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Original Research

Design, Fabrication and Testing of a Weighing Lysimeter

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ABSTRACT: Detailed crop evapotranspiration data (ET) are anticipated to advance agricultural water management. Presumptions such as explicit yield and the failure to get ET values during brief periods are problems associated with the inaccuracy of non-weighing lysimeters. The goal of this research is to develop, build, and test a weighing lysimeter. Using lysimeters, estimate crop ET directly by measuring the mass adjustment of a detached soil volume. The lysimeter is made out of a metal frame shaped like a hold or cabinet. The interior box has a motocycle tube and a lysimeter basin on top of which a crop can be sown. As the lysimeter container presses the cylinder, the water in the burette rises, a decrease in the mass of the can results in a drop in the water level in the burette, and the evapotranspiration may then be calculated based on the dip in the water level.

Keywords: Irrigation, Evapotranspiration, Crop ET, Agricultural water management, Agrometeorology
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INTRODUCTION

Exact crop evapotranspiration (ET) measurements are essential to optimise agricultural water resource management (Rana, and Katerji, 2000). Micrometeorological approaches like as the Bowen ratio and Eddy covariance methods have recently become popular for directly measuring ET (Payero et al., 2003). Nonetheless, lysimeters are still widely used to directly measure ET (Rana, and Katerji, 2000). Evapotranspiration (ET) is the loss of water to the atmosphere due to evaporation and transpiration. Evaporation occurs when water evaporates from soil or plant surfaces. Water lost through plant tissues is referred to as transpiration. ET is a useful indicator of how much water plants constantly lose, and the rate of ET varies amongst plants. Even in extremely dry conditions, some plants retain moisture longer than others. Hence, certain plants are more tolerant to drought than others. Using a climate-based water system regulator to estimate ET in your community will help you effectively manage irrigation and drainage (Dowdell and Webster, 2014). A lysimeter is a measuring tool that can be used to determine the amount of actual evapotranspiration that plants release (normally crops or trees). One can calculate how much water is lost through evapotranspiration by keeping track of how much precipitation a location receives and the total amount lost through the soil (Rana, and Katerji, 2000). A lysimeter is most accurate when filled with plants in a large soil tank, which makes it possible to accurately calculate the amount of precipitation and water lost through the soil. By calculating the difference between the load and the input of precipitation, the amount of water lost by evapotranspiration may be calculated (Lang and Kaupenjohann, 2004). Lysimeters have undergone extensive development throughout time, and numerous strategies have been used (Colman, 2013). Several sizes and shapes of lysimeters have been planned. Shapes include rectangle, square, and oblong (Marek et al., 2006). Moreover, lysimeter sizes vary significantly. In contrast, the lysimeter Fuhr et al. (2018) designed only covered 0.44 m^2. Lysimeters have undergone extensive development throughout time, and numerous strategies have been used (Colman, 2013). Similarly, lysimeter sizes vary significantly.

The lysimeter designed by Fuhr et al. (2018) only covered 0.44 m^2, but the lysimeter designed by Hess (2009) covered 28.27 m^2 (6 m in breadth). The size is a factor in the intended use and the desired or necessary goal. To measure the dissipation of soil water, experts also utilize lysimeters with an area as small as 0.006 m2, sometimes referred to as miniature lysimeters or small scale lysimeters.

Lysimeters can be weighed or non-weighed. Non-weighing types are used to calculate ET as a residual by calculating any remaining aspects of the soil water balance, such as precipitation and irrigation, yields (drainage and overland flow), and changes in soil water storage capacity (Hess, 2009). Non-weighing lysimeters, also known as percolation or drainage lysimeters, are used in percolation and solute transport experiments. Weighing lysimeters, on the other hand, assess crop ET directly by measuring the mass adjustment of a divided soil volume (Dowdell and Webster, 2014). Assumptions such as explicit yield and the failure to gather ET values during brief periods are challenges associated with the inaccuracy of non-weighing lysimeters. The explicit yield is considered to be constant over the whole depth of the lysimeter, as measured by the small change in water capacity depth during the estimation time frame. Varying soil parameters result in a wide range of explicit yield values for varying soil profile depths .

