

The Design, Construction and Testing of a Semi-Automated Drainage Lysimeter in Bambili, North West Region of Cameroon

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How to cite this paper: Njah, N.B. and Niba, M.L.F. (2025) The Design, Construction and Testing of a Semi-Automated Drainage Lysimeter in Bambili, North West Region of Cameroon. *Open Journal of Modern Hydrology*, 15, 141-158.
<https://doi.org/10.4236/ojmh.2025.152010>

Received: November 23, 2024

Accepted: March 31, 2025

Published: April 3, 2025

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Abstract

Water is a critical resource in agriculture, and supplying the right amount is essential for healthy plants and optimal productivity. With insufficient water, plants become stressed, unproductive, and may eventually die. In contrast, excess water can lead to diseases, nutritional disorders, and waterlogged soils. To estimate the crop evapotranspiration of carrots, a semi-automated drainage lysimeter with a surface area of 150 cm by 140 cm and a depth of 90 cm was designed, constructed, and tested under the climatic and soil conditions of Bambili in the Northwest Region of Cameroon. The materials used for construction included 12 mm thick metal sheets, soil pebbles/gravel, stones, and a soil moisture tool. The lysimeter was tested by using it to estimate the crop evapotranspiration of carrots (*Daucus carota*) through the water balance equation. The crop was irrigated daily using a watering can, and the lysimeter was used to monitor rainfall, drainage, and soil moisture. The daily data collected were used to calculate crop evapotranspiration (ET_c Lysimeter) using the water balance equation from early June to late August 2022 at three different growth stages: initial, mid, and late. The average crop evapotranspiration from the semi-automated drainage lysimeter (ET_c Lysimeter) using the water balance method was 2.6 mm, 3.5 mm, and 3.2 mm for the initial, mid, and late growth stages, respectively. Based on the results of this study, the soil monitoring tool and the weighing lysimeter setup proved to be effective, providing an easy opportunity to estimate crop water use. Hence, the lysimeter can be used to determine the crop evapotranspiration of other related crops.

Keywords

Bambili, Construction, Carrot, Cultivation, Design, Estimation,

1. Introduction

1.1. Background of the Study

Hydrologists and other water resources management experts have observed that water covers three-quarters (3/4) of the earth's surface [1]. However, inaccessibility, climate change, and high water demand for domestic, industrial, and agricultural needs have led to water shortages, primarily in developing countries. Most regions of the world engage in agriculture for food production and raw material supply to industries, but Asia and Africa are the worst hit by water shortages because they highly depend on agriculture for foreign exchange and food. Researchers have used pressed steel cylinders over an exposed soil column [2]. The majority of these methods yield cores that are too small in either area or depth to fully encompass the root zone of several actively growing crops like maize. Disturbed lysimeters can be used, but they must represent the horizon distribution of the original soil and must be conditioned for several months prior to use.

There are two major types of lysimeters: the weighing and the non-weighing or drainage lysimeters. Although weighing lysimeters have been used extensively for evapotranspiration research in the United States and other countries [3], lysimeter designs have varied widely. The design variability is due to the area of study, differing objectives, and improvement and refinement of the technology. The use of lysimeters is a proven method for measuring the movement of water and chemicals through the soil profile [4]. Field measurements of crop water use are usually made to simultaneously account for both plant transpiration and soil evaporation [2]. Transpiration is a vital function of plant life, while soil evaporation refers to the amount of water lost directly from the soil to the atmosphere. The proper monitoring, use, and management of limited water resources is a crucial step in addressing water wastage, food shortages, and poor crop yields. Lysimeters remain the most reliable research tool for the direct evaluation of evapotranspiration [2]. Semi-automated lysimeters are devices designed to measure soil water balance components, such as evapotranspiration and percolation, with reduced manual intervention. They integrate sensors and data loggers to automate data collection, offering a balance between fully manual and fully automated systems [5].

Semi-automated lysimeters have several advantages over Traditional Lysimeter Techniques, namely:

- 1) Reduced Manual Labor: Traditional lysimeters often require frequent manual measurements, which can be labor-intensive. Semi-automated systems minimize this need by continuously recording data through integrated sensors, thereby reducing the frequency of manual interventions.
- 2) Improved Data Accuracy: Manual measurements are susceptible to human

error and may lack consistency. Semi-automated lysimeters provide continuous monitoring, enhancing data precision and reliability.

3) Higher Temporal Resolution: While traditional methods may offer periodic data points, semi-automated systems can capture data at finer intervals, providing detailed insights into dynamic soil water processes.

4) Cost-Effectiveness: Fully automated lysimeters can be expensive to install and maintain. Semi-automated versions offer a more economical alternative, delivering many benefits of automation without the associated high costs.

5) Adaptability: Semi-automated lysimeters can be equipped with various sensors to measure parameters like soil moisture, temperature, and electrical conductivity, making them versatile for different research applications.

1.2. Problem Statement

Water is a critical resource in agriculture, and supplying the right amount is essential for healthy plants and optimal productivity. With insufficient water, plants become stressed and unproductive and eventually die. With an excess, they can suffer from diseases, nutritional disorders, and waterlogged soils [6] [7]. This highlights the need to supply plants with accurate amounts of water. Furthermore, this requires precision and accurate monitoring of the water movement within the soil and plants. The most accurate way to estimate water use by crops is with the use of a lysimeter, which measures water loss from plants and the surrounding soil. In Cameroon, literature is scarce, indicating that research using lysimeters to estimate the evapotranspiration rate of crops in different regions of Cameroon is not readily available. Existing lysimeters worldwide are completely manual and require complete human intervention for operation and analysis. This is time-consuming and less accurate, hence the need for accurate monitoring and measurements. With advancements in sensor technology and the Internet of Things (IoT), it is therefore necessary to incorporate soil sensors for more accurate soil moisture monitoring and determination of crop evapotranspiration.

