RESULTS OF MEASUREMENTS WITH RENQVIST'S EVAPORATION RECORDER IN SOUTH FINLAND IN SUMMER 1950

By

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Abstract

The dependence of evapotranspiration on certain meteorological factors has been studied. The effect of direct sunshine seems to be considerable, but that of wind weak. A comparison is made between the observed values of evapotranspiration and those calculated in proportion to saturation deficit.

From the year 1938 the Hydrological Bureau has had an evaporation recorder designed by Renqvist, at Tikkurila in South Finland (25°02'E, 60°17'N). It consists of an open tank, a cube of 1 m^3 capacity, filled with earth. The tank is placed on a weighbridge standing in a cellar so that its open upper surface is on a level with the surrounding field. The movements of the weighbridge are recorded on a paper on a rotating drum. Renqvist [1] has given a report concerning the structure and action of the recorder at the general assembly of the International Union of Geodesy and Geophysics in Brussels, 1951. He pointed out that the air temperature, saturation deficit and wind are, of course, elements of major importance. He stated that on many days the evaporation amounted to 10 mm and the condensation to 0.5 mm. There is also a brief reference to the recorder in the report of the Tulvakomitea (Flood Committee) [2]. The results of the earlier measurements are not published.

The observation station on the slope of a little hill is surrounded mainly by open field. In summer 1950 lupins (Lupinus polyphyllus) and grasses grew on the surface of the evaporation tank. The purpose of the experiment was to measure the evapotranspiration. The uppermost layer (about 30 cm) in the evaporation tank consists of soil taken from the immediate vicinity of the recorder and transferred to it undisturbed. At the bottom there are sand and stones.

In summer 1950 the recorder was in action during the period 17.5—30.9. During that time the wind velocity at 2 meters' altitude, the rainfall and the hours of sunshine were recorded continuously. During some periods of the summer hourly measurements of the air temperature, saturation deficit and cloundiness were made at the observation station. In addition the meteorological measurements made by the Agricultural Research Center at a distance of 300 m from the observation station were available.

The recorder was covered during the winter. When the measurements were started in spring, the soil in the tank had to be moistened artificially. To what extent the moisture content of the earth cointained in the tank resembled that of the surrounding soil is unknown. Though their conditions were similar at the beginning of the observation period, they change in a different way in the closed vessel as in the open. In August, during a dry period, the plants growing in the evaporation vessel were plainly more withered than those growing in its surroundings. Besides the watering at the beginning of the observation period, water was added to the evaporation vessel 5 times during the summer (13.6, 18.6., 21.6., 28.6. and 21.8., in all about 160 litres). The position of the recorder on the slope disturbs the natural air current and may affect the evapotranspiration.

Fig. 1 shows the 5 day totals of evapotranspiration, rainfall and sunshine duration. For the whole observation period (17.5—30.9.) the measured evapotranspiration was 346 mm and the rainfall 251 mm. The summer of 1950 was quite dry. In May and June pricipitation was only about half the average. In July the rainfall somewhat exceeded the average. August was very dry, and the precipitation was considerably below 50 per cent of the average. At the observation station there was an unbroken dry spell from 2.8—27.8. In September precipitation greatly exceeded the average. The evapotranspiration increases from the beginning of the summer continuously until about June 20. In July the evapotranspiration continues fairly evenly. In August it falls off steeply. The steepness may be due to the long rainless period. The greatest evapotranspiration occurs in the principal flowering period of the lupins in the end of June. Accordingly to Fig. 1, only very marked changes of precipitation are reflected

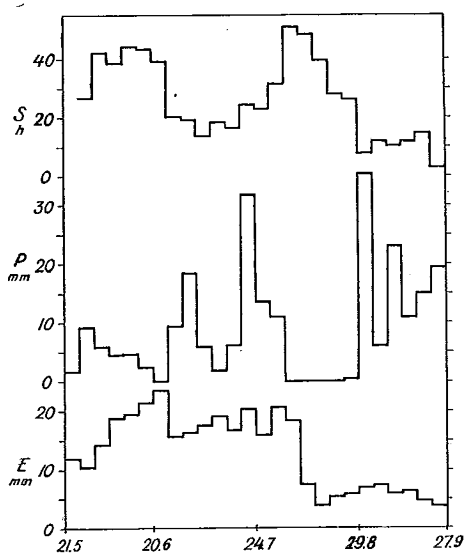

Fig. 1. The five day totals of the evapotranspiration (E), rainfall (P) and sunshine duration (S).

in the evapotranspiration. No parallelism is observed in the trends of these two factors. Between the trends of the sunshine duration and of the evapotranspiration there is a considerable parallelism.

