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EVAPOTRANSPIRATION MEASUREMENTS WITH A WEIGHABLE LYSIMETER IN SURINAM

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Summary

A description is given of a weighable lysimeter suitable for measuring evapotranspiration of agricultural surfaces such as row crops or grass. The lysimeter tank is weighed using butyl-nylon rubber load cells filled with de-aired water. Pressure changes in the load cells are measured with a manometer. The standard deviation is 0.5 mm water depth. First results with Tocograss (Ischaemum aristatum) showed that the potential evapotranspiration was considerably lower than the free water evaporation estimated according to Penman's method. This lysimeter is the first of its kind in Surinam.

Introduction

An increasing intensity in hydrological and water resource studies is noticeable in many parts of the world. In the majority of these studies evaporation is a key parameter, which calls for accurate determination. Unfortunately an exact measurement presents many problems. Evaporation from extended water or land surfaces cannot be determined directly. Several methods are available to determine estimates of evaporation, the final choice depending on the situation at hand.

Direct measurements from small plots, pans or lysimeters are in principle water balance methods. The water balance method can also be applied in large scale studies to riverbasins, polders, lakes etc. Usually reliable estimates can only be obtained over long periods. When short periods, i.e. 10-day intervals or shorter, are considered the changes in groundwater and soil moisture storage and the amounts of seepage water may constitute a problem.

As in the water balance method, evaporation calculated with the energy budget method is found as the residual item. Net radiation and heat fluxes must be known which in turn requires knowledge of temperature and humidity gradients. The energy budget method has been used in many experiments to estimate evaporation from lakes and compared favourably with the water balance method (e. g. Anderson, 1954; Keijman and Koopmans, 1973).

Aerodynamic methods, among which the bulk aerodynamic method and the method of the vertical vapour transfer coefficient, are used for the determi-

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nation of lake evaporation as well as evapotranspiration. The bulk aerodynamic method only requires simple meteorological observations but makes use of an empirical constant. The derivation of the transfer coefficient from the wind profile is the main obstacle to a correct estimate according to the second method.
Penman has sought to eliminate the disadvantages of the energy budget and aerodynamic methods by combining the two. After introducing several empirical relationships the resulting formula only uses standard meteorological data. Although the method has some shortcomings, of which the determination of surface roughness and the influence of partial soil cover on evapotranspiration should be mentioned, the results are often sufficiently accurate for hydrological studies.

The lysimeter

As was pointed out in the preceding paragraph weighable lysimeters are the only instruments that allow a direct measurement of the evapotranspiration. However, due to the limited dimensions of most lysimeters precautions must be taken to make the results applicable to a field with the same vegetation. Lysimeters can be used effectively when the vegetation within the container is not different from that of the surroundings. In an environment with a deep rooted vegetation or tropical forests such as in the interior of Surinam, lysimeters of the kind as described hereafter are of little use.
In Surinam relatively little is known about the exact magnitude of the evapotranspiration of both agricultural surfaces and natural woodland vegetation. In order to measure, under the climatic conditions of Surinam, the evapotranspiration of row crops and other surfaces e.g. grass it was decided to construct a large weighable lysimeter at the Centre for Agricultural Research in Surinam (CELOS), Paramaribo. This lysimeter is the first of its kind in Surinam and in the Caribbean area.
Weighable lysimeters currently used in several parts of the world are weighed on the basis of various principles using different techniques (Bloemen, 1964; Hanks and Shawcroft, 1965; Rose et al. , 1966; Black et al. , 1968; Ritchie and Burnett, 1968). At CELOS the hydraulic load cell technique was chosen on account of its simplicity and as literature reports indicate its dependability.

Lysimeter tank and cellar

The lysimeter consists of a rectangular inner tank 1.80 m long, 1.50 m wide and 1.3 m deep, made of 6 mm steelplate, with internal strengthening of 4 cm I-beams. A 3 cm wide gutter was welded to the upper-outside of the tank to remove surface run-off. The water flows through a series of perforations (0.5 cm) into this gutter (see fig. 1).

