DESIGN AND DEVELOPMENT OF SMART FIELD LYSIMETER

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CERTIFICATION

I hereby undertake that this report is an original one and no part of this report falls under plagiarism, if found otherwise at any stage, we will be responsible for the consequences.

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Certified that the contents and form of final year design project entitled **Design and Development of Smart Field Lysimeter** has been found satisfactory for requirements of the degree.

Supervisor: _____________

Dr. Fiaz Hussain

Dedicated

To

Almighty Allah Subhanautallah

And Syedina Rasool Allah

(Sallallahu alaihi wa'alaihe wasallam)

And

To our beloved Parents

(Whose contributions are unforgettable for Us)

Table of Contents

List of Figures

Acknowledgement

The research project titled "Design and Development of Smart Field Lysimeter" was successfully completed in the Irrigation and Drainage Lab of Department of Agricultural Engineering, PMAS-Arid Agriculture University Rawalpindi under the Pakistan Engineering Council (PEC) Annual Award of Final Year Design Projects (FYDPs) for the year 2022-2023. The Project was supervised by Dr. Fiaz Hussain, Assistant Professor, Department of Agricultural Engineering, Arid Agriculture University Rawalpindi.

ABSTRACT

The changing climate and increasing population are the most significant challenges to crop productivity and water resource management of Pakistan. In Pakistan, where water scarcity is a significant challenge for agriculture, for such issues, precision irrigation is a promising solution to enhance water use efficiency and crop productivity. Smart lysimeter enables controlled collection and analysis of water dynamics/movement through the soil profile in agricultural system. In this FYDP, we developed indigenized smart field lysimeter for accurate calculation of crop water requirement (CWR) of shallow rooted crops. This device is equipped with different sensors such as soil moisture sensors, soil temperature sensors and weight sensors etc. for accurate measurement of crop water requirement (CWR). The smart field lysimeter was designed by incorporating data logging technologies with advanced sensing capabilities and developed using indigenized local materials. The project is unique in terms of its real time monitoring of cropping system that will provide essential data for sustainable agricultural water management and will benefit researchers, agronomists, policy makers and stake holders.

Keywords: Smart field lysimeter; Soil moisture sensors; Crop water requirement; Real-time monitoring; Agricultural water management

CHAPTER 1
INTRODUCTION

1.1 Global Scenario

The studying of soil-water interactions is one of the important aspects for sustainable water management. This can be done by using smart/precise irrigation tools. The growing concerns about environmental degradation and the need for sustainable water resource management have highlighted the importance of studying soil-water interactions and their impacts on ecosystems. Lysimeters is a commonly used tool for studying water and nutrient dynamics in soil systems. Lysimeters offer valuable insights into the water balance within agricultural systems, enabling informed decision-making for irrigation scheduling and water conservation strategies. Researchers and policymakers worldwide are increasingly embracing lysimeters as essential tools for understanding and managing water resources in agriculture (Nicolás-Cuevas et al., 2020).

Traditional lysimeters requires manual data collection and lack real-time monitoring capabilities. To address these limitations and enhance environmental monitoring practices, the integration of smart technologies into lysimeters has gained significant attention (Wang et al., 2022).

The optimal management of water resources enables more efficient water use. For this purpose, crop evapotranspiration (ET_C) is an important data source for adjusting the amount and frequency of irrigation to meet the needs of each crop (Nicolás-Cuevas et al., 2020).

With the challenges posed by a growing population and changing climate patterns, there is a heightened focus on optimizing irrigation practices, conserving water resources, and enhancing crop productivity.

1.2 Pakistan's Context

Efficient water resource management is of utmost importance because country is facing water scarcity. The water scarcity is a significant challenge for agriculture, so the accurate measurement and monitoring of soil-water interactions become crucial for sustainable cropping system. Smart field lysimeter provides real-time data on soil moisture, nutrient leaching, and other critical parameters that can revolutionize the cropping system and best to manage agriculture water management in irrigated regions of Pakistan. This can empower farmers, policymakers, and researchers to make informed decisions and optimize irrigation and fertilizer application strategies.

1.3 Lysimeters

Lysimeters have long been recognized as valuable tools for studying water dynamics in agricultural systems. A lysimeter is a measuring device to measure the amount of actual evapotranspiration released by plants. These experimental setups enable controlled collection, quantification, and analysis of water infiltrating or percolating through the soil column. By simulating realistic field conditions, lysimeters provide insights into essential soil-water-plant interactions, allowing researchers to study the effects of water movement on crop growth, evapotranspiration, and nutrient availability. Over the years, lysimeter designs have evolved, incorporating improvements such as weighing systems and data acquisition technology to enhance accuracy and reliability (Ratke et al., 2023).

Lysimeters are used to calculate the amount of water lost by plants owing to evaporation. They monitor the amount of precipitation and irrigation water applied to the crop, as well as the amount of water lost through percolation in the soil. This information can be used to determine how much water and evapotranspiration the crop needs. Lysimeters are crucial equipment made up of tanks or containers that govern how much water can stay in the soil and monitor the soil water balance, how much water moves vertically, or how much water is present in the soil (Hussain et al., 2023).

Equation of Lysimeter:

$$ET_C \text{ (mm/hr)} = \text{Mass Loss} - \text{Drainage Loss} + \text{Irrigation and/or Rainfall}$$

1.4 Types of Lysimeters

There are two types of lysimeters: weighing and volumetric. The volumetric technique estimates the ET_c as a residual by monitoring the other components of the soil water balance. The change in mass acquired by weighing the container in which the soil is located is used to calculate the gain or loss of water in weighing lysimeters. Lysimeters are often viewed as difficult to handle, expensive to produce, and their use and maintenance demand special attention, limiting their use to research facilities. In the literature, various weighing lysimeters have been discussed. Weighing lysimeters have a long history of development, with many different designs being used (Payero et al., 2009).

