EVAPORATION AND SOIL MOISTURE IN FORESTS AND CULTIVATED FIELDS

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I. *Evaporation.* Considerable work has recently been done in the Chicago region by Fuller[1] and others on the evaporating power of the air in such natural plant associations as the Cottonwood, Pine and Oak dunes, Edaphic prairie and Beech-Maple forest. In this work the beech-maple forest has been considered the most satisfactory standard for comparison of other plant associations and it has therefore been used in this paper as a basis for comparing the evaporating power of the air in cultivated fields. The region near Otis, Indiana, offers excellent conditions for such a study and is accessible to Chicago, therefore it has been selected for this work. The beech-maple forest for this investigation is bordered by cultivated fields of wheat and oats which have soils of a similar nature. The methods of cultivation in the wheat field are evidently superior to those in the oat field, as indicated by the greater depth of humus and the texture of the soil. The evaporating power of the air and the soil moisture of these habitats has been determined during the season extending from May 3 to August 23, 1913.

In determining the evaporation power of the air the Livingston[2] porous cup atmometer was used according to the usual methods employed. All instruments were properly standardized before being set up and at frequent intervals during the season. By comparison of these coefficients with that of a standard atmometer, all readings were reduced to a common

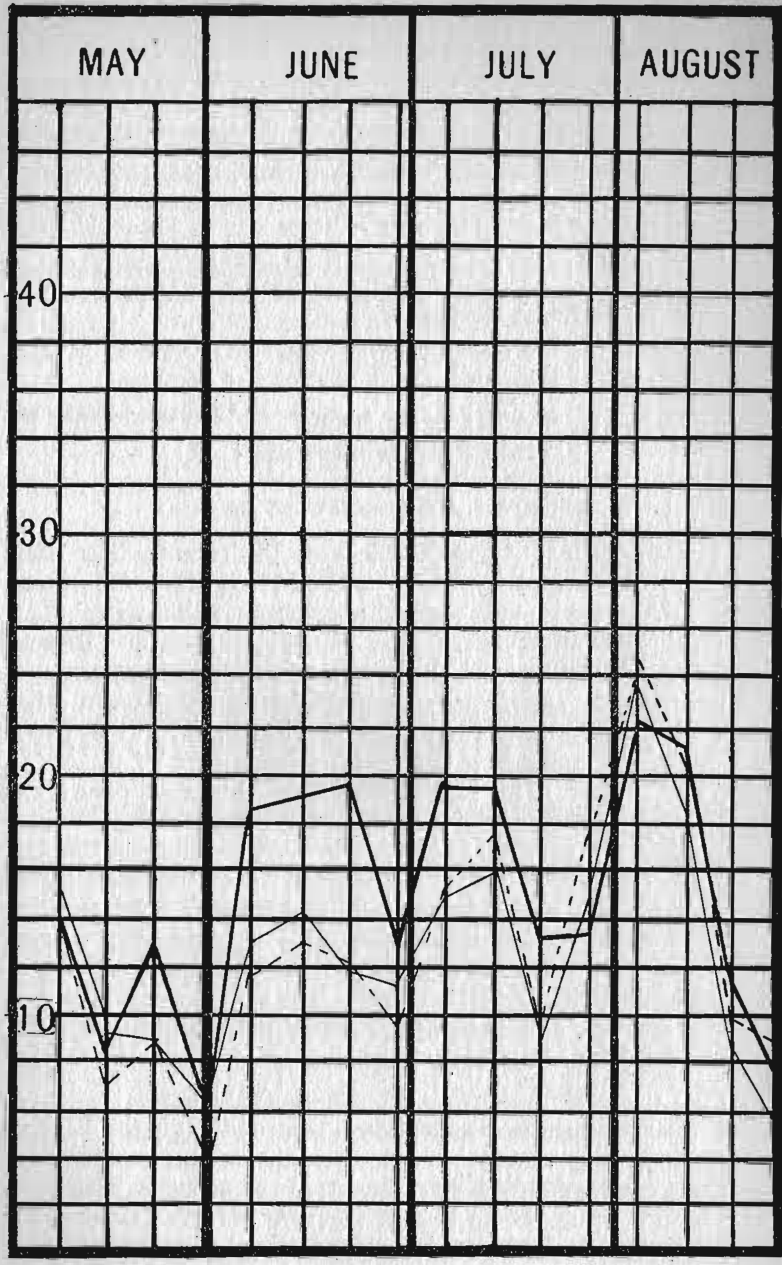

Figure 1: Graphs representing the range of evaporation at three stations in the beech-maple forest.

