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EVAPORATION RESEARCH WITH FOUR DRAINAGE-LYSIMETER PLOTS IN THE ROTTEGATSPOLDER (NETHERLANDS)

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SUMMARY

Of the three methods applied in the Rottegatpolder to determine the evaporation, viz. (1) the evaluation of the vertical vapour transport, (2) the method of the water balance for the entire polder and (3) the use of four drainage-lysimeter plots, the first two were discussed in the Annual Bulletin 1954. Method No. 3 is described in this article.

The "bottom" of a drainage-lysimeter is a drainage system discharging in a measuring pit. This drainage system can be used in summer for subsoil irrigation of the lysimeter plot. Quantities of drain water and irrigation water can be determined.

The sides of the lysimeters are wooden walls, rammed into the soil. The ground water level inside and outside the lysimeters is the same.

For determining the change in subsoil moisture storage it appeared to be necessary to sample at the beginning and at the end of each balance period the soil profile layer by layer on 360 different locations. Therefore it was impossible as yet to grow different crops on the four lysimeters.

The evaporation is obtained from the water balance of the four lysimeters together, with a standard deviation of about 3 mm. and is in rather good agreement with the evaporation derived from the polder balance.

RESUME

Dans le Rottegatpolder trois méthodes sont utilisées pour déterminer l'évaporation :

- 1°. La méthode du transport vertical de vapeur d'eau.
- 2°. La méthode du bilan d'eau du polder entier.
- 3°. La méthode du bilan d'eau de quatre lysimètres de drainage (25 × 25 m. chacun).

Les deux premières méthodes sont décrites dans l'Annual Bulletin 1954, la troisième est traitée dans cet article.

Le fond d'un lysimètre de drainage est con-

stitué par un système de drainage, déversant dans un puits de mesurage et qui, durant l'été, peut également servir pour l'infiltration. Les quantités d'eau de drainage ou d'infiltration sont donc mesurables.

Les parois des lysimètres sont formées par des cloisons enfoncées dans le sol. Le niveau phréatique est le même en dehors et dans les lysimètres.

Pour pouvoir déterminer les changements des teneurs en eau des profils il s'avéra nécessaire de prélever des échantillons au début et à la fin de chaque période du bilan, sur chaque couche du profil, sur 360 endroits différents. C'est la raison pourquoi il ne nous fut pas encore possible de cultiver chaque année quatre cultures différentes sur les quatre lysimètres.

L'évaporation qu'il nous fut possible de déterminer à l'aide du bilan d'eau des quatre lysimètres avec un coefficient de variation de 3 mm. seulement, correspond assez bien avec l'évaporation déterminé à l'aide du bilan d'eau du polder entier.

I. INTRODUCTION

In the Annual Bulletin 1952 (pages 85,86) is reported briefly the purpose and design of the evaporation research in the Rottegatpolder, a small polder (87 hectares=215 acres) located about 10 kilometers (6 miles) NE of Groningen, a town in the north-eastern region of the Netherlands. It is a joint project of six government services and institutes* belonging to the Ministries of Traffic and Waterways and of Agriculture. The object of the research in the Rottegatpolder is to test the so-called method of determining the vertical water-vapour transport to measure the evaporation of the soil surface, which may be bare or covered with vegetation. For this purpose the results obtained by determining the vertical vapour transport are checked by the data obtained from the water balance of the entire polder. Both methods of measuring the evaporation are discussed in the Annual Bulletin 1954 (pages 116-121) by DEIJ and LATOUR.

The vapour-transport method is employed to determine the evaporation of a limited area around the place where on different levels above

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the surface of the soil or the vegetation, the dry and wet bulb temperatures and the wind velocities are measured. This area is covered by one or only by few different crops, whereas in the entire polder several types of crops are grown.

Therefore either the vapour-transport method should be applied to several fields in the polder so that the most important crops are represented on these fields or relative evaporation data of fields with different crops should be obtained in another way, *e.g.*, by means of lysimeters. Lack of experience in the Netherlands with the vapor-transport method and the high costs of several sets of apparatus required by this method led to the application of lysimeters in the Rottegatpolder.