These challenges led to the following specific objectives:

- To determine the key design specifications for constructing a semi-automated lysimeter suited to the climatic and soil conditions of Bambili, North West Region of Cameroon.
- To cultivate carrot (*Daucus carota*) in the lysimeter under the specific soil and climatic conditions of Bambili.
- To evaluate the evapotranspiration rate of carrot using a soil monitoring tool within the designed lysimeter, providing data for improved water management in local agricultural practices.

2. Research Methodology

2.1. Study Area

This research was carried out in the University of Bamenda located in Tubah Sub

Division of the Northwest Region of Cameroon. It is located some 10 km North East of Bamenda city. The University is located between latitude 6° North of the Equator and longitude 10° East of the Greenwich Meridian, and it is about 1600 m above sea level [8] [9].

2.2. Material Selection

The selection of materials for constructing the semi-automated lysimeter was based on several key criteria, including durability, accuracy, cost-effectiveness, and suitability for the environmental conditions of Bambili, North West Region of Cameroon. Each component was carefully chosen to ensure the efficiency and reliability of the lysimeter system.

2.2.1. Arduino Microcontroller

The Arduino microcontroller was chosen for its affordability, ease of programming, and compatibility with multiple sensors. It allows real-time data collection and processing, making it ideal for automating the lysimeter's monitoring functions. A Raspberry Pi was considered but rejected due to its higher power consumption and complexity for simple sensor integration.

2.2.2. 20 × 4 LCD Display

A 20 × 4 LCD screen was selected for its ability to display real-time data readings such as soil moisture, temperature, and rainfall. It provides a clear and immediate visual output for field monitoring. A smaller LCD (16 × 2) was assessed; however, it was found to be less effective due to limited display capacity.

2.2.3. Moisture Sensor (SG00325)

The soil moisture sensor was selected for its ability to provide accurate soil water content measurements, which are crucial for determining evapotranspiration rates. Equally, the Gravimetric soil moisture measurement was reviewed but was less practical due to its labor-intensive process and inability to provide continuous data.

2.2.4. Aluminum Metal Sheet

Aluminum was used for constructing the lysimeter enclosure due to its durability, resistance to corrosion, and lightweight nature, making it suitable for long-term field deployment. Stainless steel was an option but was ruled out due to its higher cost and added weight, which could make installation more difficult.

2.2.5. Power Bank

A rechargeable power bank was chosen as the energy source to ensure continuous operation of the system, especially in remote locations where grid power is unavailable. A solar panel was taken into account but was excluded due to cost constraints and the potential for inconsistent sunlight in certain seasons.