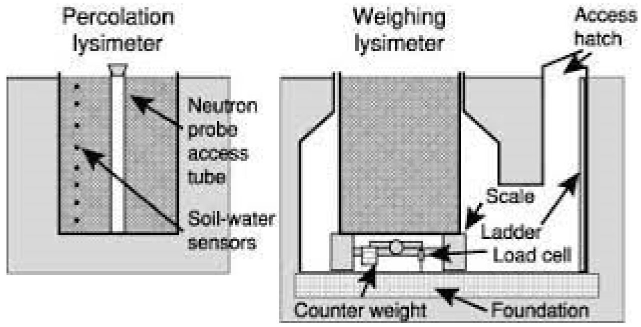

Figure 1 Types of Lysimeters

Improvements in the design and installation of lysimeters entirely supported by load cells and data collection systems have lately permitted the design and installation of lysimeters entirely supported by load cells without the use of balance beam mechanisms or other moving parts (López-Urrea et al., 2021).

1.5 Working Principle

The Lysimeter is made up of two primary parts. The cylindrical dirt monolith that is continuously weighed is the first component. The second component, which is normally housed in a separate field box, consists of equipment for collecting and measuring percolated water as well as returning water to the Lysimeter as necessary to keep the soil water level in the Lysimeter at the same level as the surrounding soil. The vegetation on the Lysimeter surface should be consistent with the surrounding vegetation.

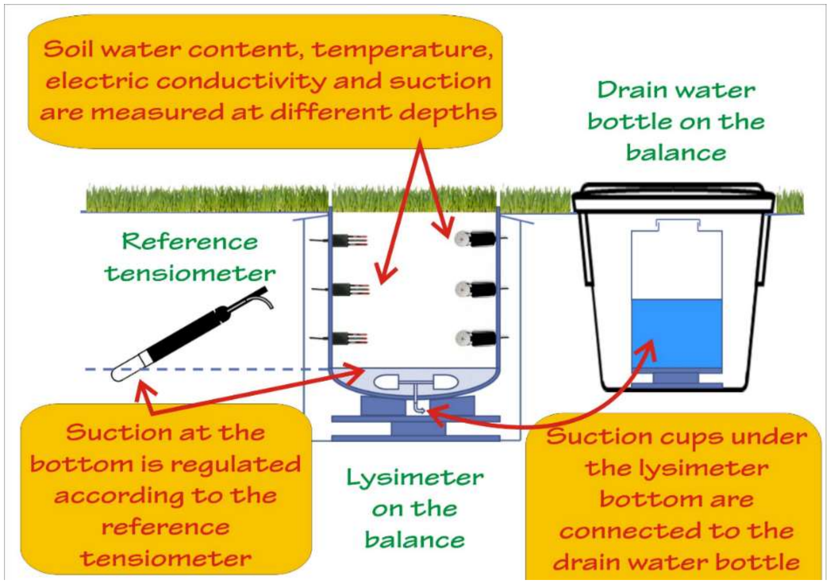

Figure 2 Basic structure of Smart Lysimeter.

The Smart Field Lysimeter is depicted schematically in the above figure. The soil monolith is housed in a stainless-steel cylinder with several sensor apertures on the sides. A stainless-steel cylinder and a jack, which can be handled manually for smaller lysimeters, are used to withdraw the undisturbed soil monolith from the natural soil. The cylinder carrying the soil monolith is buried underground inside a protective container (the lysimeter housing). The container is balanced on an electronic balance, which continuously measures its weight.

1.6 Smart Field Lysimeter

The word "lysimeter" finds its origin in the Greek term "lysis," denoting the act of dissolution or loosening, symbolizing the water percolation process through layers of soil. The smart field lysimeter consists of sensors that measure different parameters within soil profile. These sensors include soil moisture sensors, soil temperature sensors, humidity sensors, etc. which aid in measuring the real-time data of the field conditions. This parametric adaptability makes it a smart and efficient tool.

The design and development of smart field lysimeters offer several advantages over traditional lysimeters. Firstly, the integration of advanced sensors and data acquisition systems enables continuous data collection, eliminating the need for manual measurements. This real-time monitoring capability provides a comprehensive understanding of soil-water dynamics, including infiltration rates, evapotranspiration, and drainage patterns. Secondly, smart lysimeters can remotely transmit data to a centralized system, allowing researchers and stakeholders to access information anytime and anywhere. This enhances the efficiency and convenience of environmental monitoring, especially in large-scale agricultural systems. Moreover, the integration of smart technologies facilitates data analysis and visualization, enabling the identification of trends and patterns that may not be apparent through manual data collection methods.

Furthermore, the design and calibration of weighing lysimeters are integral to accurately measure evapotranspiration and water infiltration rates, providing essential data for irrigation planning (Doležal et al., 2018). Recent advancements in sensor technology, such as compact and removable weighing lysimeters (Ávila-Dávila et al., 2021; Nicolás-Cuevas et al., 2020), and the application of image detection systems and data fusion techniques for comprehensive agricultural monitoring (Wang et al., 2022), have further enhanced the capabilities of smart field lysimeters. Additionally, research on automated irrigation systems, utilizing IoT and cloud computing, has provided valuable insights into control strategies and data management aspects (Vera-Repullo et al., 2015).

Building upon the knowledge derived from previous studies, this thesis aims to design and develop indigenized smart field lysimeter. By incorporating data logging technologies and advanced sensing capabilities, an indigenized smart field lysimeter system was designed to enable real-time monitoring, precise irrigation management, and improved water resource utilization. The outcomes of this research not only benefit researchers and agronomists but also inform policymakers and stakeholders in formulating strategies for sustainable agriculture and water management.

CHAPTER 2
LITERATURE REVIEW

In this chapter, a review of related research work interconnected with the current study is presented conducted by several scientists around the world.