Since weighable lysimeters are expensive and rather small, in order that border effects of clay monoliths, if they shrink, may become important, a special type of lysimeter has been developed, the so-called drainage-lysimeter.

II. THE DRAINAGE-LYSIMETERS

The lysimeters should be constructed in such a way that it would be possible to make water balances for rather short periods, say two weeks or a month. This means that it should be possible to determine for such a period:

- (i) the quantity of water drained from the lysimeter soil (L).
- (ii) the quantity of water, which has been subirrigated in the lysimeter (I)
- (iii) the change in water content of the entire soil profile (G), and
- (iv) the precipitation on the lysimeter (R).

Then the evaporation (V) can be derive from the formula of the water balance:

$$V = R + I - L - G$$

In order to obtain the extent of G it is necessary to determine at the beginning and at the end of a balance period the moisture contents of the entire soil profile by sampling and drying the soil samples. Therefore the surface of each lysimeter must be so large that this sampling does not disturb the soil structure in the lysimeter in a serious way. Furthermore on large lysimeters the border effects as well as the influence of heterogeneities of soil and crop would be small. These arguments led to a dimension of the drainage-lysimeters in the Rottegatpolder of $25 \times 25 = 625$ squares meters.

The usual way to construct a light lysimeter is to dig a pit, to build a concrete tray in it and to fill this tray with the excavated soil. It is not possible, however, to apply this method to a clay soil in general and especially to the sticky clay soil in the Rottegatpolder, since the disturbed soil will never recover its original structure.

Therefore for "bottom" of the drainage-lysime-
tre a tile drainage system at a depth of about 90 centimeters below soil surface has been used. This system is composed of a square tile line, going round at a distance of about one meter on the inner side from the lysimeter outline, and four tile lines at distances of about five meters (see Figure 1a).

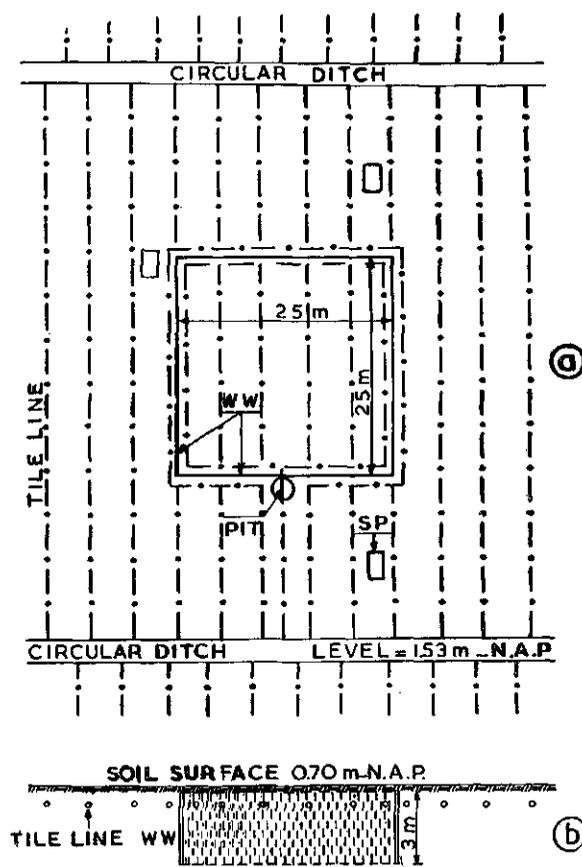


FIGURE 1:—(a) Scheme of the drainage system of the lysimeter plot and the surrounding field
WW=wooden wall, rammed into the soil
SP=sampling plot
N.A.P.=reference level (New Amsterdam Level).
(b) Vertical cross section through the lysimeter plot

The field outside the lysimeter plots is drained in the same way and at the same depth by tile lines, five meters apart from each other, which discharge into the circular ditch. Around and about one meter outside the lysimeter plot is a tile line, which is connected with the field system (Figure 1a).

