noise, and signal drift are some of the factors that contribute to load cell sensitivity uncertainty. These lead to slight variations in measurements by compromising the precision of the load cell's force response.

Temperature variation-The range of temperature observed was 26.5- 29.5*C. The variation was non uniform and inconsistent. Variations in temperature can cause expansion, contraction, or drift in materials and electrical components, which may decrease accuracy and performance. In sensitive systems like load cells, temperature changes can lead to measurement uncertainties.



Relative Humidity- Environmental factors that affect sensors and equipment stability, such as humidity, have an impact on measurement accuracy. In this case we kept the sample and the setup in a closed room near the window with sunlight. The fan was always switched on which caused evaporation to happen in night as well.

In this figure the evapotranspiration took place in a range of 50-60% relative humidity.



Data Processing and Human Error-Uncertainties are introduced by human mistake in data processing through subjective interpretation, approximation, and rounding. While human errors in data entry, calibration, or analysis affect accuracy, digital processing can contribute small but cumulative errors.

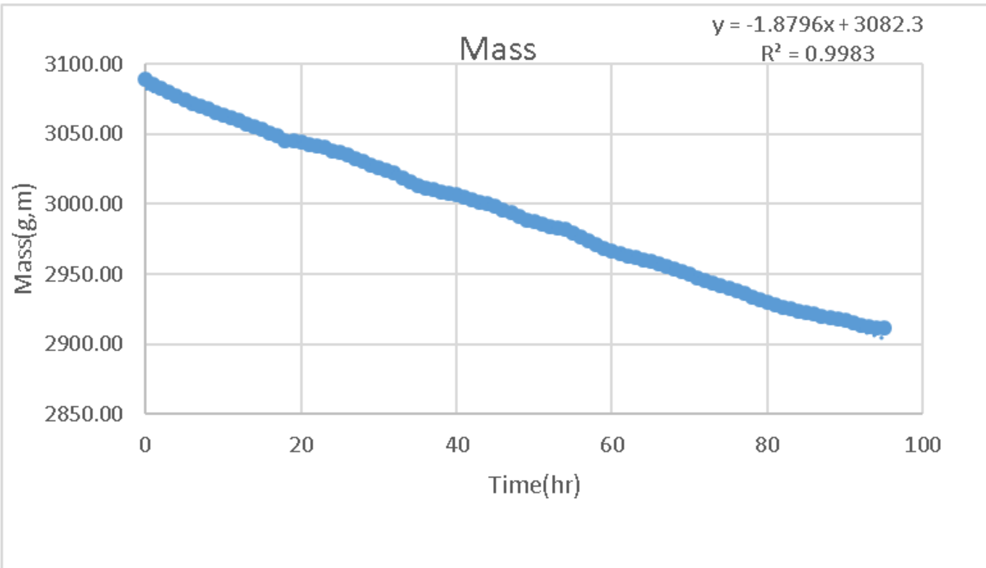
Uncertainty Analysis

1. Measurand - Average Evapotranspiration rate ‘e’ ($\frac{g}{cm^2 s}$)

e = f(D,M, t)

2. Mathematical Model - $e = \frac{m}{\frac{\pi d^2}{4}}$

We have the following graph for mass decrease with time from where we can calculate m at different time intervals.



3. Estimate of D: 16.994 cm

Estimate of m: -5.2×10^{-4} $\frac{g}{s}$

4: Standard Uncertainty

	Source of Uncertainity	Type of Evaluation	Distribution	ai	Divisor	Sensitivity Coefficient	Standard Uncertainty	Unit
	Resolution	B	Rectangular	0.02	$\sqrt{12}$	1	0.00577	cm
D	Repeatability	A	Normal	0.02225	1	1	0.022254	cm
	Combined				1	2.698×10^{-7}	0.02298	cm
m	Combined		Normal	0.000177	1	4.409×10^{-3}	0.000177	g/s

5: Inputs are not related so covariance is not calculated.

6: Estimate e = $2.36 \times 10^{-6}\ \frac{g}{cm^2 s}$

7: Combined Uncertainty – $7.804 \times 10^{-7}\ \frac{g}{cm^2 s}$

Mass rate has more contribution in uncertainty than diameter.

8: Evaporation rate (g/cm2s) -$(2.36 \pm 0.78) \times 10^{-6}\ \frac{g}{cm^2 s}$

Percentage uncertainty - 32.77 %

9. Degree of freedom – 6, Degree of freedom of mass rate - 95

Degree of freedom of evaporation rate- 95

10 Expanded Uncertainty considering 95% confidence level α = 0.05 two tailed .

Coverage factor k = 1.985 using t distribution.

ku_e= $1.986 \times 7.804 \times 10^{-7}$ = 1.549×10^{-6}

Expanded Uncertainty e = $2.36 \pm 1.55 \times 10^{-6}\ \frac{g}{cm^2 s}$

Evapotranspiration E = $\frac{e}{density} \times 36000\ \frac{mm}{hr}$ = $(8.50 \pm 5.58) \times 10^{-2}\ \frac{mm}{hr}$

The evapotranspiration rate E is $(8.50 \pm 5.58) \times 10^{-2}\ \frac{mm}{hr}$ or $2.04 \pm 1.34\ \frac{mm}{day}$

Conclusion

After four days of consistently collecting data we have concluded that evapotranspiration rate is $2.04 \pm 1.34\ \frac{mm}{day}$

This method provides a foundational approach to eestimating evapotranspiration and understanding uncertainity based on available data from sensors