Agriculture smart sensing (ASS) is a new paradigm that utilizes low-cost, low-energy sensors to automate processes and enhance agricultural productivity. It offers quantitative and qualitative improvements in production, benefiting farmers financially and ensuring the delivery of fresh products. ASS employs consumer electronics (CE) devices to automate tasks, monitor soil health, crop growth, livestock health, and detect anomalies. These devices use various communication protocols to transmit sensory data. ASS offers a wide range of applications and has great promise for the development of efficient and cost-effective CE devices for agriculture. This taxonomy investigates many uses and improvements in smart sensing for agriculture while addressing the difficulties encountered in developing such devices (Kumar et al., 2021).

Recent technological advances, notably in artificial intelligence (AI), have had a significant impact on remote sensing and smart agriculture. By delivering sensor-based technology and gadgets, AI-enabled sensors, also known as smart sensors, in conjunction with the Internet of Things (IoT), have revolutionized agriculture. The study investigated several sensor and technologies of IoT developments that assist researchers, agriculturists, remote sensing scientists, and legislators (Ullo & Sinha, 2021).

The Internet of Things (IoT) is a game-changing technology to enable a smart environment. Sensors have tremendous promise in scientific research. For a unified operating picture due to ubiquitous sensing capabilities. IoT sensors are being used efficiently in a variety of applications, encouraging smart surroundings. Analyzing various sensor applications, it sheds light on which type of sensor is appropriate for specific IoT applications (Sehrawat & Gill, 2019).

IoT plays an important role in linking sensor devices for a variety of functions, such as smart irrigation systems that monitor water levels, climate, and irrigation efficiency. Through IoT, AI, DL, ML, and wireless communications, unmanned aerial vehicles (UAVs) and robots contribute to functions such as harvesting, weed identification, and livestock applications. Smart Decision Support Systems (SDSS) is for real-time analysis and proper decision-making (Said Mohamed et al., 2021).

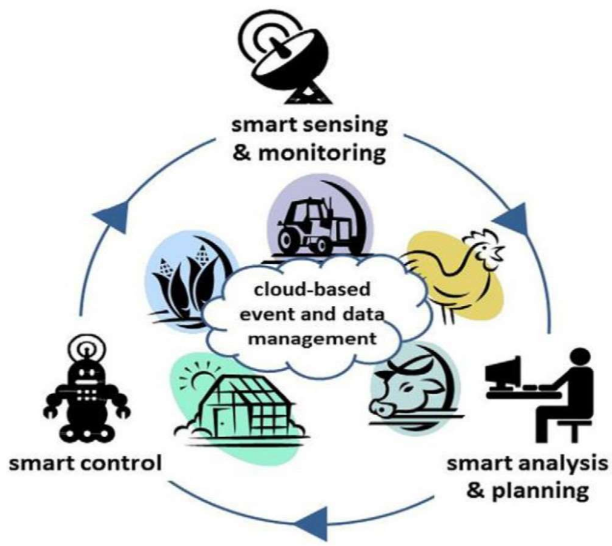

Figure 3 Smart Sensing Cycle. Source (Said Mohamed et al., 2021)

Camarinha developed a smart lysimeter model with the help of IoT sensors for the analyses and collection of data on parameters such as soil temperature and humidity at different depths, air temperature and humidity, and solar exposure (both visible and infrared) in addition to evaporation and transpiration. In addition, the system takes high-resolution photos of the target crop, for pest and crop analysis to monitor and increase agricultural productivity (Camarinha-Matos et al., 2022).

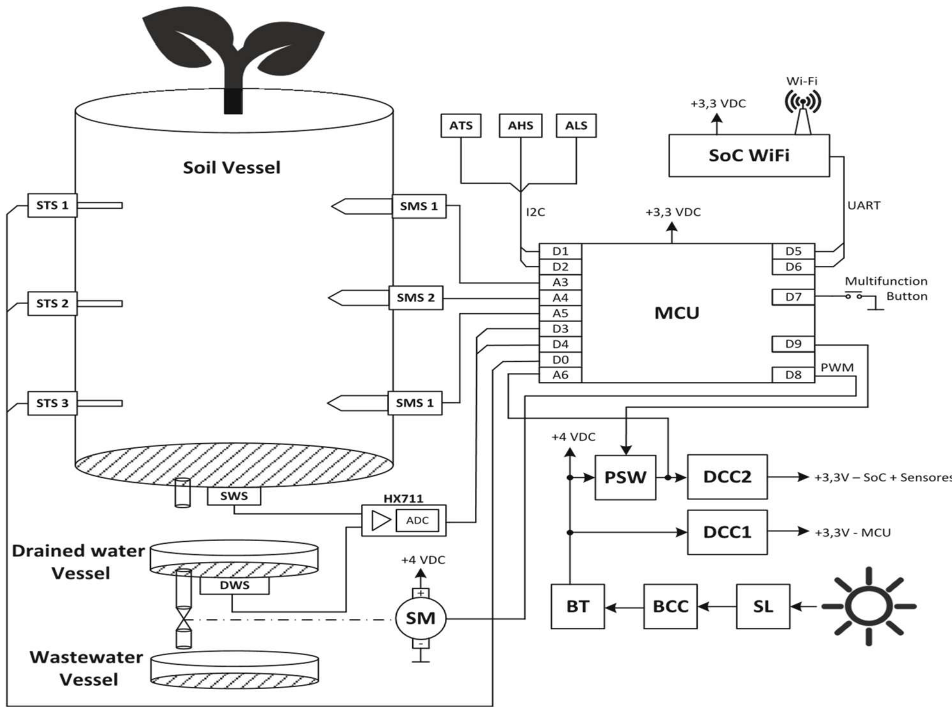

Figure 4 Smart Lysimeter module developed by (Camarinha-Matos et al., 2022)

A low-cost, portable smart lysimeter was designed by the Department of Biosystems Engineering at University of Arizona. Equipped with sensors, the Smart Lysimeter analyzes real-time monitoring, measures pH, electric conductivity, and drainage rate in a greenhouse. The design includes a collection tank housing sensor, pumps, and a Raspberry Pi microcontroller with an LCD screen for data interaction as shown in the figure (Schmidt et al., 2018).