The drainage lysimeter field in the Rottegatpolder is about 250 meters long and 60 meters wide and has four lysimeter plots. It is surrounded by a circular ditch the water level of which is kept at a constant height of about 80 centimeters below soil surface and 10 centimeters above the

tile lines by means of an automatic pumping system. The adjacent allotments are drained in the same way and have a ground water table at nearly the same depth.

The drainage system of a lysimeter plot, which is separated from the field system, is connected with a measuring-pit. Figure 2 shows a vertical cross-section of such a pit.

Drainage system D of the lysimeter plot is connected with cistern A by means of pipe CP. The overflow of the cistern is in level with the water surface in the circular ditch. The drain water flows in the lower part of the pit and its quantity can be measured by means of the pump P and water-meter W.

If in summer the ground water table is falling

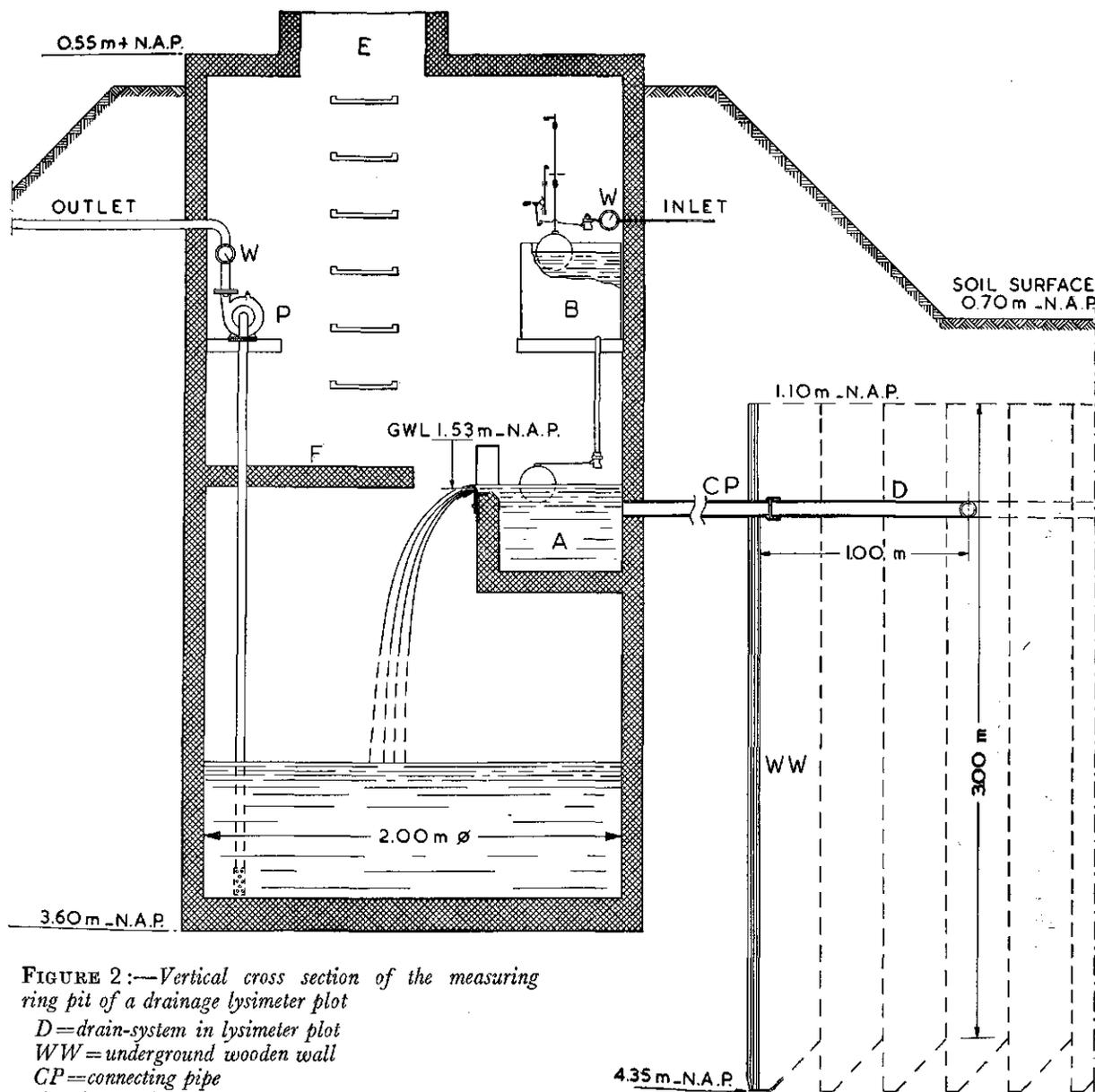


FIGURE 2:—Vertical cross section of the measuring ring pit of a drainage lysimeter plot

- D=drain-system in lysimeter plot
- WW=underground wooden wall
- CP=connecting pipe
- A=cistern with overflow and float-valve for water supply
- B=buffer-tank for water-inlet with special float-valve
- E=entrance of the pit
- F=concrete floor
- P=pump with float-switch
- W=water-meter
- GWL=constant ground water level
- N.A.P.=reference level (New Amsterdam Level)