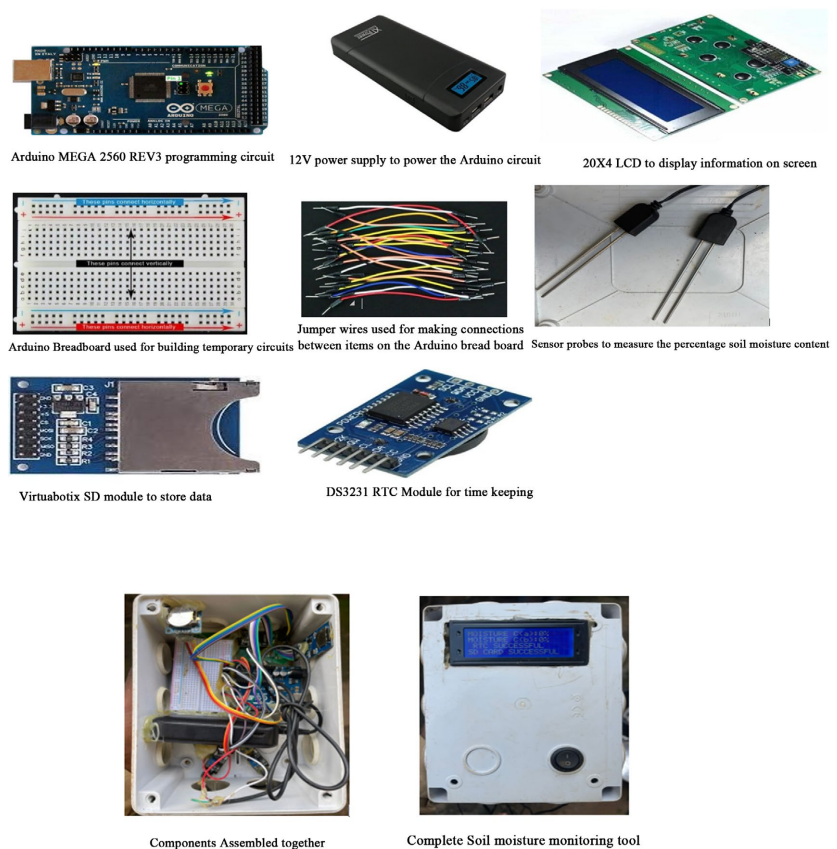
2.3. Project Design

2.3.1. Design of Soil Moisture Monitoring Tool

The soil moisture monitoring tool was designed to measure and track soil water

content in real time. The system used an Arduino MEGA 2560 as the central processing unit to collect data from soil moisture sensors and display the results on a 20×4 LCD screen. It also records data to an SD card and includes a real-time clock (RTC) for timestamping measurements. Other materials that were made use of included: a 12 V power supply, Jumper wires, Sensor probes (SG00325), Virtuabotix SD module. The sensor works by measuring the electrical resistance between two metal probes, which is inversely related to the soil moisture content. Higher soil moisture leads to lower resistance, and drier soil leads to higher resistance. The calibration of the SG00325 was done by placing the sensor in soil samples with known moisture content. The sensor reading was recorded at different moisture levels (field capacity, wilting point) and then a calibration curve was created that converts the sensor's resistance readings to percentage moisture. Ideally, calibration is done by testing the sensor in a container of soil that has been dried to a specific moisture content and then rehydrated to measure the sensor's response.

The SG00325 has an accuracy of $\pm 3\%$ - 5% , depending on soil conditions. It's important to note that resistive sensors like the SG00325 can be influenced by soil salinity, temperature, and probe corrosion. The sensor may show reduced accuracy in clay-heavy soils or highly saline soils; hence, it is best in loamy or sandy soils. **Figure 1** illustrates the materials used.

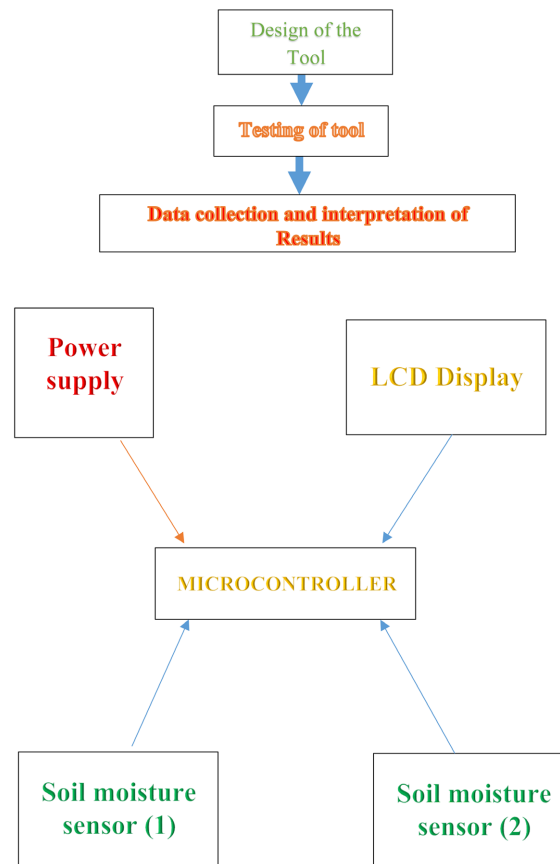


Source: Fieldwork (2022).

Figure 1. Materials used in constructing the soil moisture monitoring tool.

2.3.2. Design of a Semi-Automated Drainage Lysimeter

The overall methodology for this project is shown in **Figure 2**. This includes, but is not limited to, the design of the soil moisture monitoring tool, closely followed by testing of the tool, data collection, and interpretation of the results.



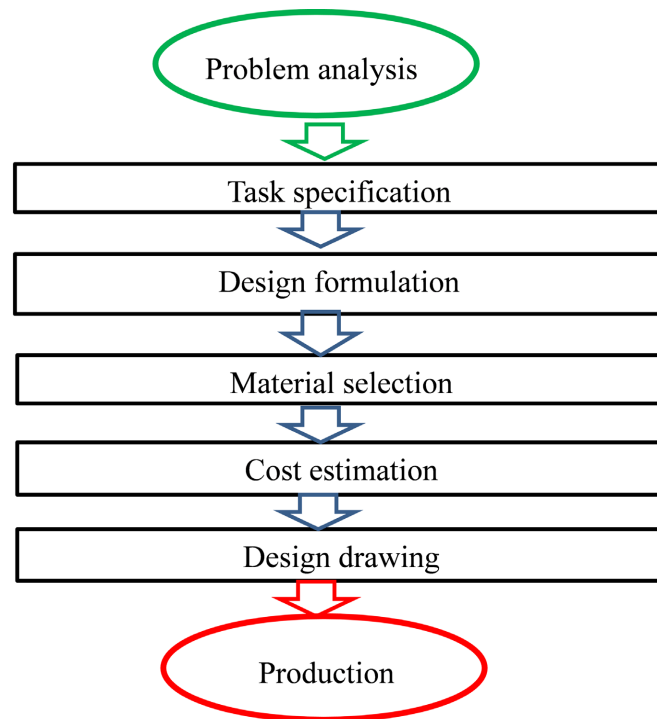
Source: Fieldwork (2022).

Figure 2. Design layout of the soil moisture monitoring tool.

1) The Design Process of the Soil Moisture Monitoring Tool

In order to design and construct the lysimeter successfully, the following steps (**Figure 3**) were used to realize the design: The Problem analysis, which involves identifying the primary issue and establishing its causes and effects; Task specification, which defines the units of work associated with activities in engineering work orders; and Design formulation, which involves combining various components and optimizing process parameters. It also includes selecting the most suitable material to meet the requirements of a specific application, estimating costs, creating design drawings, and carrying out production.

