THE ACTUAL EVAPOTRANSPIRATION AS A FUNCTION OF THE POTENTIAL EVAPOTRANSPIRATION AND THE SOIL MOISTURE TENSION

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Summary

The real (actual) evapotranspiration of grassland falls below the potential evapotranspiration when the soil is drying. The rate of reduction depends on the moisture tension of the soil and on the intensity of the potential evapotranspiration as a measure for the evaporation. The real evapotranspiration may keep up with the potential evapotranspiration of a definite intensity; the wetter the soil, the higher the intensity at which reduction begins to occur.

In a peat soil the effect of soil moisture tension on the reduction in evapotranspiration was smaller than in a clay soil.

Introduction

The question at which moment a crop begins to show a limitation in its water consumption, due to a decrease of the soil moisture content, was answered by Penman (1949). He gave a schematic diagram demonstrating that a crop will maintain its potential evapotranspiration until the moisture quantity of the "root constant" (3 inches) plus the capillary risen water (1 inch) have been completely exhausted.

Observations on a clay soil

Observations with the set of 32 weighable monolyth lysimeters with grass near Wageningen (Makkink, 1953) showed that the concept of Penman's diagram is not true.

On May 7th 1953 the soil moisture content of a clay soil (59–61% particles $< 16\,\mu$ in the layer 0–10 cm of the soil) with the water table at –70 cm began to fall below field capacity. The waterloss soon became smaller than on a sandy soil with the water table at –50 cm, where the water loss may be taken for the potential evapotranspiration (Fig. 1). In this figure the broken line represents the hypothetical curve of Penman; the bends are in accordance with the quantity of rain fallen in the period concerned.

The continuous line shows the summarized actual evapotranspiration of a clay soil plotted against the summarized potential evapotranspiration. The discrepancy between the lines proves that the soil water had become more and more less available. This phenomenon may be represented by $E_R = f(E_P, S)$ in which E_R and E_P mean the real (actual) and potential evapotranspiration per 24 hours and S the soil moisture tension or suction force.

For each of 14 periods of a length of 7–14 days the E_R per day was plotted against the average soil moisture tension. One of them is reproduced in Fig. 2. The periods were chosen so that the evapotranspiration in each of them was rather homogeneous. E_R was calculated from water balance sheets of the lysimeters. The soil moisture tension was measured with Bourdon tensiometers with a horizontal porous cup at about –5 cm.

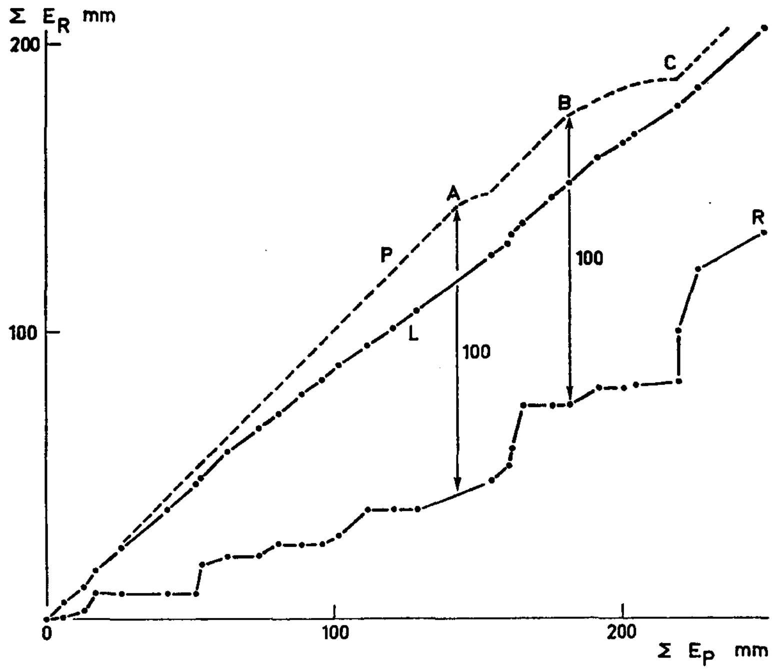

FIG. 1. REAL EVAPOTRANSPIRATION OF GRASS AS A FUNCTION OF THE POTENTIAL EVAPOTRANSPIRATION. P curve after PENMAN. A and B points where 100 mm has been withdrawn and limitation starts. C limitation removed. L curve after the lysimeters. R rain same scale as ΣE_R ; the points correspond to those of the other curves.