the overflow water-supply from the buffer-tank B starts automatically by means of the float-valve in A. The buffer-tank is refilled automatically from the provincial water-supply line by means of a special float-valve, which is opened either complete or closed. So it is possible to measure the water-supply with a water-meter, which is

working correct only if the velocity of the water is enough.

In this way the ground water tables within and outside the lysimeter plots could be maintained at the same height within two centimeters. Structure of the subsoil is rather dry and with such small differences in ground water level, no water would flow from the lysimeter plot into the drainage system of the surrounding field or *vice-versa*. The experiments in the first two years (1948 and '49), however, have given contrary results. Differences of 30 mm and more between the quantities of drain water of the different lysimeter plots—which

were carrying one and the same crop—were measured. It appeared that the permeability of the "soil wall" with a thickness of about two meters around the lysimeter plots was too high.

To eliminate this difficulty a wooden wall was rammed into the soil along the circumference of each lysimeter plot in February and March 1950. The top of this wall is situated at a depth of 40 centimeters below surface, so that tillage implements can pass over it. The lower end of the wall reaches up to 3.40 meters below surface (Figures 1 b and 2). It appeared that it was a decisive measure.

TABLE I

Precipitation (R), sub-irrigation (I), drainage (L), change in moisture content of the soil profile (G) and evaporation ($V=R+I-L-G$) for the drainage-lysimeters (quantities in mm) in different balance periods. Mean values for the four lysimeter plots.