With non-weighing lysimeters, ET values can only be obtained over the entire estimation time range. Daily ET is only a standard incentive for the estimation time period, and variations due to day to day changes and constraints cannot be noticed. These misconceptions about soil aggravation and non-weighing lysimeters could be alleviated by applying solutions recently developed for gauging installations (Dowdell and Webster, 2014).

Massive lysimeters are expensive to build, install in place, and maintain. For a long time, soil water balance assessments have made use of smaller than expected or miniature lysimeters (Hess, 2009). Using lysimeters, calculate crop ET by measuring the mass adjustment of a disconnected soil volume. However, the ET calculated from mass changes should be adjusted to account for mass changes caused by reasons other than ET, such as seepage or water input (Malone et al. 2000).

Weighing lysimeters with various weighing components have been planned. Water-powered suspended load cells, deck scales, load cells inserted at the lower section of the lysimeter, single burden cell with offset, and flexure level activity offset with a heap cell are examples of weighing instruments (Colman, 2013).The objective of this study is to design and fabricate a weighing lysimeter.

MATERIALS AND METHODS

Study area

The study was carried out behind the Department of Agricultural and Bio-Environmental Engineering workshop in Auchi Edo State. Auchi Polytechnic is located between latitude 6^0 70”00” to 7^0 18”00” North of the Equator and longitude 6^0 49”00” East of the Greenwich Meridian. Auchi is the headquarters of Etsako-West Local Government Area of Edo State, Nigeria. The area covers a total land area of 94, 562 km^2. Auchi is underlain by sedimentary formation of the Miocene-Pleistocene age. The area is found in the South Central (lower Niger sedimentary rock areas).

Materials used for construction

The materials used for the construction of the lysimeter are shown in (Table 1) and the qualities of such materials are also described.

Table 1: Materials used

S/NO	DESCRIPTION	QTY	UNIT
1	Sheet metal	2 ½ 2x4	5.0cm x 7.6cm x 3.6cm
2	Glue	1	Cosecant glue
3	Nails	$2^{1/2}$&2”	
4	Cutting disc	2	
5	Grinding disc	2	
6	Drainage tray	3	
7	Ply board	1/2 & 1/3	
8	Burette	3	
9	Motocycle tube	3	
10	1” hose	3 yards	
11	½ “ hose	1 yard	
12	2 litres Jerican	3	
13	Lysimeter basin	3	
14	Angle bar	1m	

Description and principle of operation of the Lysimeter

Each lysimeter is made up of a metal frame in the shape of a shelf or drawer. The inner box houses a motocycle tube and a lysimeter basin on top of which a crop can be sown. A burette is connected to the tube and filled with water; as the lysimeter bucket presses the tube, the water in the burette rises; a decrease in the mass of the bucket causes a drop in the water level in the burette; and the evapotranspiration can then be estimated based on the drop in the water level (Plates 1-3).

Water enters the lysimeter by rainfall or irrigation. Increases in the weights of the Lysimeter tanks (due to water addition) put pressure on the tubes, causing the water level in the manometer glass tube to rise. Soil evaporation and water utilised by plants through transpiration and metabolic processes induce a decrease

Plate 1: Lysimeter construction process

Plate 2: Lysimeter Container

Plate 3: Complete Lysimeter set up

in the weight of the Lysimeter and hence the level of water in the manometer. Excess water in the Lysimeter tank went into the runoff collector, while water above the soil water holding capacity went to the drainage collection at the bottom of the Lysimeter tank. Throughout the crop growth season, the amount of water in the manometer glass tube was checked on a regular basis. The drainage and runoff collectors were also observed, particularly when there was a rainfall event, and their depth was measured. Water added (via rainfall or irrigation), crop water used (via evapotranspiration from cropped soil surface, transpiration from cropped covered surface with polythene mulch, or evaporation from bare soil surface), water drained, and runoff all contributed to the difference in the level of water in the manometer glass tube between two consecutive days. The difference in the Lysimeter's weight in the absence of precipitation, irrigation, runoff, and drainage results from evapotranspiration, transpiration, and/or evaporation, depending on the situation. Using a relationship that was first established in the lab between the height of water in the manometer glass tube and the known weight packed into the Lysimeter tank, the weight of the Lysimeter tank on any given day was calculated from the level in the manometer glass tube (Aliyu, 2015). The established relation is:

$$W = 1135.8*H + 202.5 \quad (1)$$

Where, W is the weight of the Lysimeter in gramme (g) and H is the height of water in the manometer glass tube in cm. A factor of "7.57*10-3" is used to convert the difference in Lysimeter tank weight between two consecutive days to the depth of water in millimetres each day. Based on the Lysimeter's surface area (1320.8 cm2) and the water's density (1.0 g/cm3), this factor was calculated. Direct measurements of runoff and other elements of the soil water balance are taken from each lysimeter.