A portable smart weighing lysimeter was designed to determine real-time crop coefficient (K_c) and water requirements of chrysanthemum crops at CPCT, IARI, New Delhi, India. The obtained K_c values for chrysanthemum crops aligned well with the FAO 56 paper's recommendations, with values decreasing as the season progressed. The smart lysimeter provides real-time measurement, mobility, and precise findings which makes it an important instrument for calculating CWR and K_c for crops (Sagar et al., 2022).

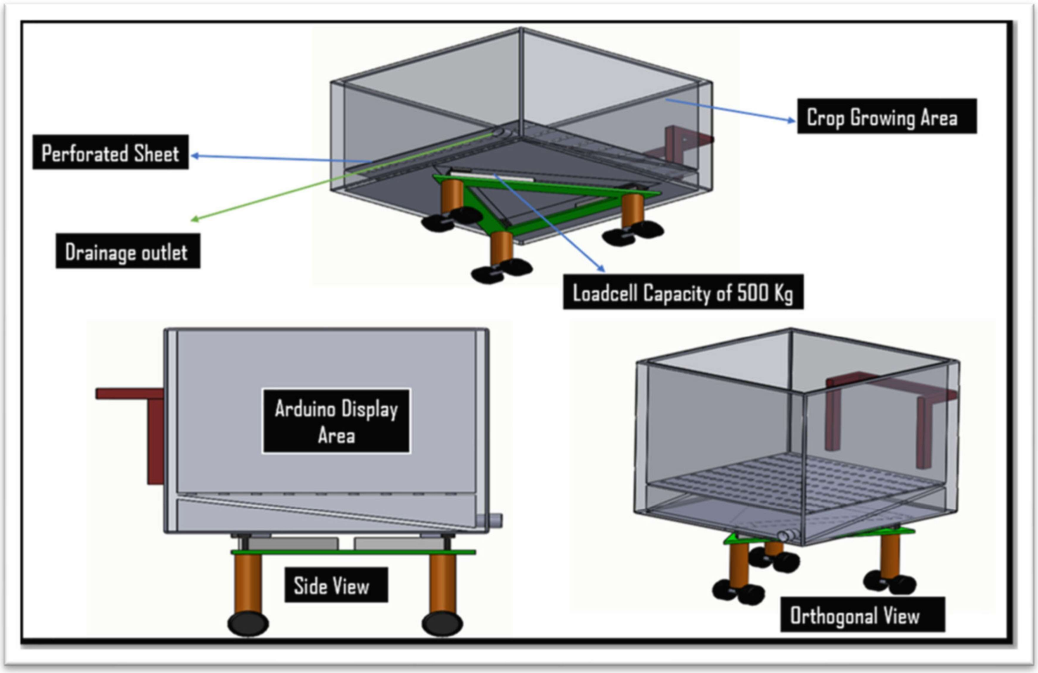

Figure 5 Smart Lysimeter developed by (Sagar et al., 2022)
for Chrysanthemum Crops in CPCT, IARI, India.

Weighing lysimeters, which measure weight changes over time, are critical in monitoring crop water intake. By detecting weight swings in plants, soil, and water, these lysimeters determine crop evapotranspiration. A low cost field scale weighing lysimeter design consists of Arduino Mega microcontroller, HX711 load cells, and a Printed Circuit Board (PCB) was installed at a demonstration farm in Vicksburg (Dong and Hansen, 2023).

The soil moisture behavior and water infiltration rate of a silt loam soil were studied using a compact weighing lysimeter by Ávila-Dávila under varied rainfall situations. There were two ways used: one for soil below field capacity and one for soil over field capacity. Both procedures efficiently established soil infiltration curves for different application times, according to the results. The soil originally exhibited variable and rapid penetration before reaching a consistent infiltration rate as its pores filled. While the mass conservation and continuity equations are straightforward and satisfactory, more study with more advanced measurement tools such as soil moisture and water potential sensors is required to track wet front movement in saturated situations (Ávila-Dávila et al., 2021).

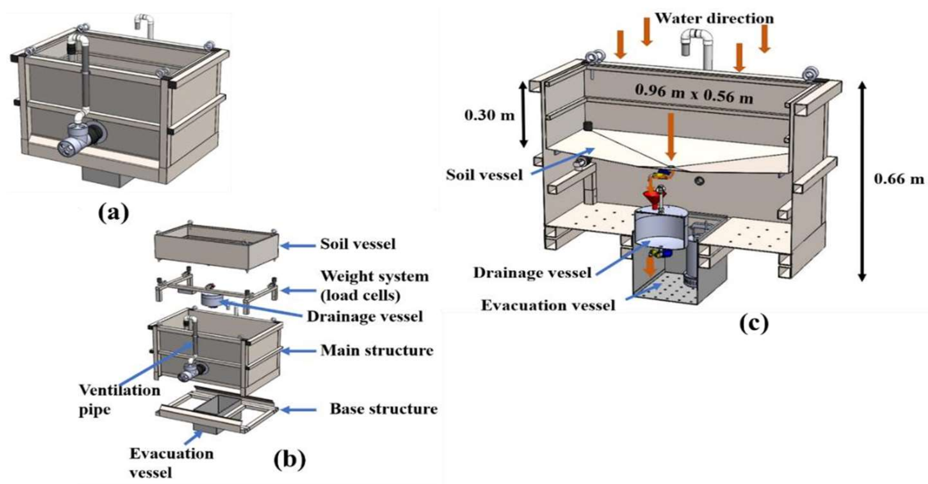

Figure 6 Compact Weighing Lysimeter developed by (Ávila-Dávila et al., 2021)

(Payero & Irmak, 2008) developed weighing lysimeter in West Central Nebraska to measure evapotranspiration (ET) of maize and soybean. Each lysimeter costs about $12,500 to build and install, depending on equipment and labor availability. They identified that higher resolution dataloggers may increase the resolution of lysimeters, lowering measurement errors at lower ET values (Payero & Irmak, 2008).