Balance period	Number of days	R	I	L	G	V	Crop
8—3-'51/ 5—4-'51	28	116	0	70	+ 8	38	bare
5—4-'51/ 2—5-'51	27	36	0	22	— 21	35	
2—5-'51/ 1—6-'51	30	84	0	26	+ 3	55	
1—6-'51/ 3—7-'51	32	33	0	3	— 12	42	potatoes
3—7-'51/ 2—8-'51	30	58	0	0	— 5	63	
2—8-'51/ 4—9-'51	33	80	13	0	+ 6	87	
4—9-'51/ 2—10-'51	28	29	9	0	— 10	48	
2—10-'51/31—10-'51	29	12	6	0	— 1	19	
31—10-'51/ 4—12-'51	34	132	0	64	+ 37	31	
4—12-'51/ 9—1-'52	36	102	0	93	+ 9	0	
9—1-'52/ 6—2-'52	28	75	0	70	+ 8	— 3	
6—2-'52/29—2-'52	23	24	0	20	— 8	12	winter wheat
29—2-'52/ 4—4-'52	35	48	0	28	— 1	21	
4—4-'52/ 2—5-'52	28	28	0	9	— 23	42	
2—5-'52/ 5—6-'52	34	33	35	0	— 34	102	
5—6-'52/27—6-'52	22	52	32	0	+ 15	69	
27—6-'52/ 1—8-'52	35	134	30	0	+ 41	123	
1—8-'52/ 2—9-'52	32	85	0	24	+ 10	51	
2—9-'52/ 1—10-'52	29	75	0	15	+ 5	55	
1—10-'52/30—10-'52	29	67	0	25	+ 6	36	
30—10-'52/10—12-'52	41	111	0	85	+ 8	18	
10—12-'52/13—1-'53	34	66	0	76	— 6	— 4	bare
13—1-'53/ 3—2-'53	21	33	0	30	+ 1	2	
3—2-'53/ 4—3-'53	29	37	0	44	— 3	— 4	
4—3-'53/26—3-'53	22	7	0	2	— 10	15	
26—3-'53/ 4—5-'53	39	110	0	56	— 1	55	barley
4—5-'53/ 4—6-'53	31	73	0	5	— 7	75	with clover
4—6-'53/ 7—7-'53	33	56	10	0	— 24	90	
7—7-'53/ 3—8-'53	27	81	6	2	+ 22	63	
3—8-'53/ 1—9-'53	29	137	2	56	+ 22	61	
1—9-'53/ 2—10-'53	31	72	0	21	— 9	60	
2—10-'53/29—10-'53	27	16	0	3	— 4	17	clover
29—10-'53/ 2—12-'53	34	28	1	12	— 1	18	
2—12-'53/ 2—4-'54	121	180	1	112	+ 6	63	
2—4-'54/28—4-'54	26	17	0	12	— 27	32	
28—4-'54/ 2—6-'54	35	58	0	17	— 9	50	
2—6-'54/ 1—7-'54	29	81	0	14	+ 16	51	potatoes
1—7-'54/ 3—8-'54	33	124	0	35	+ 13	76	
3—8-'54/ 2—9-'54	30	93	0	35	— 2	60	
2—9-'54/ 7—10-'54	35	150	0	66	+ 12	72	
7—10-'54/ 1—11-'54	25	52	0	37	— 3	18	bare

III. MEASUREMENTS

The precipitation has been measured by means of two rain gauges. Before May, 1953, these were situated in the neighbourhood of the drainage-lysimeter field. After that two rain gauges on the lysimeter field are used. They can be raised so that the upper rim of each gauge is nearly constant at about 40 centimeters above the upper surface of the growing crop. The standard deviation of the monthly precipitation (mean for the results of both rain-gauges; Table I) appeared to be about one mm. The quantities of water, which are drained from or by sub-irrigation are infiltrated in the lysimeters and measured by means of watermeters as explained above. The standard deviation of the monthly mean quantity for the four lysimeters (Table I) was about one mm.

The determination of the change in the subsoil moisture storage has given great difficulties. Owing to the heterogeneity of the soil structure in a horizontal direction and to local differences in evapotranspiration it appeared necessary to sample at the beginning and at the end of a balance period the soil profile, layer by layer, up to a depth of 80 centimeters at 360 different locations. Since this

intensive sampling would much disturb the soil of the lysimeters these locations are divided into 12 sampling plots, three of which are situated around each lysimeter (Figure 1 a). Each sampling plot can be used six times and must be replaced then by a new one. The moisture percentages (in grammes per 100 gram dry soil) were converted into millimeters by means of the volume-weights of the different soil layers, which were determined once for all in 1952. These mean that volume-weights appeared to vary between 1.20 and 1.33 grammes per cubic centimeter.

In this way it appeared possible to keep the standard deviation of the mean monthly change in subsoil moisture small enough (about two mm). The data obtained on this change in moisture storage are given in Table I.

It will be evident that due to the necessity of the very intensive sampling a comparison of four different crops on the drainage lysimeter field is not possible as yet.

IV. RESULTS

The mean values for the five entries of the water-balance of the drainage-lysimeters for the