The variation of the evapotranspiration from day to day was very great, but the trend during the growing period is nevertheless plainly discernible. This trend displays a close correlation with the developmental phase of the plants. It is noticeable that the area of the evaporation surface changes during the growing period. In table 1 there are the average, greatest, and

Table 1. The daily means and extremes of the evapotranspiration (E) in each month and the monthly totals of the evapotranspiration (E) and rainfall (d).

Month	E (mm/day)			E (mm/month)	P (mm/month)
	Average	Max	Min.		
June	3.8	6.4	1.7	115	24
July	3.5	5.2	1.4	109	92
August	1.9	4.7	0.3	58	24
Sept.	1.1	2.2	0.3	34	96

smallest daily evapotranspirations for each month. Besides this there are in the same table the monthly totals of the evapotranspiration and rainfall.

In table 2 there are correlation coefficients between the daily means of the evapotranspiration and certain meteorological factors. The values for July have been chosen for analysis, since the evapotranspiration measurements seem to have been more reliable during this month. In July the evaporation tank was not watered artificially, rainfall was about normal and evapotranspiration strong. Coefficients have also been calculated between the evapotranspiration and certain meteorological factors observed 3 times per day at the Agricultural Research Center.

Table 2. *Correlation coefficients (July 1950).*

Relation between evapotranspiration and		Coefficient
wind velocity		0.06 ± 0.18
duration of sunshine		0.74 ± 0.08
mean temperature	Agricultural Research Center	0.58 ± 0.12
maximum temperature	Agricultural Research Center	0.62 ± 0.11
saturation deficit	Agricultural Research Center	0.78 ± 0.07
wind velocity	Agricultural Research Center	0.28 ± 0.17
cloudiness	Agricultural Research Center	—0.56 ± 0.12

The maximum temperature gives a better correlation than the mean temperature. This is easily understood, for transpiration occurs mainly by day. The highest correlation was obtained between the evapotranspiration and saturation deficit. As a rule the wind velocity is considered to be one of the most important elements influengcing evaporation. According to the correlation coefficients obtained in this examination, the influence of wind on evapotranspiration is very slight. At the observation station the wind velocity is given as the mean of 24 hourly wind velocities measured by a continuously recording anemometer. At the Agricultural Research Center it is the mean of 3 daily observations measured with Wild's plates. As to the cloudiness and sunshine duration, the correlation cofficients calculated show that direct solar radiation and light have a profound influence on the evapotranspiration. The correlation between duration of sunshine and evapotranspiration is a surprising one, in view of the very approximate nature of the record for the duration of sunshine and of the fact that the strength of radiation has not been taken into account at all.

The dependence of evapotranspiration on meteorological factors was investigated for those days when the daily evapotranspiration had attained at least the relative extreme of 0.1 mm/day. A check was made of whether certain meteorological factors had exhibited a relative extreme on the same days. During the whole observation period the evapotranspiration had a relative maximum on 33 days and a relative minimum on 35 days. The results of the examination are represented in the table 3. The evapotranspiration and the duration of sunshine were observed at the observation station and all the other factors at the Agricultural Research Center.

Table 3. Dependence of the evapotranspiration on meteorological factors. The number of days, when a ralative extreme of the evapotranspiration and some meteorological factor have coincided.