By extrapolation E_P was found in the figures at the ordinate for the tension of 0 m water column.

From the E_P's thus obtained, we selected 4 classes of E_P-values and plotted for each class the E_R against the average soil moisture tension of the 12 lysimeters with the clay soil, which originated from one parcel. One of those diagrams is given in Fig. 3. Similarly there were made 6 classes of soil moisture tension and for each one the E_R was plotted against the E_P. One example is represented in Fig. 4.

After both series of curves, $E_R = f(S)$ and $E_R = F(E_P)$, a nomogram could be drawn, which fitted the data as good as possible. From this the picture of Fig. 5 was derived, which shows that on a wet soil the potential evapotranspiration is maintained at least for intensities up to 4 mm per 24 hours. The drier the soil the more the real evapotranspiration falls below the potential. On a rather dry soil (a suction of 7 m water at –5 cm) and with a potential evapotranspiration of 4 mm/24 hours, the reduction is about 30 %, but with a potential evapotranspiration of 2 mm/24 hours the reduction is almost negligible. In Fig. 6 is shown how after the nomogram the maximum unreduced evapotranspiration depends on the soil moisture tension.

The question must be raised whether the indications of the tensiometers were correct for the higher readings. Therefore the tensiometer values were plotted against those obtained with nylon resistance units, which in 1955 were present in the same layer as the tensiometer cups (Fig. 7). In the same diagram a second line was drawn for the same type of nylon units, checked in

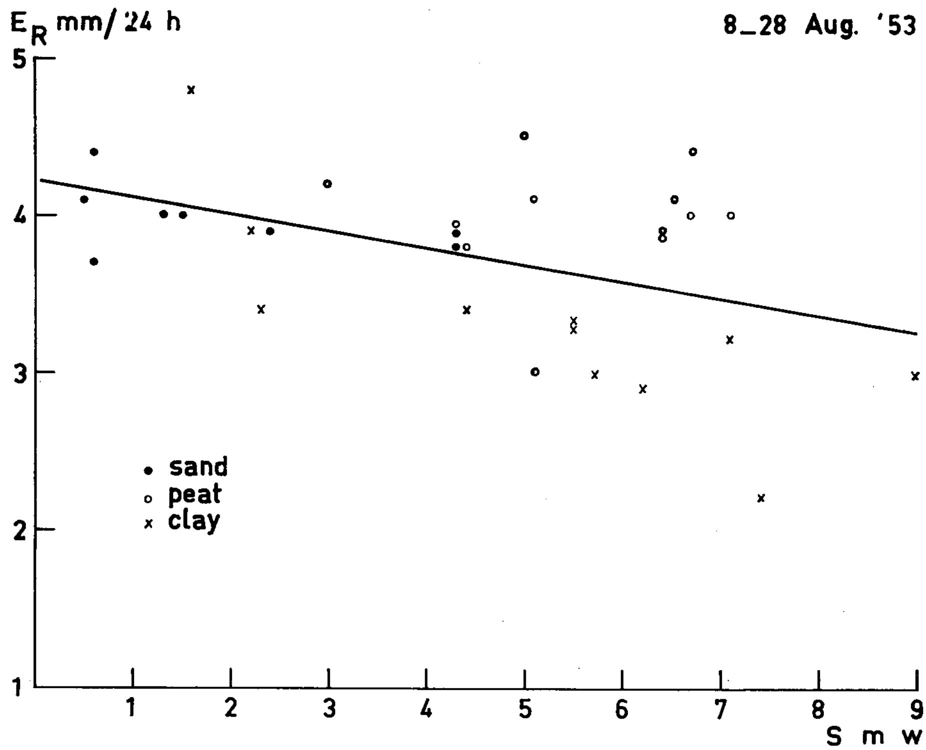

FIG. 2. REAL EVAPOTRANSPIRATION INTENSITY PLOTTED AGAINST THE SOIL MOISTURE TENSION IN THE PERIOD OF MAY 18th–28th 1953 FOR 32 LYSIMETERS, IN ORDER TO FIND THE POTENTIAL EVAPOTRANSPIRATION INTENSITY BY EXTRAPOLATION TO THE ORDINATE.