Figure 7: Inner and outer lysimeter boxes (Payero & Irmak, 2008).

Schmidt developed a precision weighing lysimeter for measuring tobacco evapotranspiration in Bahia, Brazil. The lysimeter was 1.60 m long, 1.10 m wide, and 0.60 m deep, having a 1.76 m2 internal soil surface area. It was placed in a shaded region designated for tobacco production. The lysimeter was built up of a steel inner box and a burnt-clay exterior box. Data was collected using a weighing platform with four 1,000 kg load cells and a datalogger (C. D. S. Schmidt et al., 2018).

Evapotranspiration from twelve individual plants in a glasshouse was measured using a mini-lysimeter device with twelve load cells (20 kg capacity). A data logger linked to a multiplexer aided in the acquisition of load-cell signals in full-bridge excitation mode. This mini-lysimeter device provides an economically effective and robust approach for correctly monitoring evapotranspiration with appropriate resolution (Misra et al., 2011).

A lightweight and portable weighted lysimeter was built for horticulture crops by Nicolas. This lysimeters was easy to assemble, transport, and install with minimal soil disruption. After testing, the measurement accuracy findings show that the prototype is reliable. A comparison with other weighing lysimeters demonstrates the precision and dependability of this prototype, which successfully decreases the size and depth requirements of conventional lysimeters. In places with limited water resources, this novel instrument provides an accurate and effective alternative for measuring crop water requirements (Nicolás-Cuevas et al., 2020).

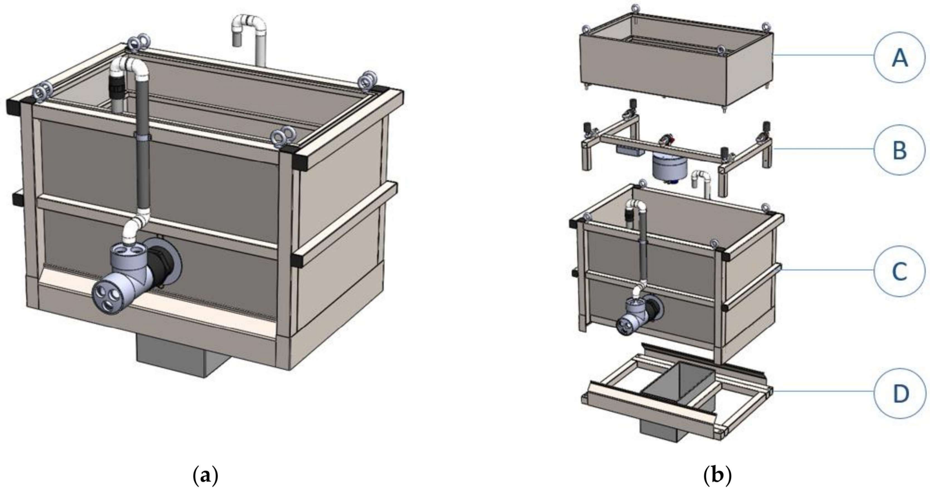

Figure 8 Lysimeter developed by (Nicolás-Cuevas et al., 2020) (A) culture tank; (B) cultivation tank support; (C) main structure; and (D) base.

(Soler-Méndez et al., 2021) developed portable weighing lysimeter for assessment of CWR, soil field capacity for efficient irrigation control of horticultural crops. The results were optimized due to controlled environment that leads to agricultural water management.

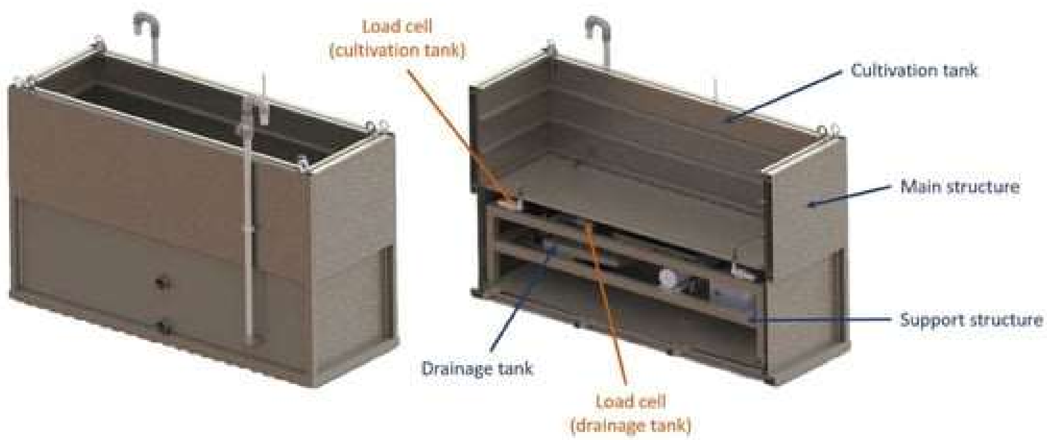

Figure 9 Portable weighing lysimeter structure. Source (Soler-Méndez et al., 2021)

According to review of literature as discussed above, the lysimeter is a compatible device for accurate estimation of crop water requirement (CWR) and crop coefficient (K_c). Researchers have developed various portable, smart field lysimeters according to local conditions. By keeping in view, the knowledge derived from the literature review, we also tried to develop a field scale, smart lysimeter using indigenized materials. That lysimeter was low-cost and stand alone, it was used to study soil-water interactions to measure CWR and K_c values.