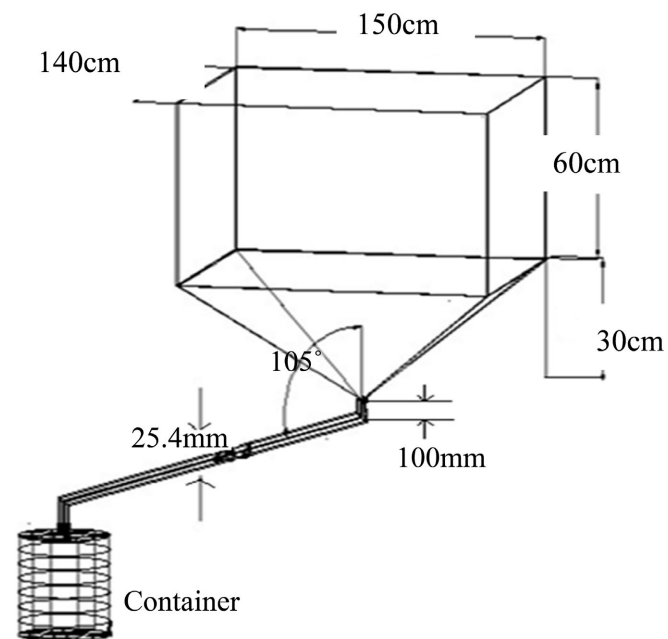
The Design formulation of the soil monitoring tool consisted of a drainage lysimeter, which was 150 cm long, 140 cm wide, and 90 cm deep. The drainage chamber was designed to be inclined at 45° for easy collection of flow from the drainage area, while the drainage pipe was inclined at 10° to prevent backflow of water from the drainage area.



Source: [10].

Figure 3. Design process of the semi-automated drainage lysimeter.

After the material selection, the design drawing of the soil moisture monitoring tool was done, in order to ease the construction of the semi-automated lysimeter in the workshop, as shown in **Figure 4**.



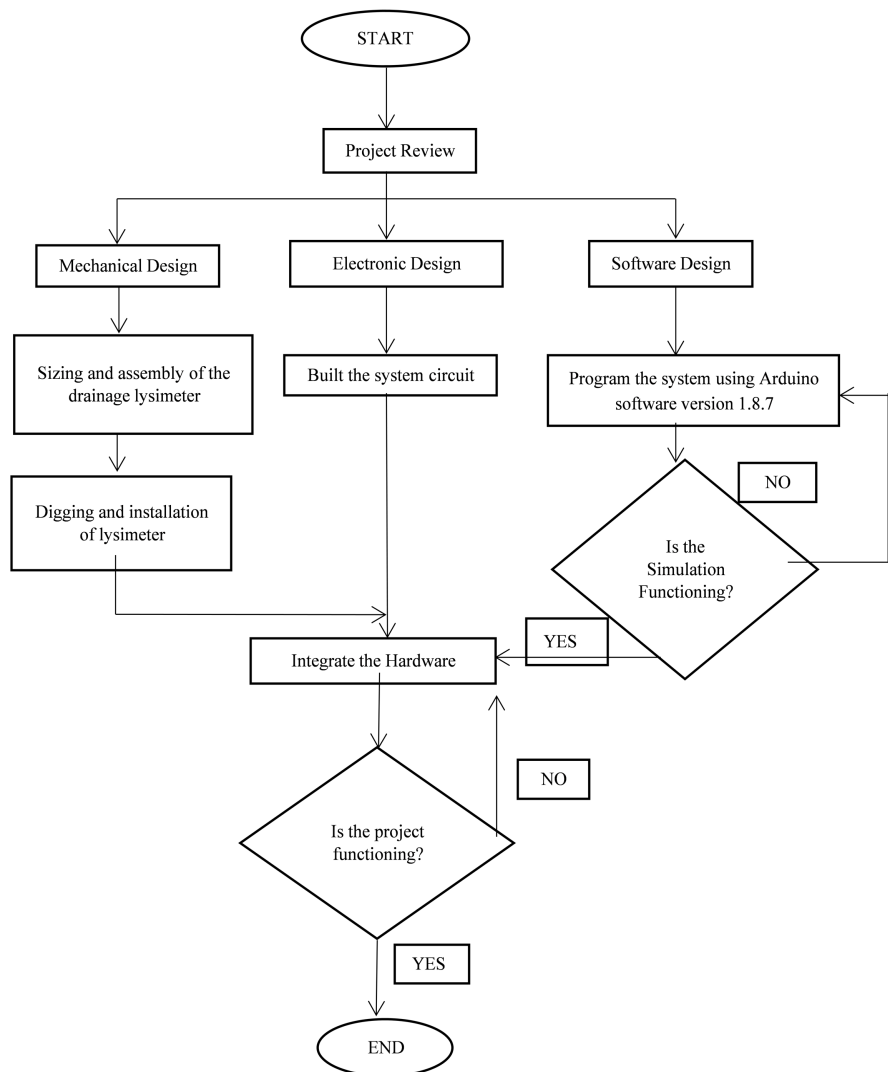
Source: [2].

Figure 4. Schematic sketch of the lysimeter.

2) Construction and Installation of the Drainage Lysimeter

A galvanized metal sheet of 12/10 was used, and the various dimensions were marked and cut using a filling machine. These parts were then assembled and welded using a welding machine and an electrode. An opening was then created at the bottom, where an iron pipe of length 10 cm and diameter 300 mm was fitted onto the opening and welded. This opening constituted part of where water drained from the surface of the lysimeter into the container.