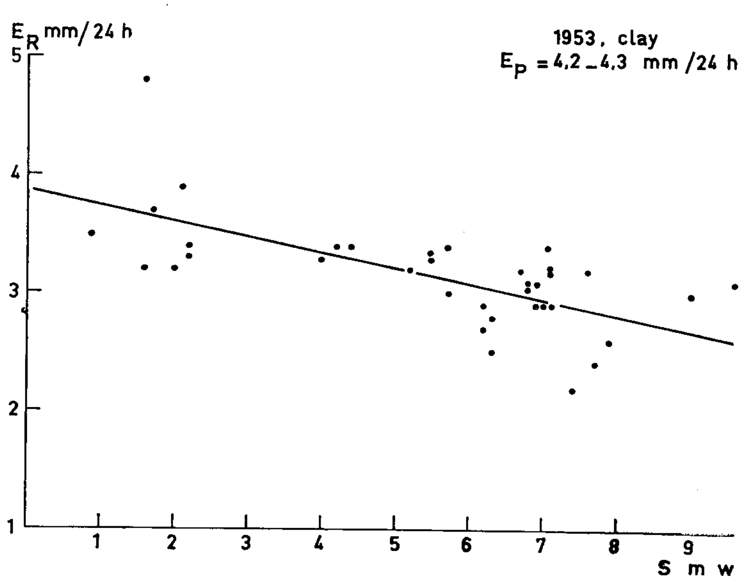

FIG. 3. REAL EVAPOTRANSPIRATION INTENSITY PLOTTED AGAINST THE SOIL MOISTURE TENSION FOR THE CLASS OF E_P -VALUES 4.2–4.3 mm/24 hours.

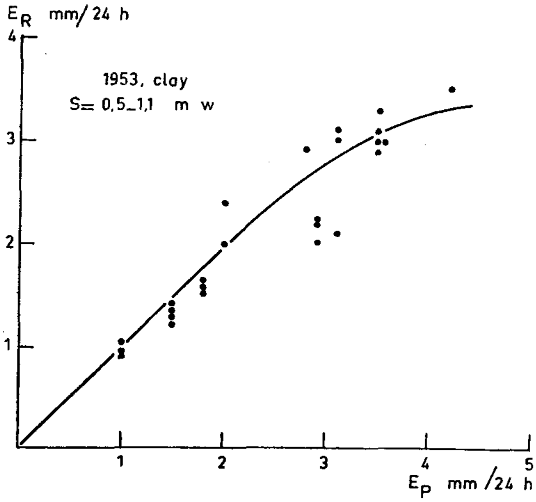

FIG. 4. REAL EVAPOTRANSPIRATION INTENSITY PLOTTED AGAINST THE POTENTIAL EVAPOTRANSPIRATION INTENSITY FOR THE CLASS OF S-VALUES 0.5—1.1 m WATER COLUMN.

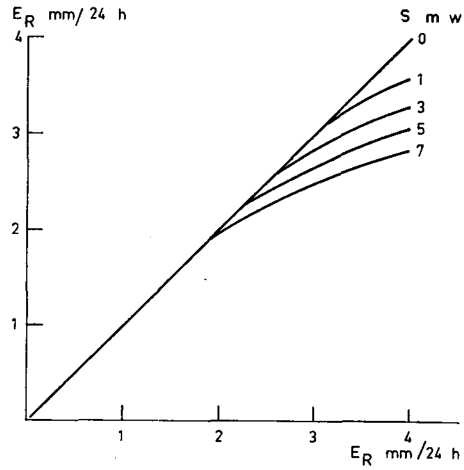

FIG. 5. REAL EVAPOTRANSPIRATION INTENSITY AS A FUNCTION OF THE POTENTIAL EVAPOTRANSPIRATION INTENSITY AND THE SOIL MOISTURE TENSION IN A CLAY SOIL.

a porous plate apparatus and in a soil sample of which the relationship between the pF and the moisture content was known. This curve has been kindly put at our disposal by Mr. G. P. WIND of the Central Institute of Agricultural Research at Wageningen. It has been inserted on our own curve at the point of the average of our values in the wet range, where tensiometers indicate correctly. The curves show some discrepancy, but the deviation is not great and necessitates to increase the values of the tension scale only little.