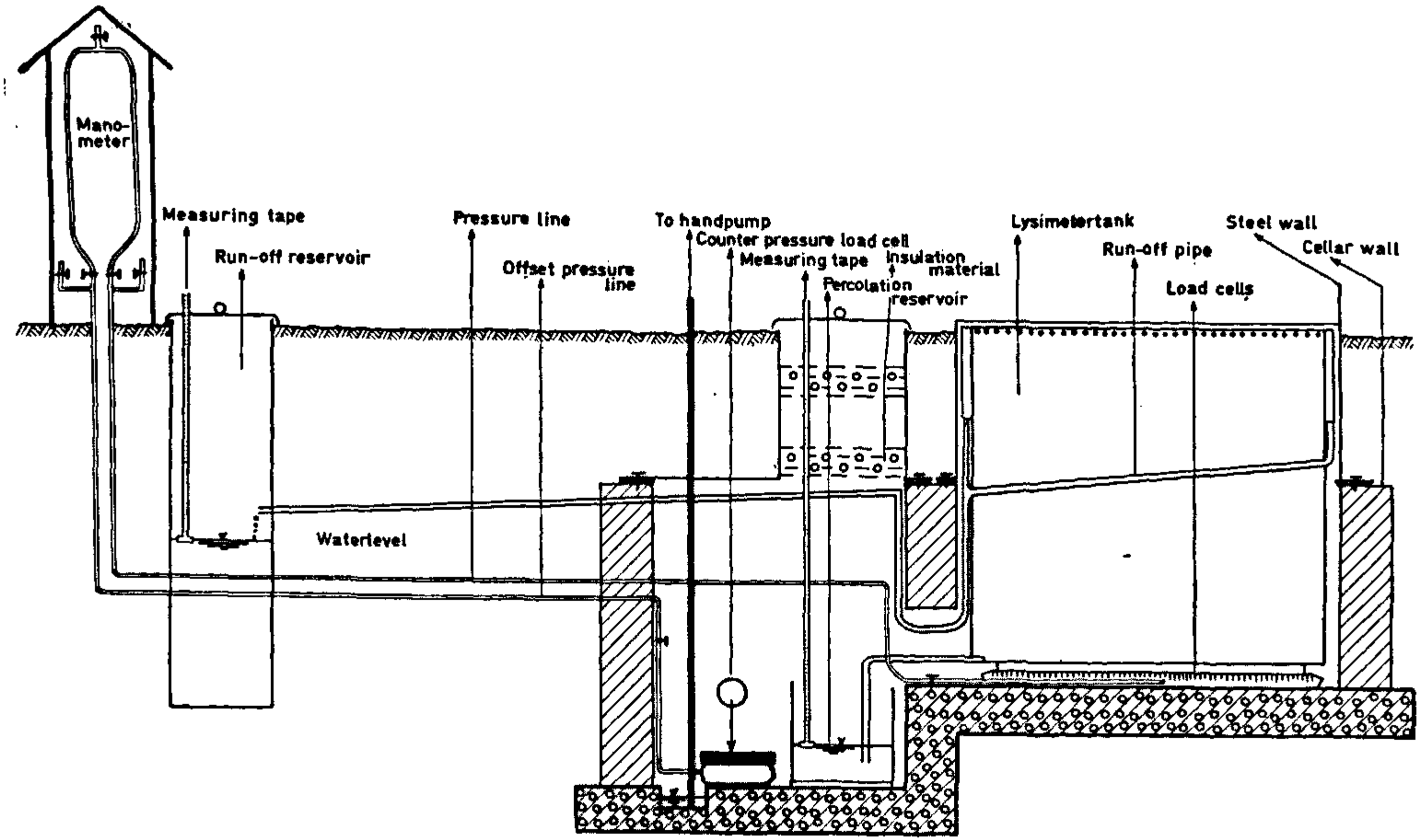

Fig. 1 Schematic drawing of the lysimeter

With only a few centimetres tolerance around, the lysimeter tank fits into a cellar with a reinforced concrete floor. The upper 0.62 cm of the cellar walls consist of 6 mm steelplate with external strengthening of 4 cm angular beams. This was done to minimize surface disturbance and interference with crop row distances. Both cellar and lysimeter tank are watertight and are provided with drainage facilities.
At the bottom, inside the tank a sloping concrete floor has been placed on which rest a few thin layers of filter sand to facilitate the drainage of percolating water. Surface run-off and percolating water are collected in separate cylindrical reservoirs in which the water level can be determined.
The gap between the cellar wall and the lysimeter tank was fitted with metal covers that do not interfere with the free movement of the tank. The covers prevent precipitation water from running into the cellar. However, water that somehow leaks into the cellar is collected in a small pit from which it can be removed with a handpump.
To the bottom on the outside of the tank two channels were welded that hold wooden blocks (Greenheart, Tabebuia serratifolia) which transmit the weight of the lysimeter to the load cells.
The lysimeter tank has been carefully refilled with the orginal soil, which locally consists of approximately 1 m heavy clay overlaying fine sand. The evaporating area is 2.696 m^2.