Two non-recording rain gauges that were installed in an appropriate location around the experimental plot to directly receive the precipitation were used to measure the amount of precipitation. The expressions used for the computation of the daily evaporation from bared soil Lysimeter, evapotranspiration from cropped Lysimeter and transpiration from cropped Lysimeter covered with black polythene are respectively as follows:

$$E, T, ET = P_i - R_{offi} - D_{pi} - \Delta S \quad (2)$$

$$\Delta S = [(W_{i+1} - W_i)\ CF] \quad (3)$$

Where;

P_i = rainfall amount (mm) of day ‘’i’’ ; R_{offi} = runoff of day ‘’i’’ ; D_{pi} = deep percolation (mm) of day ‘’i’’ ; W_i = weight of lysimeter soil (g) on day ‘’i’’ ; W_{i+1} = weight of lysimeter soil (g) on the next day interval; CF = conversion factor of the lysimeter (to convert weight to depth of water using density of water (1g/cm^3) and area of the lysimeter); E, T, and ET; is the evaporation (from bare soil), transpiration (from cropped soil covered with black polythene) and evapotranspiration respectively. The following are some features that make this lysimeter design practicable:

1. Simplicity of construction and design.
2. Extreme sensitivity and precision.
3. Near frictionless suspension.
4. Portability easily moved from place to place for a study of varying microclimatic conditions.
5. Inexpensive.
6. Compact, requiring only a single placement hole.
7. Undisturbed soil column in bucket.
8. Little temperature sensitivity of weighing system.
9. Can be flood or sprinkler irrigated.
10. Adaptable to either long or short duration experiments.

RESULTS AND DISCUSSION

After construction, the lysimeter bucket was filled with sand collected from the test site and then set on top of the plywood resting on the water-filled tube. As the sand was added, the water in the tube rose due to the difference in weight. When water from irrigation or rainfall is supplied, the water level in the manometer rises, and the water column expands as a result of an increase in the weight of the lysimeter bucket. When the water evaporates or is used by the crop, the water level continues to drop.

Conclusion

The weighing lysimeter was built using the processes indicated above, ensuring its robustness and durability. This lysimeter can be used to measure evapotranspiration for research and practical reasons. With this work's success, it is advised that the lysimeter be utilised for evapotranspiration studies, evaluating different crops and comparing the results to other ways of calculating evapotranspiration.

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REFERENCES

Aliyu, A. (2015) ‘’Performance of two agro-hydrological models in a sandy clayed loamy soil in ABU Zaria. Unpublished MSc thesis submitted to the Department of Agricultural Engineering, ABU Zaria.

Colman, E. A. (2013). A laboratory study of lysimeter drainage under controlled soil moisture tension. Soil Sci. 1946;62:365-382.

Dowdell, R.J. and Webster, C.P. (2014). A lysimeter study using nitrogen N-15 on the uptake of fertilizer nitrogen by perennial ryegrass swards and losses by leaching. J Soil Sci. 1980;31:65-75.

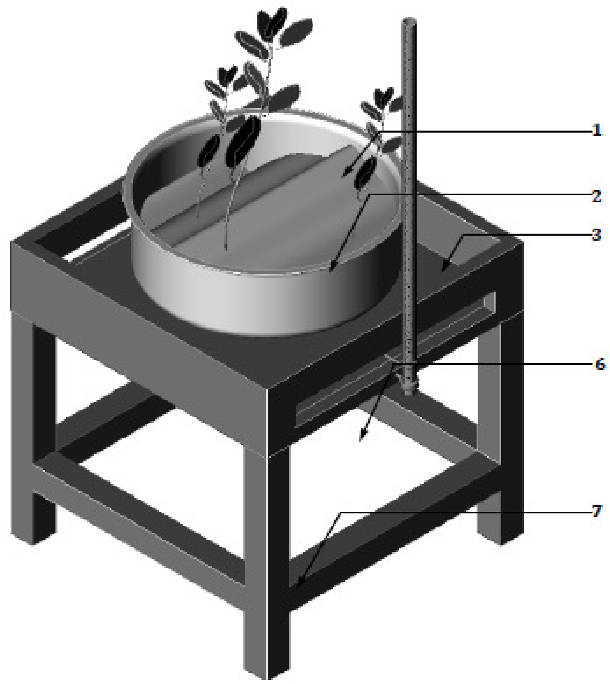
Fuhr, F., Burauel, P., Dust M., Mittelstaedt, W, Pütz, T., Reinken, G., Stork, A. (2018). Comprehensive tracer studies on the environmental behaviour of pesticides: The lysimeter concept. ACS Symp Series.2018;699:1-20.