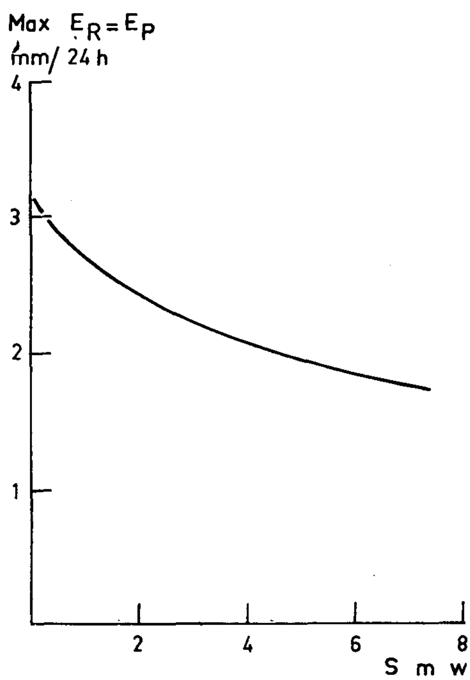

FIG. 6. THE MAXIMAL NON-REDUCED EVAPOTRANSPIRATION INTENSITY AS A FUNCTION OF THE SOIL MOISTURE TENSION.

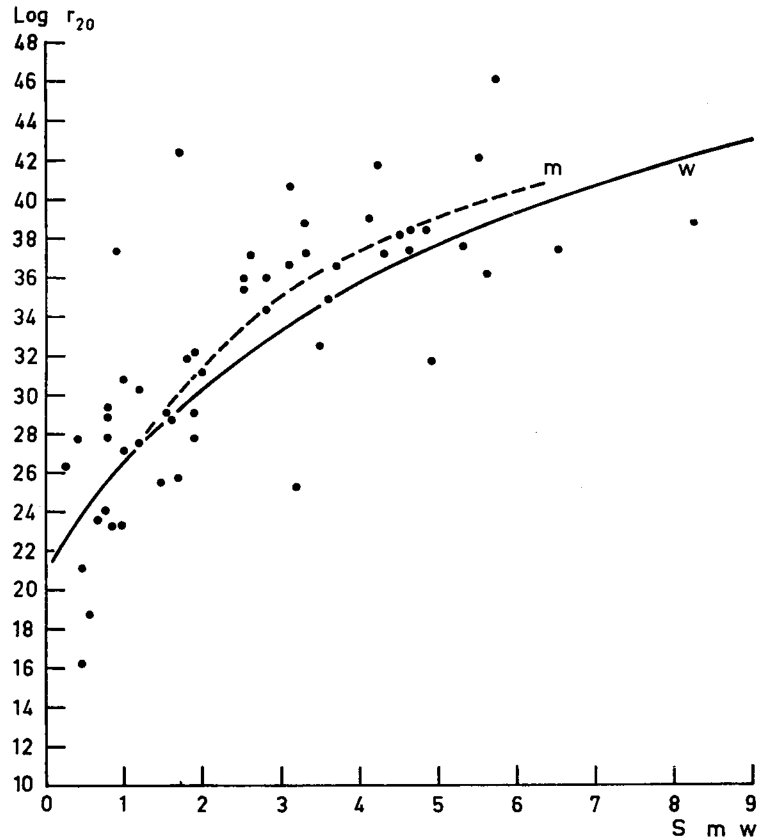

FIG. 7. THE LOGARITHM OF THE ELECTRIC RESISTANCE AT 20° C OF A CLAY SOIL (MEASURED WITH NYLON UNITS) PLOTTED AGAINST THE SOIL MOISTURE TENSION MEASURED WITH TENSIOMETERS. M values observed by the authors, W curve after observations of Mr. G. P. WIND.