The weighing system

The inner tank is weighed using two interconnected hydraulic load cells, an inverted-U-tube type manometer and a counter pressure load cell. All load cells were filled with de-aired water which contained some coppersulphate (0.5%) as an algae inhibitor. A change in weight of the lysimeter will alter the load cell pressure which is measured in the manometer. Since the total pressures are approximately 7 m watercolumn, a single manometer standpipe is not practical and an inverted-U-tube is used instead.
Pressure offset is obtained with the third load cell on which a load is applied by means of a lever. To reduce temperature error the third load cell was placed in a second underground cellar which is in open connection with the lysimeter cellar (see fig. 1).
The load cells were made from 25 cm inner diameter butyl nylon pipe*; those under the lysimeter are 1.65 m long, the counter pressure load cell is 0.36 m long. The ends were closed by vulcanization and in the middle the cells are connected to the copper piping system that leads to the manometer. Inflated with water and under normal loading conditions they are about 8 cm thick.

* Carlisle Corp., Carlisle Pa. USA, distributed by Watersaver Co., Denver, Colo. USA

The manometer was placed above ground level at about 3 m from the lysimeter (see fig. 2). The piping system is provided with several shut-off valves as a precautionary measure; moreover they allow to change the amount of air in the manometer or repairs to be carried out. Pressure differences are converted to depth of evaporation on the basis of the ratio of total evaporating area to loading area, in our case this ratio is about 3.

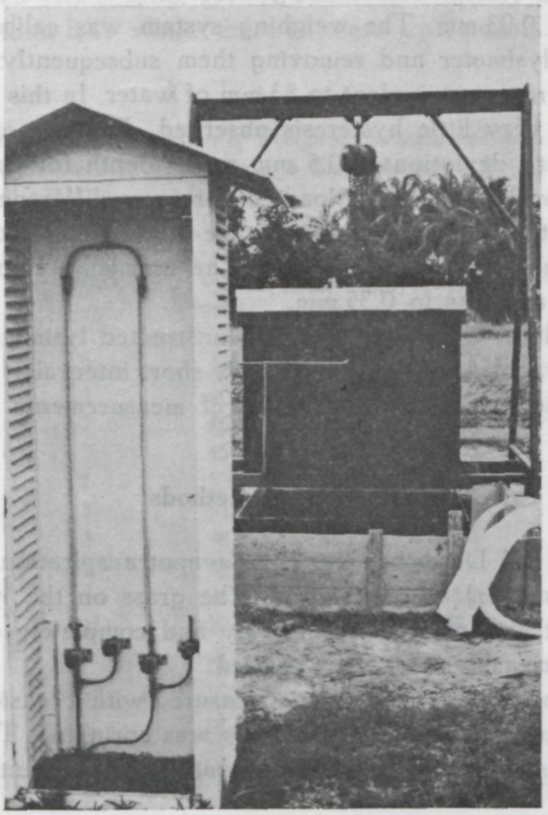

Fig. 2 Lysimeter during construction; manometer on the left, lysimeter tank above cellar in the background.

The amounts of surface run-off and drainage water are determined by measuring the change in water levels in the cylindrical reservoirs. This is done by means of a float and attached metal measuring tape. The reservoirs are periodically emptied by means of a handpump.

Calibration tests

The water balance of the lysimeter may be written as:

$$E = P - (R + D + \Delta S)$$

in which E denotes evapotranspiration, P precipitation, R run-off, D drainage and ΔS the change in soil moisture storage. Precipitation is measured nearby with a 400 cm^2 raingauge at 0.4 m above ground level. Investigations (e.g. Koopmans, 1972) showed that the difference between rainfall recorded with gauges at 1.5 m height and rainfall measured at ground level are negligibly small.