Hess, T. M., (2009). The Impact of Climate Variability over the Period 1961-1990 on Soil Water balance of Upland Soil in the North-East Arid Zone of Nigeria. A Ph.D. thesis, Institute of Water and Environment, Canfield University, Silsoe.

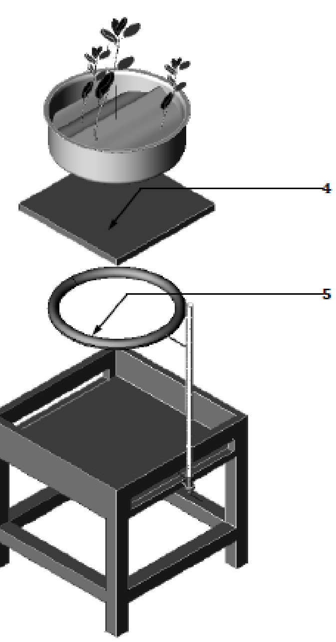
Lang, F., Kaupenjohann, M. (2004.) Trace element release from forest floor can be monitored by ion exchange resin tubes. Journal of Plant Nutr Soil Sci. 2004;167:177-183.

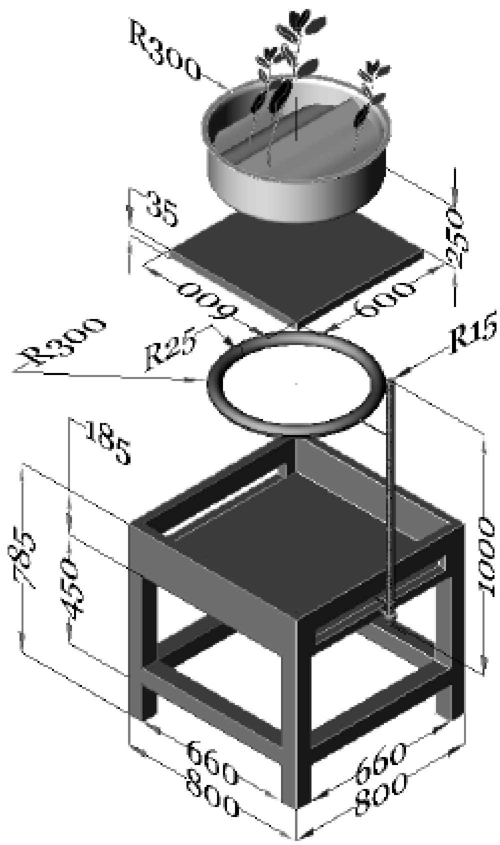
Payero E. A., Kennedy L. and Grams A. (2003). Evaporation measurement and simulation. J.Agric. in the tropics. Vol 12:23

Rana, G. and N. Katerji. (2000). Measurement and estimation of actual evapotranspiration in the field under Mediterranean climate: a review. European Journal of Agronomy 13:125-153.WHO .2004.“Guidelines for Drinking Water Quality” World Health Organisation (third edition), Geneva.



7	WOODEN SUPPORT & STAND	-	METAL	FAB
6	LYSIMETER TABLE	1	METAL	FAB
5	TUBE	1	RUB	PUR
4	WOOD BOARD	1	WOOD	PUR
3	BURRET	1	GLASS	PUR
2	SOIL	-	SOIL	-
1	LYSIMETER CONTAINER	1	STEEL	PUR
ITEM	**DESCRIPTION**	**QTY.**	**MAT.**	**REM.**

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35
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785
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