An algorithm of the entire system was used to check the various processes that were used in the construction of the lysimeter, as seen in **Figure 5**. In the beginning, the project review was done in order to ascertain the various mechanical, electronic, and software designs to be used in this research. The mechanical design entails sizing and assembly of the drainage lysimeter, digging, and installation of the lysimeter, while the electronic design entails building the system circuit.

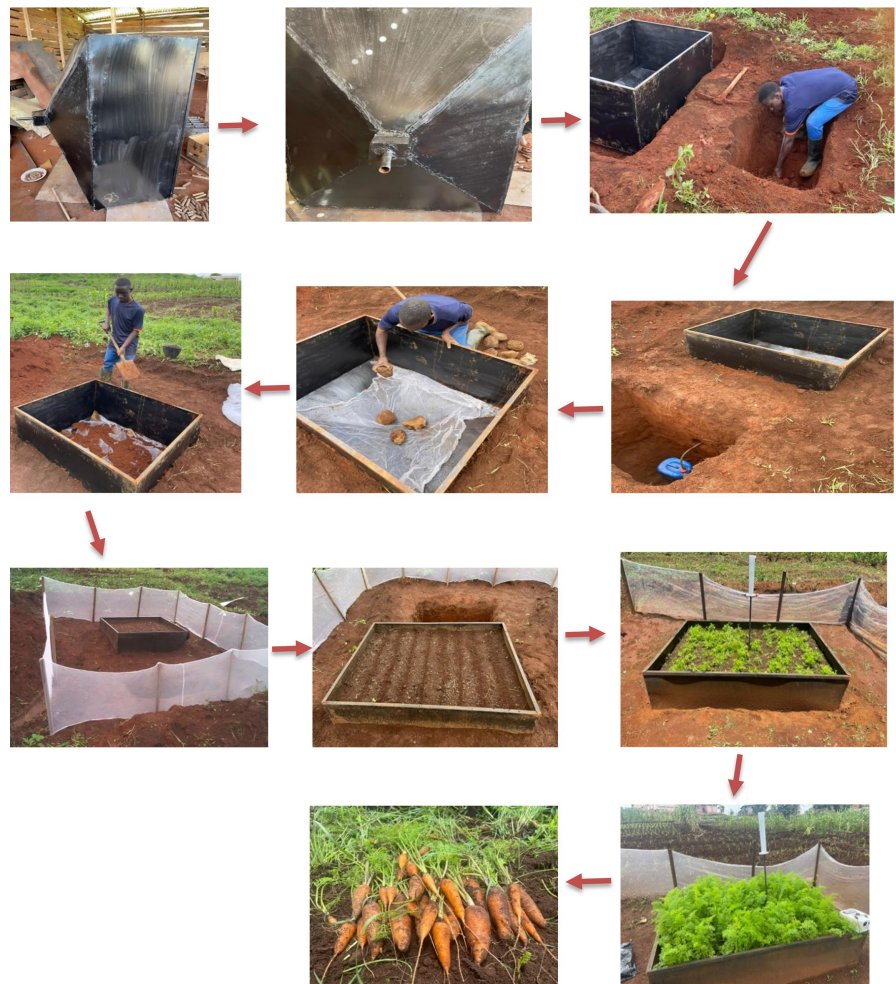


Source: Author 2023.

Figure 5. The construction of the algorithm of the entire system.

The software design involved the type of software used in the circuit, which was the Arduino software version 1.8.7. Furthermore, all the various processes were simulated to check if the entire system was functional in order to obtain concrete results, which helped achieve the desired results.

The total depth of the lysimeter was 90 cm where gravel of 40 mm thick was placed inside the pit at the height of 30 cm and compacted with a hammer to provide a stable foundation before installing the lysimeter. The gravel was carefully placed to support the protruding end of the lysimeter where the drain pipe passes through. From where the gravel ended, 30 cm height of the remaining 60 cm was filled with soil to give support and level to the ground surface as illustrated in **Figure 4**. In order to prevent soil particles from falling into the lysimeter and causing blockage through the drainage outlet, a mesh size of 0.21 mm was placed at the bottom of the lysimeter after the gravel to act as a filtering mechanism and facilitator of drainage, before putting the pebbles on top. Since it was important to use a filtering layer, a coarse sand material was overlain on the pebbles to further ease drainage (**Figure 6**).



Source: Fieldwork (2022).

Figure 6. Lysimeter construction, installation and cultivation of carrot (testing).

The lysimeter was allowed to set for two weeks so that the manure would be ready for use. Before transplanting, the lysimeter was left to stop draining from the drainage outlet after Saturation, and the initial soil moisture data was recorded.

An adjacent pit was dug as the drainage collection point, where a collection container was placed. The container used for drainage collection was a 20-liter plastic container with a 100 cm connection pipe inserted through the lid to prevent evaporation of the drainage water.

2.4. Cultivation of Carrot in the Lysimeter

Organic manure (fowl droppings) was applied to the cropped area at the rate of 25 tonnes per hectare, following the recommendation of Uguru [11]. The carrots were directly seeded at a distance of 15 cm by 15 cm for optimum fattening and aeration, as illustrated in **Figure 6**. Weeding was done twice a week during the course of this study. This was because weeds not only compete with the crops for space and nutrients but also transpire at a rate that negatively affects the results of the evapotranspiration studies. The addition of the weeds' transpiration values to the actual evapotranspiration values would obviously be misleading. Therefore, uprooting of the weeds as soon as they sprouted was done to curb this problem. The irrigation system used to apply water to the crop was the manual sprinkler type (watering can). A known volume of water was measured out and gradually applied to the crops at 7 a.m. on days with no rainfall. This was done uniformly until the measured irrigation water was exhausted. The 7 cm freeboard provided in the lysimeter was designed to avoid runoff issues arising from irrigation or rainfall, either into or out of the lysimeter. The lysimeter was drained by gravity, and drainage water was captured from the adjacent pit through a drain pipe. Changes in soil moisture were determined by the soil moisture sensors embedded in the soil at different heights above the surface. A 250 ml rain gauge was mounted at the center of the cultivated area, where the amount of daily rainfall was measured and recorded.