Meteorological element	Number of days			
	Maximum evapotranspiration (33 days)		Minimum evapotranspiration (35 days)	
	Meteorological factor with		Meteorological factor with	
	max.	min.	max.	min.
Duration of sunshine	17	1	1	18
Mean temperature	11	2	4	16
Maximum temperature	12	1	2	15
Saturation deficit	21	2	1	23
Wind velocity	18	4	6	10
Cloudiness	1	24	21	0

The results of the analysis in table 3 agree with that given by the correlation calculation. Regarding the influence of wind, this earlier analysis gave a completely negative result. According to Table 3 there is a plain dependence between especially strong evapotranspiration and wind velocity. When the evapotranspiration has a relative minimum, the wind velocity seems not to be of any great significance. This may imply that strong winds often occur in connection with weather conditions which reduce evapotranspiration. The effect of the wind is a secondary one, acting only when other factors are favourable. Even in a weak wind there has been measured strong evaporation. For instance on July 30, the mean wind velocity measured at the Agricultural Research Center was 0.3 m/sec whilst evapotranspiration was 3.1 mm/day. Nevertheless, usually the evapotranspiration had a low value when wind velocity was low. Likewise very strong winds lead in general to a high evapotranspiration. But if one attempts to analyse the influence of the wind by plotting evapotranspiration against wind velocity, no correlation is observed. Fig. 2 shows the dependence of the daily evapotranspiration on the maximum temperature (measured at the Agricultural Research Center) while the wind velocity is 0-2 m/sec and 4-6 m/sec. One finds that the evapotranspiration increases with the wind velocity.

Sunshine seems to have a definite influence on the transpiration process. The plain influence of the maximum temperature and cloudiness may be in some way connected with the effect of sunshine.

In Fig. 3 there are shown the courses of the evapotranspiration and certain meteorological factors on the basis of hourly observations during a period of two days in the end of June. The high correlation between sunshine and transpiration is plainly visible. For instance on June 29 the evapotranspiration displays 2 maxima between which the sun was behind the clouds. The strong evapotranspiration was confined to those times when the sun was shining. The influence of cloudiness is more indefinite. It appears from the figure that the value for cloudiness may be high even

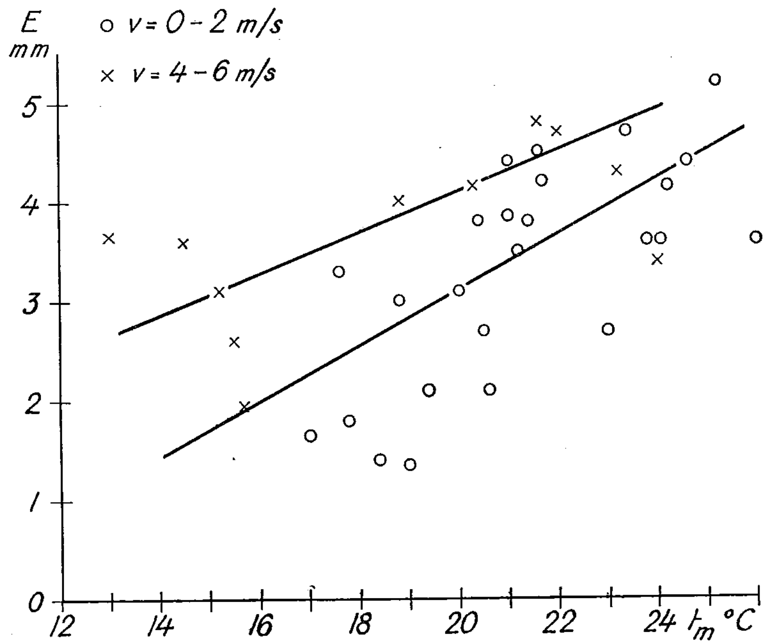

Fig. 2. The dependence of the evapotranspiration (E) on the maxima temperature (t_m) at different wind velocities.

when the sun is shining. The wind velocity, temperature and humidity are measured at 2 m's altitude. Their influence is less plain. Often the trend is not so consistent with the evapotranspiration as in Fig. 3. The maxima of the temperature and saturation deficit often change later than those of evapotranspiration. In Fig. 3 the maxima of the wind velocity and evapotranspiration change together. On June 30, at 12 o'clock the evapotranspiration, while different factors were simultaneously favourable,