Calibration of the run-off and drainage reservoirs showed a standard deviation for both of 0.03 mm. The weighing system was calibrated by placing weights on the lysimeter and removing them subsequently. The tests have extended over a range equivalent to 83 mm of water. In this range the system was linear with very little hysteresis observed. Analysis of the test results yielded a standard deviation of 0.5 mm water depth for each measurement. The sensitivity was 2.9 mm H_2O load cell pressure difference per mm evaporation. Most of the error appeared to arise at the registration of the water levels in both tubes of the manometer. The maximum error which may be introduced here amounts to 0.35 mm.

From these results it is evident that the constructed lysimeter is not suitable for measuring evapotranspiration over very short intervals (e.g. some hours). However, sufficient accuracy is obtained if measurements are made over a longer period.

First results and comparison with other methods

From August 21 till December 21, 1972 evapotranspiration from Tocograss (Ischaemum aristatum) was measured. The grass on the lysimeter and the surrounding plot was planted during July and completely covered the area by the time the measurements were started.

Whenever the soil moisture tension, as measured with a tensiometer at a depth of 0.2 m exceeded 200 millibars, the grass was sprinkled. The actual evapotranspiration was therefore supposedly equal to the potential evapotranspiration.

In order to keep the grass in the same vegetative stage it was cut several times a week throughout the course of the experiment.

Manometer readings were carried out three times a day. Daily values of the evapotranspiration were computed, but in view of the standard deviation of 0.5 mm comparison with other methods was performed for 10-day periods only.

The decade values -ET - obtained by summing the daily values have been compared with data from a Class A Pan -Eo(A)- and with the evaporation computed by means of the Penman method -Eo(P)-. The Class A Pan was situated in the meteorological recording area at CELOS some 40 m away from the lysimeter. Except for wind velocity all data required for the computation of the Penman evaporation were obtained from the Centre's meteorological records. Penman's orginal formula has been applied. Incoming short-wave radiation was measured directly. The instrument used was a Kipp* solarimeter with one thermopile and two glass hemispheres. In table 1 the 10-day values are presented together with the totals over the entire experimental period. For comparison average data for short cut grass obtained with non weighable lysimeters at the Agricultural Experiment station, located about 8 km away, have been included (Kamerling, 1971). The results clearly show that Eo(P) is always higher than ET, while there is close agreement between Eo(A) and ET.

Table 1 The potential evapotranspiration of Tocograss as measured with a lysimeter —ET— compared with the evaporation from a Class A pan —Eo(A)— and the Penman evaporation —Eo(P)—

Month	Year	'Decade'	ET (mm)	Eo(A) (mm)	Eo(P) (mm)	ET/Eo(A)	ET/Eo(P)
Aug.	1972	3	53.6	54.6	65.1	0.98	0.82
Sept.	1972	1	40.0	42.3	54.9	0.95	0.73
		2	46.9	48.8	60.3	0.96	0.78
		3	45.1	48.3	58.3	0.93	0.77
Oct.	1972	1	53.2	50.2	59.7	1.06	0.89
		2	51.2	56.1	65.6	0.91	0.78
		3	48.4	53.2	65.2	0.91	0.74
Nov.	1972	1	38.8	39.7	49.8	0.98	0.78
		3	31.8	30.2	38.2	1.05	0.83
Dec.	1972	1	28.3	27.9	40.2	1.01	0.70
		2	27.4	26.6	32.8	1.03	0.83
Total			464.7	477.9	603.1	0.98	0.79
Kamerling (1971)						0.85	0.78

This is in conformity with earlier results obtained from a water balance study of the CELOS polder for a 70-day period in the wet season of 1971. Although for the computation of the Penman evaporation slightly different coefficients were used, the results also indicated that evapotranspiration computed from the water balance is considerably lower than evaporation computed according to Penman's method: over the entire 70-day period the evapotranspiration was found to be approximately 200 mm as opposed to 270 mm computed with Penman's method. The lysimeter results presented in table 1 that relate to the wet season (December), agree rather well with these water balance measurements. Moreover it appears from table 1 that the potential evapotranspiration

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during the dry season (Sept. - Oct.) is significantly higher than during the wet one.
Total ET during September and October amounted to 285 mm; at the same time 200 mm rain was recorded, causing a deficit of 85 mm.
Except for some minor interruptions mainly due to clogging of the run-off pipe, the system performed adequately during these first trials. Measurements of the actual as well as of the potential evapotranspiration from other crops will be carried out in the near future.

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