2.5. Method used in Estimating the Evapotranspiration of Carrot

The Water Balance Method (WBM) was used to determine the evapotranspiration of the crop. The WBM is a widely used approach to estimate evapotranspiration (ET), focusing on the conservation of water in a given system. This method is based on tracking the movement of water through a soil-crop system, taking into account all water inputs (rainfall, irrigation) and outputs (evapotranspiration, drainage). By monitoring changes in soil moisture, the WBM provides an effective estimate of crop water usage. Some advantages of this method are that it's easy to understand and apply, especially when limited climatic data is available, and requires basic tools such as soil moisture sensors, rain gauges, and irrigation records, making it relatively inexpensive and can be adjusted to suit specific soil and crop conditions, making it versatile for a wide range of agricultural environments.

The values of the data collected were first converted to millimeters by converting liters to millimeters and then dividing by the total surface area of the lysimeter. The initial soil moisture content was recorded before transplanting and the first irrigation.

Soil moisture content sensors were used to determine soil moisture content values in percentage, which were then converted to volumetric values. Runoff into and out of the lysimeter was zero because the design and installation of the lysimeter restricted runoff by allowing a freeboard of 7 cm above the ground surface. Crop evapotranspiration was determined using the water balance equation, as shown in Equation 1 in the literature review under methods used for estimating ETc [12].

$$ETc = I - D - \Delta S \quad (1)$$

where ETc = Crop evapotranspiration;

I = Irrigation;

D = Drainage;

ΔS = Change in soil water moisture.

Irrigation and drainage were calculated in millimeters by dividing the quantity of water irrigated or drained by the surface area of the lysimeter.

3 Results and Discussion

3.1. Design Specifications Obtained for a Semi-Automated Drainage Lysimeter

A 150 cm long by 140 cm wide and 90 cm deep constructed lysimeter (**Figure 7**) was used alongside a successfully designed and tested soil moisture monitoring tool (**Figure 8**) for the cultivation of carrots. It should be noted that the dimensions of the constructed lysimeter were based on cost, durability, and the availability of materials. The soil moisture monitoring tool was designed to eliminate the manual (gravimetric) method of measuring soil moisture content in the laboratory, thereby reducing drudgery and saving time.



Source: Fieldwork (2022).

Figure 7. Constructed drainage lysimeter.



Source: Fieldwork (2022).

Figure 8. Soil moisture monitoring tool.

The depth of a lysimeter is a critical design parameter and varies depending on the intended purpose of the tests. Because of the critical role of plants in removing water from landfill covers, the depth, distribution, and density of plant roots must be considered when determining the depth of a lysimeter under a landfill cover.

The lysimeter depth should permit the development of normal rooting density and rooting depth while providing similar “available” water profiles to the field profile [13]. The areal extent of lysimeters depends on the spatial variability in the properties of soil cover and vegetation. The length and width are usually five times larger than the depth to ensure that preferential flow processes (*i.e.*, rapid flow in features such as cracks, fissures, root channels, and wormholes) are captured in the test and that the construction process mimics full-scale conditions [14] [15]. Okechukwu constructed a lysimeter with dimensions 200 cm by 160 cm by 170 cm for the cultivation of spinach to reduce soil erosion and leaching of nutrients during the wet season, and crop evapotranspiration was calculated [2]. Additionally, Sahoo *et al.* constructed a lysimeter with dimensions of 120 cm by 120 cm by 100 cm to estimate the crop evapotranspiration rate of carrots in three seasons (the first season from the second week of April to the end of August, the second season from mid-August to the end of December, and the last season from mid-December to mid-April) [16].

In this research, the dimensions of the lysimeter (150 cm by 140 cm by 90 cm) were chosen based on the cost and durability of materials. The soil monitoring tool was designed to measure the percentage of soil moisture content throughout the experiment.

3.2. Cultivation of Carrot in the Lysimeter

Carrots were cultivated in the lysimeter at a spacing of 15 cm by 15 cm, with efficient weed management to prevent water loss through evapotranspiration by weeds. A good yield of 0.8 kg/m² was obtained from the area.

According to [17] and [18], several crops have been cultivated in a designed, constructed, and tested lysimeter (e.g., African spinach, rice, sunflower, etc.). Sahoo *et al.* indicated that a carrot spacing of 20 cm by 15 cm resulted in a yield of 0.9 kg/m² [16]. Okechukwu suggested a transplant spacing of 30 cm by 15 cm to encourage the development of larger and more succulent spinach leaves, obtaining a yield of 0.5 kg/m² [2]. Tyagi *et al.* recommended a spacing of 25 cm by 25 cm for the cultivation of rice in a lysimeter to achieve a yield of 1 kg/m² [18] [19].