CHAPTER 3
PROBLEM STATEMENT AND OBJECTIVES

3.1 Problem Statement

In Pakistan, farmers and irrigation managers often face challenges in determining the accurate crop water requirement (CWR) for irrigation scheduling and agricultural water management. According to literature review, in Pakistan, Agri-Engineers and irrigation managers used FAO 56 manual and climate data for estimation of evapotranspiration for designing and modelling irrigation systems. In addition, the crop coefficient K_c, the most important parameter for crop water requirement (CWR) is also obtained on ad-hoc basis from literature data. This kind of parametric adaptability may bring uncertainty in design of irrigation scheduling system. Smart field lysimeter is one of the devices that can provide real-time accurate measurement of both parameters (ET_o and K_c) to make informed decisions about irrigation, but the cost of the smart device is expensive and need to develop indigenized smart field lysimeter for accurate assessment and monitoring of crop water.

3.2 Objectives

This Project has the following objectives.

1. To design and develop indigenize smart field lysimeter for measuring evapotranspiration (ET).
2. To provide recommendations for making informed decisions about irrigation scheduling.

CHAPTER 4
MATERIALS AND METHODS

By keeping in view, the literature review described in the previous section of this thesis, we adopted the following methodology which is shown underneath.

4.1 Preliminary Study

We conducted an initial inquiry to assess the various requirements and constraints in developing an indigenized smart field lysimeter. This analysis included area weather trends, crop varieties, available assets, and budget.

4.2 Conceptual Design

Based on the literature review and preliminary study, we developed a conceptual design for the indigenized smart field lysimeter. This design includes details of sensor selection, data acquisition system, communication protocols, and interfaces for real-time data monitoring. The lysimeter architecture utilizes current data logger technology to build a low-cost, high-performance solution. The design corresponds to data logging standards, with the goal of achieving cost-effectiveness and efficiency.

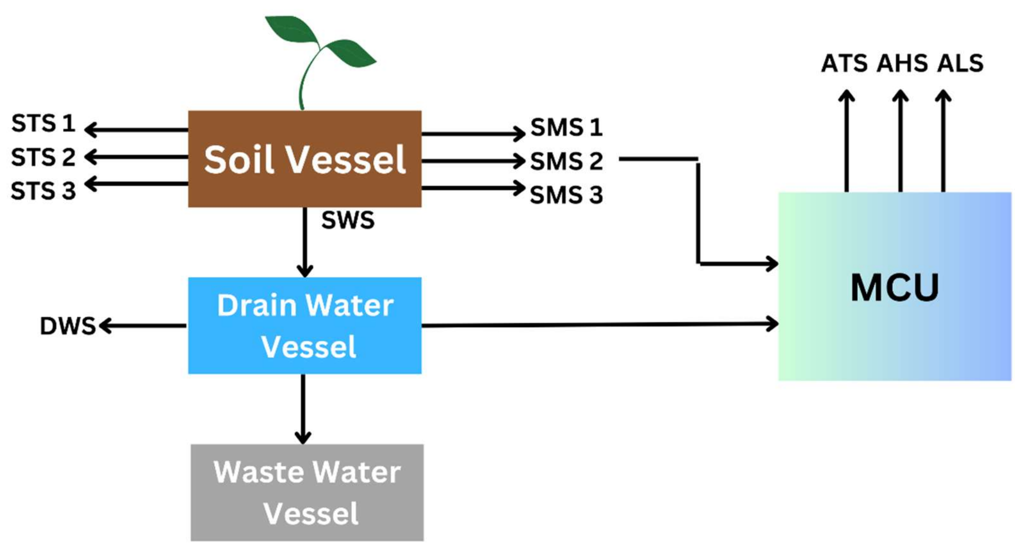

Figure 14 Flow Chart of Smart Lysimeter

The above figure shows the basic conceptual design of the indigenized smart field lysimeter.

Acronym	Description
MCU	Microcontroller Unit
ATS	Ambient Temperature Sensor
AHS	Ambient Humidity Sensor
ALS	Ambient Light Sensor
STS	Soil Temperature Sensor
SMS	Soil Moisture Sensor
SWS	Soil Weight Sensor
DWS	Drained Water Weight Sensor

Table 1: List of Acronyms

4.3 Material Selection

Selection of materials for the indigenized smart field lysimeter involves a meticulous selection process. The chosen materials should exhibit durability in the face of local climatic conditions and provide accurate data collection capabilities. Assessing the availability of resources within the region is crucial to ensure a sustainable supply chain. Additionally, cost-effectiveness plays a pivotal role in adhering to budget constraints, while maintaining the lysimeter's operational efficiency and longevity.

For this, we visited different markets and opted for the locally available materials which can aid in the designing and development of lysimeter structure. While selecting the materials, we kept in mind to ensure the long life and sustainable materials that would be efficient and pocket friendly.

We looked for different components that were needed for the lysimeter architecture which includes blue poly drum, solar panel and batteries, a flow meter pump, load cells, data logger, microcontroller, angle iron, metal sheets, different types of sensors i-e Temperature, Soil Moisture, Humidity, Light etc. Lastly, we choose the materials that fit best for our design and budget.

4.4 Components of Lysimeter with Specifications

The indigenized smart field lysimeter architecture is comprised of the following major components:

1. **Pumping System:**

A bi-directional pump is a type of pump that is designed to operate in both directions of fluid flow. It is capable of pumping fluid in one direction and then reversing the flow and pumping in the opposite direction.

In our smart lysimeter system, we have implemented a bi-directional pumping system to regulate water levels within the crop. The primary objective of this system is to ensure optimal water management. When an excess amount of water is supplied to the crop, our pump initiates operation, effectively removing the surplus water and transferring it to a designated drainage tank. Similarly, in situations where the crop requires additional water, the bi-directional pump facilitates the transfer of water from the tank back into the crop, maintaining the desired water balance. This approach enables precise control and regulation of water levels within the lysimeter system, promoting efficient crop growth and minimizing water waste.