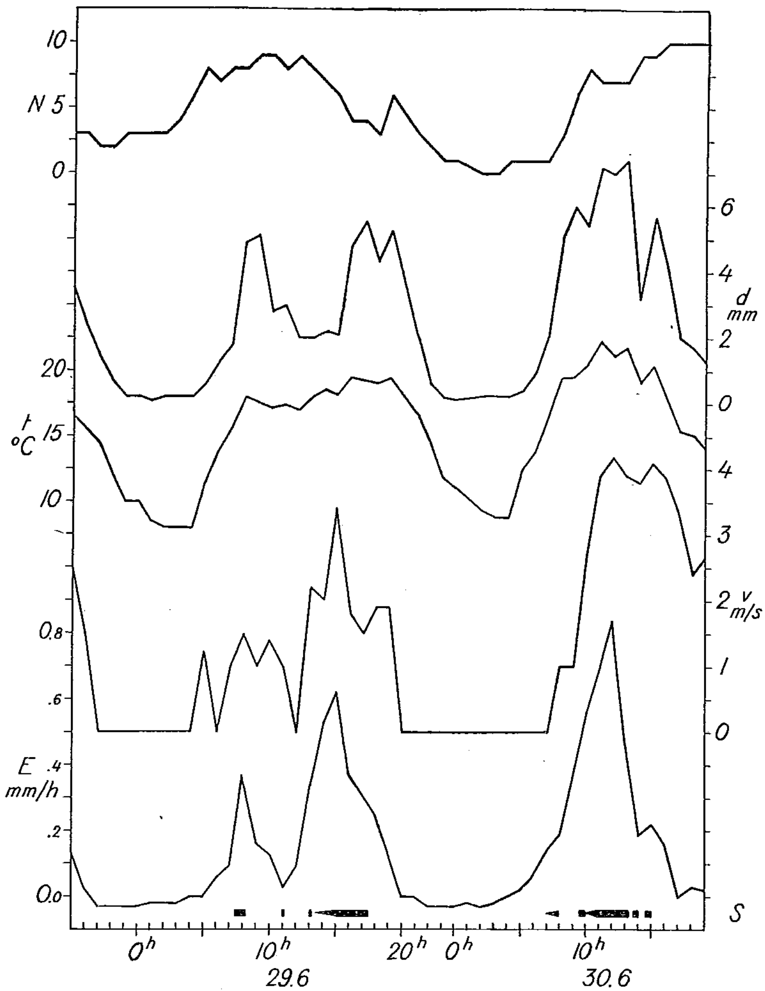

Fig. 3. The course of the evapotranspiration (E), temperature (t), saturation deficit (d), wind velocity (v), cloudiness (N) and sunshine duration (S) during a period of two days.

was 0.84 mm/hour, which is one of the highest values for evapotranspiration during the observation period. In most cases the strongest evapotranspiration has occurred a little after noon. On the days shown in the figure the evapotranspiration has approximately corresponded to the average evapotranspiration of June and July. On both nights, condensation has taken place.

The saturation deficit is often used in dividing the annual evapotranspiration determined by some method between different months (Kusin's method). In table 4 the sum of the measured evapotranspiration of June-September is divided in proportion to the saturation deficits of these months. For comparison the measured monthly evapotranspiration are also included in the same table.

Table 4. The evapotranspiration of June-September divided in proportion to the saturation deficit

Month	Evapotranspiration (mm) Calculated	Evapotranspiration (mm) Measured	Saturation deficit (mm)
June	97	115	3.9
July	85	109	3.4
August	97	58	3.9
September	37	34	1.5
Sum	316	316	

Between the measured evapotranspiration and that obtained by aid of the saturation deficit there is a considerable difference. The measured evapotranspiration change more from one month to another than the calculated ones. Especially plain is the difference in August, when precipitation was low. The differences are easy to explain, for the saturation deficit is not the measurement of the evaporation from the surface of the earth, but a quantity showing the possibilities of evaporation. In August the evapotranspiration remained low, because there was not enough moisture in the soil.

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