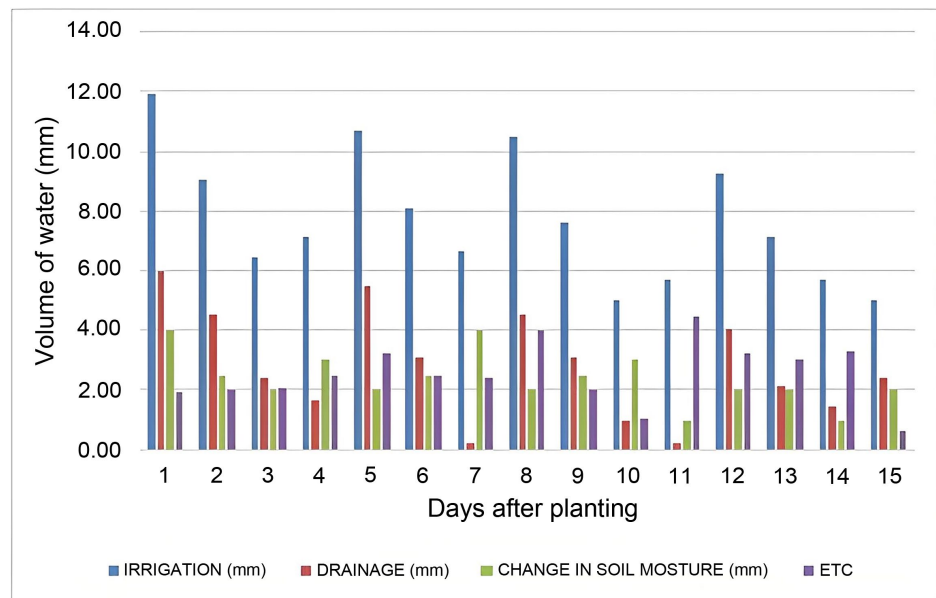
Before selecting a crop, the root length is taken into consideration. The carrots cultivated in the lysimeter in this research were spaced 15 cm by 15 cm to allow enough room for the development of healthy roots. With efficient maintenance, a yield of 0.8 kg/m² was obtained, which [20] identified as the average yield of carrots cultivated under normal conditions. These results prove that there was good drainage for the cultivation of carrots in the lysimeter. The yield (0.8 kg/m²) is slightly lower than that obtained by [16], indicating that the research was efficient. The climate of Tubah is sub-tropical, with cold temperatures ranging from 16°C to 26°C, an annual rainfall of 186 mm [9], and black loam soils, which favor the cultivation of carrots under normal conditions.

3.3. Estimating the Evapotranspiration Rate of Carrot

After designing the lysimeter, the cultivation was carried out successfully, and we collected data on the amount of irrigation, drainage, and soil moisture content on a daily basis. The Evapotranspiration of Carrot (ET_c) at different growth stages was calculated using the water balance equation. The Evapotranspiration of Carrot (ET_c) at three (3) different growth stages were calculated. These 3 stages were: the initial stage (from emergence to 31 days after planting, as shown in **Figure 9**), the mid-stage (from 32 days after planting to 86 days after planting (**Figure 10**) and the late stage (from 87 days after planting to 130 days after planting) as illustrated in **Figure 11**. However, these periods vary slightly within some carrot species. We used a range of 15 days randomly in each growth phase to calculate the crop evapotranspiration rate of the crop to avoid a congested graph.

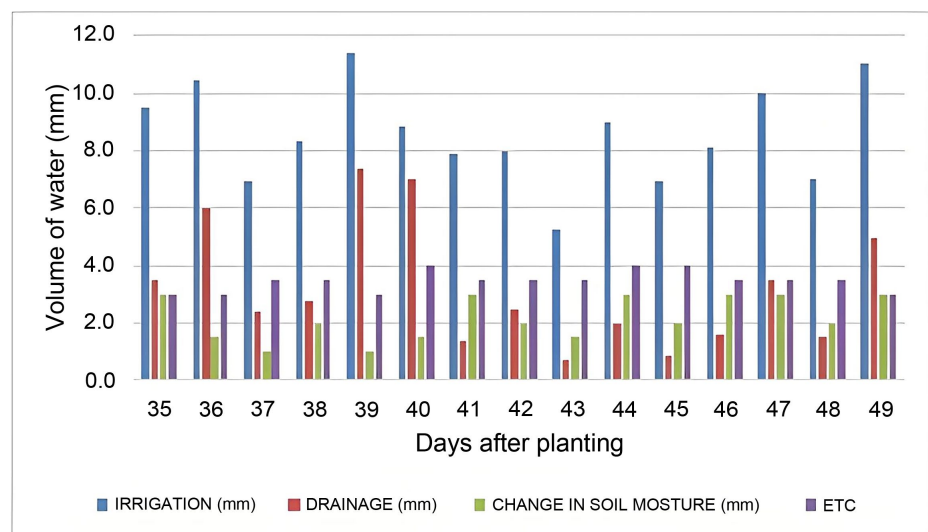
The estimated crop evapotranspiration (ET_c) rates for carrot in this study were 2.8 mm/day, 3.56 mm/day, and 3.7 mm/day for the early, mid, and late stages, respectively. These values are slightly higher than those reported by Sahoo *et al.* [16], indicating that the results of this study are efficient. Although research on carrot ET_c is limited, the work of Sahoo *et al.* is highly regarded [16]. In their research, the ET_c increased over time from 2.6 mm/day during the early stage to 3.53 mm/day in the mid stage, before decreasing to 3.2 mm/day in the late stage. This pattern was attributed to canopy development during the initial growth stages, as noted by Tyagi *et al.* [18].