Specifications:

- It measures the discharge in LPM (liter per minute).
- We used a relay of 1 data pin to control the switching system.

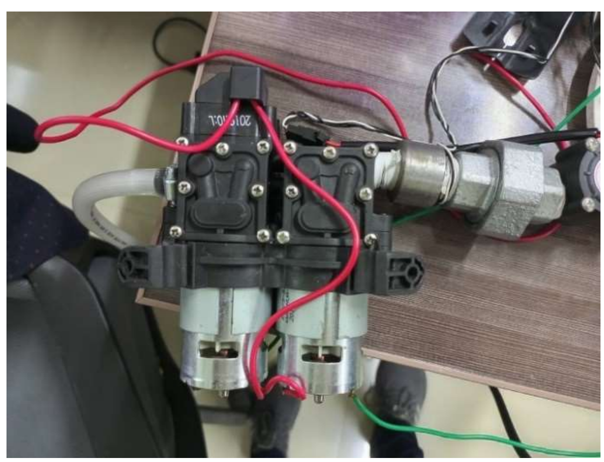

Figure 10 Bi- Directional Pump

2. **Weighing Platform:**

The weighing platform is an integral part of the lysimeter setup, typically located beneath the lysimeter or integrated within its structure. It is designed to support the lysimeter and accurately measure changes in its weight over time. The platform is equipped with load cells or other weight-measuring devices that can detect even slight variations in the mass of the lysimeter and its contents.

Figure 11 Gauge Sheet

By continuously monitoring the weight of the lysimeter, researchers can determine the water balance dynamics, including evapotranspiration rates and water infiltration or drainage. The data obtained from the weighing platform allows scientists to study the movement of water within the lysimeter system, quantify the water requirements of plants, and investigate various hydrological processes in soil and vegetation.

Figure 12 Weighing Platform

We require two weighing platforms for specific purposes. One platform is intended for measuring the weight of the soil tank, while the other is designated for measuring the drainage tank. To fulfill this requirement, we have employed a 200kg weight cell for the soil tank and an 80kg weight cell for the drainage tank. The frame for each load cell has been constructed using locally available materials. The load cell for the soil tank has been crafted from a 10-gauge sheet, while the load cell for the drainage tank has been fabricated using a 14-gauge sheet.

Specifications:

- 2 load cells were used in the system to incorporate the weight of the lysimeter tank and drain tank simultaneously.
- For the soil vessel, a weighing platform was made up of mild steel of 10-gauge sheet with the dimensions of 14” × 14” and a load cell of 200kg.
- Similarly, another weighing platform was made for the drainage tank of MS 14-gauge sheet with dimensions 1ft × 1 ft and a loading capacity of 100kg.

3. **Drain Tank:**
A drain tank refers to a container or reservoir that collects the drainage or percolate water that passes through the lysimeter system. A lysimeter is a scientific instrument used for studying the movement of water through soil and the associated processes, such as leaching and nutrient transport. The drain tank serves as a collection point for the water that drains or percolates through the lysimeter, allowing researchers to measure and analyze the quantity and quality of the water

that flows out of the system. The drain tank is used to catch the drain water from the crop, and we can also use the drain tank as a water storage tank and use bidirectional pump to maintain the crop water requirement.

Specifications:

- We used a plastic tank or container to hold all the percolated water from the soil vessel into this tank with the action of gravity.
- The height of this tank was 16” (inches).

Figure 13 Drain Tank

4. **Lysimeter Cylinder:**

A lysimeter cylinder is a specialized device to study the water movement and other processes within the soil. It is a cylindrical container or column that is installed vertically into the ground, used to observe, and measure various parameters related to water infiltration, evapotranspiration, and nutrient dynamics.

The lysimeter cylinder is typically made of a non-reactive material, such as PVC (polyvinyl chloride) or stainless steel, to prevent any chemical reactions or interactions with the soil or water being studied. This setup allows researchers to monitor water inputs, such as rainfall or irrigation, and measure the amount of water that infiltrates into the soil, as well as the water that is lost through evapotranspiration or drained through the bottom of the cylinder. The lysimeter cylinder is filled with sand.

Specifications:

- For the lysimeter cylinder, we used a blue poly drum. The length of the cylindrical tank is 32 inches while the circumference of the tank is 52 inches.
- The major reason for selecting this type of material for lysimeter was to ensure durability and low-cost. Blue poly drum is an efficient heat resistor.
- Six sensors were installed in this lysimeter cylinder that measures the soil moisture and temperature parameters at alternate depths of 6 inches.

Figure 14 Lysimeter Cylinder

5. **Sensors:**

We employ a range of sensors to gather data pertaining to the parameters related to lysimeter like evapotranspiration, humidity, soil moisture, and temperature.

To accurately assess evapotranspiration, we rely on dedicated sensors that provide real-time measurements. These sensors enable us to gauge the rate at which water is evaporating from the soil surface as well as the transpiration occurring from plants. By continuously monitoring these values, we gain valuable insights into the water consumption patterns of the ecosystem under observation.

Moreover, our humidity sensors play a crucial role in capturing and quantifying the moisture content in the surrounding environment. These devices offer precise measurements of relative humidity, aiding us in understanding the atmospheric conditions and their impact on water availability.

In addition, we utilize sensors designed specifically for soil moisture assessment. These sensors are strategically placed in the soil profile to monitor moisture levels at various depths. This information allows us to evaluate the overall moisture distribution within the soil, thereby facilitating effective water management strategies.

Lastly, our temperature sensors assist in recording the ambient temperature within the study area. By monitoring temperature fluctuations, we can better comprehend the thermal dynamics that influence evapotranspiration and overall water balance.

6. **Data Collection:**

We use a data logger to gather our daily data from the sensors and we can connect the data logger to the laptop and store the data on our pc. We can use the collected data for our research.