The same elaboration has been carried out for 12 periods of 1952 and 11 periods of 1954. The obtained nomograms were not quite identical. In Fig. 8 for a suction force of 4 m water the curve of E_R as a function of E_P is drawn after the nomograms of the three years. For a suction force of 7 m water the deviations are greater. This grade of dryness, however, did not occur in 1952 and 1954. The situation of the curve of 1952 below that of 1953 may be due to the fact that in 1952 the tensiometer cups had a vertical position in the soil layer from 0—10 cm, whereas in 1953 they lay horizontally at a depth of 5 cm. Because tensiometers always indicate the tension of the wettest spot with which it is in contact, the real tension at –5 cm in 1952 was higher than the tensiometer indicated. Consequently the curve for 1952 shows a greater reduction of E_R .

In 1954 the cutting interval was 5 weeks instead of 4 in the preceeding years, but we do not see why this could have increased the reduction in evapotranspiration.

OBSERVATIONS ON A PEAT SOIL

Also for a peat soil (34—36 % humus and 20—22 % particles $< 16\,\mu$ in the layer 0—10 cm) a similar investigation has been carried out for the year 1953

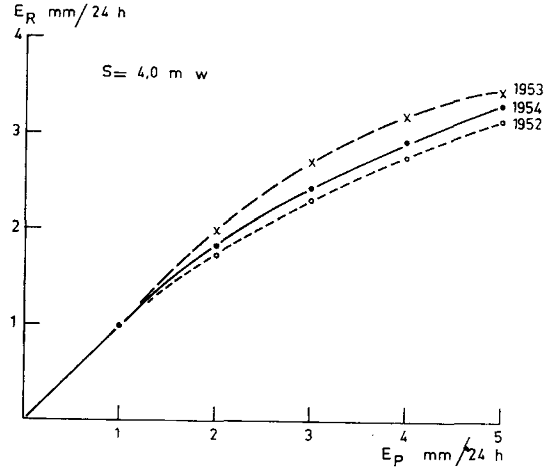

FIG. 8. REAL EVAPOTRANSPIRATION INTENSITY AS A FUNCTION OF THE POTENTIAL EVAPOTRANSPIRATION WITH A SOIL MOISTURE TENSION OF 4 m WATER COLUMN IN A CLAY SOIL IN THREE YEARS.

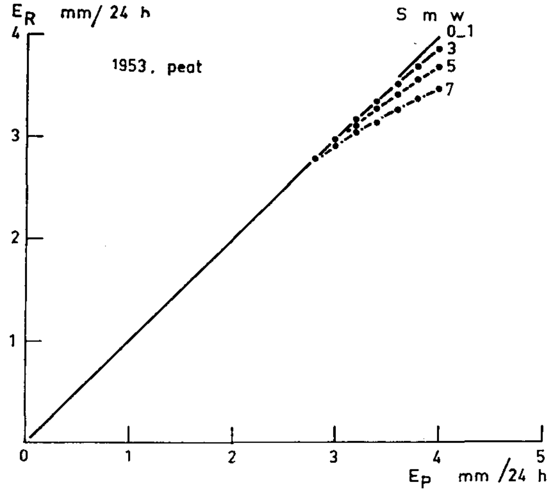

FIG. 9. REAL EVAPOTRANSPIRATION INTENSITY AS A FUNCTION OF THE POTENTIAL EVAPOTRANSPIRATION INTENSITY AND THE SOIL MOISTURE TENSION IN A PEAT SOIL IN 1953.

in which the highest soil moisture tensions occurred. The reduction of the evapotranspiration at any soil moisture tension was much smaller (Fig. 9). This means that with a definite difference between the moisture tension in the atmosphere and in the soil layer of –5 cm (characterized by a definite E_P and a definite S), on a peat soil passes more water through the grass than on a clay soil.

Consequently the supply from below the level of –5 cm must be greater in the peat than in the clay soil. Whether this is due to a greater capillar conductivity of the soil or to a deeper or denser rooting of the grass has not been investigated.

REFERENCES

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