Generally, the increase in ETc during the mid-stage can be explained by higher crop water demand due to full canopy development, as well as increased evaporative demand [21]. However, in the late stage, despite minimal variation in atmospheric demand, the transpiration rate decreases due to a reduction in the physiological activity of the plants [16]. The observed variation in crop evapotranspiration and crop coefficient is primarily driven by the plant's water requirements, which are influenced by the trend in canopy development.



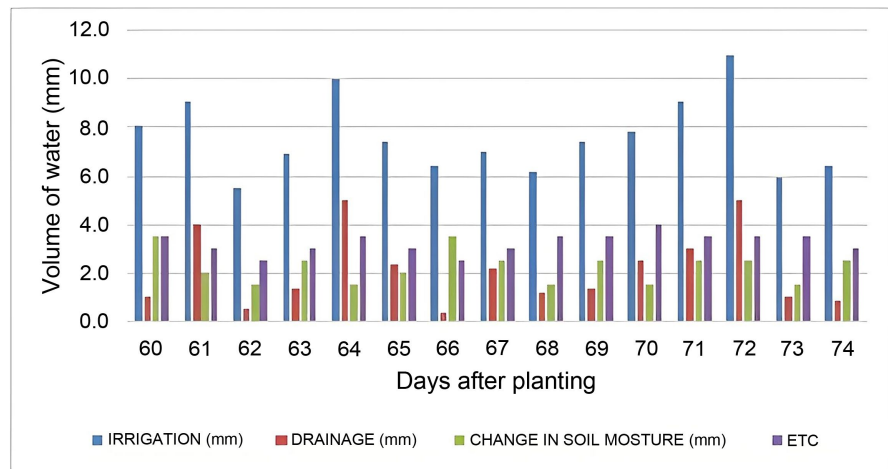
Source: Fieldwork (2022).

Figure 9. Initial stage of irrigation, drainage, change in soil moisture content and ETc of carrot against days after planting.



Source: Fieldwork (2022).

Figure 10. Mid growth stage of irrigation, drainage, change in soil moisture content and ETc of carrot against days after planting.



Source: Fieldwork (2022).

Figure 11. Last growth stage of irrigation, drainage, change in soil moisture content and ETc of carrot against days after planting.

Additionally, the results indicate that drainage increases with higher irrigation rates, while crop evapotranspiration slightly increases over time. This could be attributed to the gradual rise in temperature, as suggested by Okechukwu *et al.* [22]. Overall, the ETc values in this study are slightly higher than those reported by Sahoo *et al.* [16], who observed ETc values of 2.62 mm/day, 3.53 mm/day, and 3.2 mm/day for the early, mid, and late stages, respectively.

The findings of this study, particularly the estimated crop evapotranspiration (ETc) rates of carrot at various growth stages, have significant implications for water management in agriculture. Accurate ETc estimates are crucial for optimizing irrigation practices, ensuring that crops receive sufficient water without wasting resources. The results, which show a slight increase in ETc from early to late growth stages (from 2.8 mm/day to 3.7 mm/day), suggest that irrigation practices should be adjusted throughout the growing season to match the changing water demand of the carrot crop. The slight increase in ETc over time (especially the mid-stage) highlights the importance of considering crop development stages for water allocation, rather than applying the same water amount throughout the entire growth period. As the results indicate that temperature might play a role in the increase of ETc over time [22], this finding can inform future water management practices, particularly in the context of climate change.

4. Conclusion, Limitations and Recommendations

4.1. Conclusion

A soil moisture monitoring tool was successfully designed, tested, and used alongside a 150 cm long, 140 cm wide, and 90 cm deep drainage lysimeter, where carrots were cultivated and their evapotranspiration rate was measured.

The results of the evapotranspiration rate of carrots reflect those of other authors, and the carrots are producing well, which implies that the soil monitoring

tool and the weighing lysimeter setup for the study were effective. The system provided an easy opportunity to estimate crop water use.

The ET_c values of carrots determined from the lysimeter were validated using the Water Balance Method. The drainage lysimeter proved to be both functional and efficient. The study revealed that the crop evapotranspiration or crop water use of carrots (*Daucus carota*) in Bambili, Northwest Region of Cameroon, between June and August 2022, was 2.8 mm/day, 3.56 mm/day, and 3.7 mm/day for the initial, mid, and last stages of growth, respectively. These results are similar to those of Sahoo *et al.* [16], who reported 2.62 mm/day, 3.53 mm/day, and 3.2 mm/day for the initial, mid, and last stages of growth, respectively.

4.2. Limitations of the Study

1) Soil moisture sensors, such as the SG00325 used in this study, can be influenced by various factors like soil texture, salinity, and temperature. Calibration errors could lead to slight inaccuracies in measuring the actual soil moisture, which in turn can affect ET_c estimates.

2) Estimating drainage accurately can be difficult due to variability in soil permeability and the lack of direct measurement tools. While drainage was inferred in this study based on irrigation data, its actual value may not have been precisely captured.

3) This study does not directly account for all atmospheric variables (e.g., wind speed, relative humidity). These factors can affect evapotranspiration. Differences in weather conditions (such as wind speed and humidity) during different periods may introduce some uncertainty in the calculated ET_c values.

4.3. Recommendations

The following recommendations are made based on the study:

1) The lysimeter can be used for other related research, as it is an instrument applicable in various fields.

2) Further research should be conducted over at least two cultivation seasons to extend the findings of this study and provide a clearer picture of the annual evapotranspiration values.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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