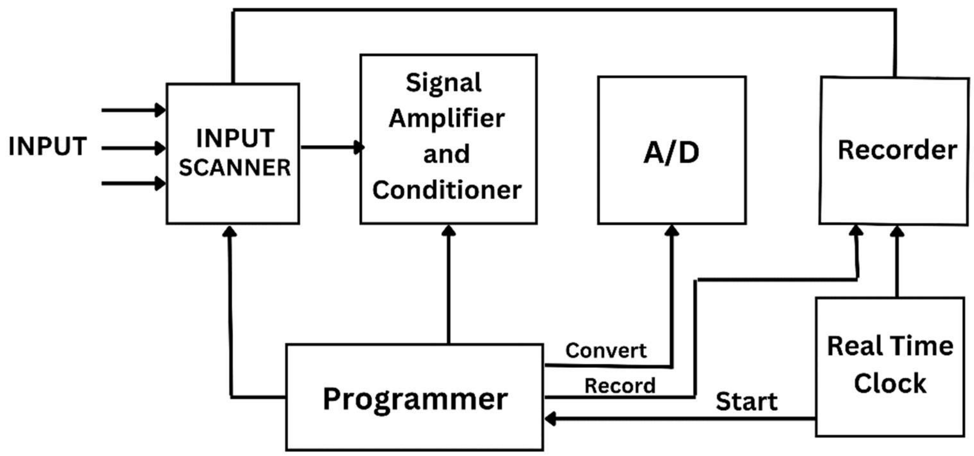

Figure 15 Line Diagram of Data Logging

4.3 Working of Lysimeter

The indigenized smart field lysimeter's physical structure consists of three interconnected vessels outfitted with various sensors. The top vessel houses the soil and plants, while the middle vessel collects and measures the wastewater draining from the soil, allowing evapotranspiration (ET) to be calculated. The effluent is then moved to the bottom tank for additional chemical and physical examination, such as percolation research.

The lysimeter module has sensors that measure soil and ambient factors. These include the temperature and humidity of the soil at various depths. It also calculates evapotranspiration by measuring the weight of the soil vessel and the drained water, as well as the ambient temperature, humidity, and light intensity. These sensors are linked to a low-power MCU (Microcontroller Unit) that oversees data collecting and transmission. The MCU also monitors and maintains the power supply, enabling all circuits to function throughout data collecting, processing, and transfer to the cloud. When the module is in standby mode, it turns off the individual circuits (sensors and SoC) to save power. After a preset polling interval, power is restored.

CHAPTER 5
RESULTS AND DISCUSSION

The Results and Discussion section of this final year project report presents a comprehensive analysis and interpretation of the data gathered throughout the study. This section aims to provide a detailed overview of the findings, shedding light on the key outcomes and their implications. This chapter is intended to evaluate the performance and accuracy of the sensors used in the lysimeter.

5.1 Readings

The following section shows different parameters of the smart field lysimeter.

- **Soil Moisture %**

  The soil moisture percent in a lysimeter refers to the percentage of water content in the soil. It is measured using instruments and indicates the amount of water present relative to the soil's capacity. It is important for water resource management and understanding plant-water relationships. The soil moisture sensors (SMS) were installed at different depths with a gap of 6 inches each inside the lysimeter cylinder.

- **Temperature Sensor**

  A temperature sensor in a smart lysimeter is used to monitor and record soil temperature. It provides essential data for irrigation management, frost protection, soil health assessment, and climate research. In the lysimeter module, three temperature sensors were installed to check the soil’s temperature at different depths.

- **Humidity Sensor**

  A humidity sensor in a smart lysimeter is used to monitor and control soil or air moisture levels. It aids in irrigation management, evapotranspiration monitoring, disease prevention, environmental research, and data-driven decision-making.

- **Load Cell Output**

  The load cell output in a lysimeter measures the weight or mass changes within the system, providing data on soil moisture dynamics and water balance.

- **Light Sensor Value**

  A light sensor in a smart lysimeter measures light intensity for monitoring photosynthesis, plant growth, energy balance, and environmental research.

  Figure 22 shows the readings of different sensors of the lysimeter system with a time interval of 1 hour. By using this data, we can calculate the evapotranspiration rate and measure the water balance.

Date/Time	Soil Moisture 1 %	Soil Moisture 2 %	Soil Moisture 3 %	Temperature 1	Temperature 2	Temperature 3	Temperature DHT	Humidity	Load cell 1 Output	Load cell 2 Output	Flowrate (LPM)	Flowrate (mL/s)	Total Flow (mL)	Light Sensor Value
6/20/2023 15:00	98	4	22	30.5	30.12	30.56	30	43.2			0	0	0	197
6/20/2023 16:00 P	98	4	22	30.5	30.06	30.56	30	44.7			0	0	0	217
6/20/2023 17:00	98	4	22	30.5	30.6	30.62	30	44.6			0	0	0	210
6/20/2023 18:30	98	4	22	30.5	30.12	30.62	30	44.6			0	0	0	208
6/20/2023 19:00 P	98	4	22	30.5	30.12	30.56	30	44.6			0	0	0	208
6/20/2023 20:00	98	4	22	30.5	30.12	30.56	30	44.6	-0.53	-3.87	0	0	0	175
6/20/2023 21:00 P	98	3	22	30.5	30.12	30.62	30	44.6			0	0	0	191
6/20/2023 22:00	98	41	22	30.5	30.12	30.56	30	44.6			0	0	0	190
6/20/2023 23:00	98	36	22	30.5	30.12	30.62	30	44.6			0	0	0	197
6/21/2023 0:00	91	54	22	30.5	30.12	30.62	30	44.6			0	0	0	210
6/21/2023 1:00	98	91	14	30.5	30.06	30.56	30	44.6			0	0	0	184
6/21/2023 2:07	98	97	44	30.5	30.06	30.56	30	44.6	-1.84	-4.07	0	0	0	206

Figure 22 Readings of different sensors

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