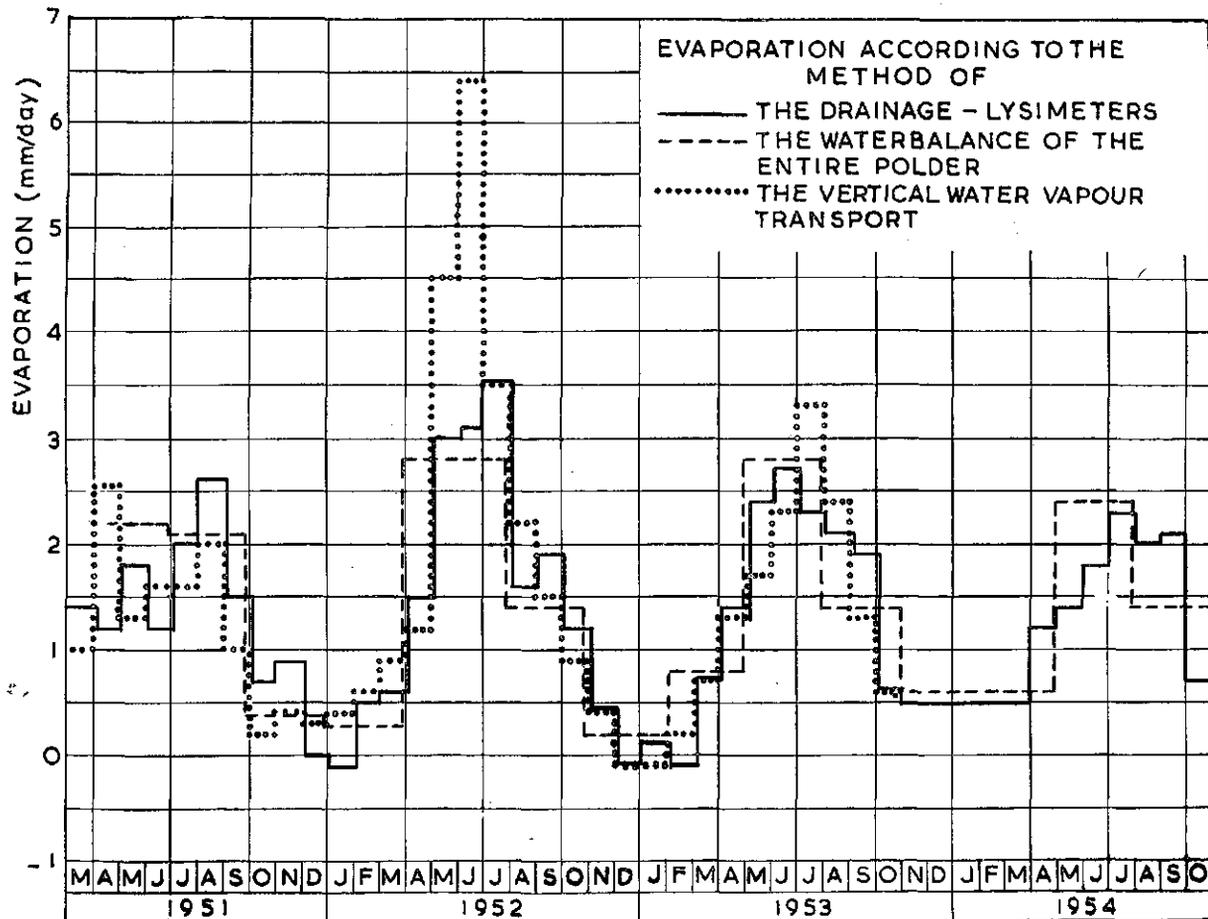


FIGURE 3

different balance periods (of generally about a month) are assembled in Table I.

To facilitate the comparison of the evaporation obtained from the water-balance of the drainage-lysimeters in one period with that in another period or with that obtained by another method, the mean every day evaporation is plotted against time for the three methods of measuring evaporation put into practice in the Rottegatspolder (Figure 3). Taking account of the differences in the nature of the soil surface and the crops on the drainage-lysimeter field (arable land), in the entire polder

(about 75 per cent arable land, 13 per cent grassland and 12 per cent roads, ditches, farm-yards etc.) and on the experimental field for vapour-transport determinations (till mid. December 1951 grassland, after that arable land) it can be concluded from Figure 3 that the evaporation of the drainage-lysimeter field is in rather good agreement with that of the entire polder. The evaporation as determined by the vapour-transport method, however, shows in several periods a deviation, which is too great. Attempts are being made to obtain a better agreement by improving the apparatus and placing it on the drainage-lysimeter field.