basis. Throughout the season readings were taken once each week and the results reduced to the average daily loss for each week. The accompanying graphs have been made with the average daily loss in cubic centimeters as ordinates and with weekly intervals as abscissae.

In the beech-maple forest three stations were established in representative positions. During this season the herbaceous vegetation was somewhat sparse and therefore probably modified conditions from time to time but little. One of these stations was placed on the crest of a low ridge which gave it somewhat more exposure to the wind. In figure 1, this station, represented by the heavy line, has a rather higher evaporation rate altho it is fairly parallel with the other two stations. Three stations were established in the wheat field, which had also been sown with clover, with more or less uniform exposure. One of these stations was surrounded by taller wheat and more vigorous clover, which produced a luxuriant crop after the wheat had been harvested. In figure 2, this station, represented by the heavy line, has a slightly lower evaporation rate. Three stations of uniform exposure were established in the oat field about June 8th, which gave fairly parallel curves. The average of these curves is plotted in figure 3 (c). No records were taken after the oats were harvested early in August.

II. *Soil Moisture*: Through the work of Briggs and Schantz[3] and others the *wilting coefficient* has been established as a more or less satisfactory standard for the comparison of available growth water for plants in various soils. It represents the water content above which the growth takes place, and is expressed in percentage of dry weight of the soil.

In the determination of the soil moisture in the habitats studied, weekly samples of soil were taken from representative stations at depths of 7.5 cm. and at 25 cm. below the surface. This soil was brought to the laboratory in closed jars where it was weighed and dried at a temperature of about 104 degrees C., until it reached a constant weight and a percentage of water was calculated on the basis of this dry weight. The wilting coefficient of the same soils were obtained by the wax seal method of Briggs and Schantz,[3] and also by the indirect centrifuge method of the same workers. In figures 4 and 5 graphs have been plotted representing the range of soil moisture on the ordinates and the weekly readings on the abscissae. Upon these same diagrams the wilting coefficients have been represented in dotted lines. The available growth water is therefore represented by the intervals between soil moisture and wilting coefficient.

Figure 2: Graphs representing the range of evaporation at three similar stations in a wheat field.

While there is a general agreement between the individual and average curve representing soil moisture, several points of variation may be accounted for by corresponding changes in conditions. In figure 4 the variations noted about July 1st may be ascribed to weather conditions, while in figure 5, the ripening and harvesting of the wheat may affect the changes noted at this time since the corresponding evaporation was not high.

Weather conditions may account for the decrease in soil moistures about August 1st, since there is a corresponding increase in evaporation.

In figure 5 the wilting coefficient of two strata coincide. This is probably due to deep cultivation rendering the soil more or less homogeneous.

As pointed out by Fuller[1], the most significant comparisons are those shown in table 1, under growth water. The mean growth-water of the beech-maple forest is taken as the standard and represented by 100. This furnishes a quantitative statement of the relation of different habitats in their mesophytic conditions. Another comparison of habitats may be shown by the ratio between the mean weekly growth water and the evaporation rate for the same time. While it may be claimed that these units are not comparable, the ratio seems to give a quantitative relation between the habitats which is thought to be valuable. Since the growth water represents the available supply for plant growth and the evaporating power of the air represents the demand made by the plants on the available water, it seems advisable that such a comparison be used in this kind of work.

SUMMARY

The evaporation rate at the surface of cultivated fields is somewhat parallel to that of the climax beech-maple forest and shows corresponding variations due to changes in weather conditions. After crops are harvested the evaporation rate is greatly increased, due to the increased exposure.

In the beech-maple forest the soil moisture is much higher in the stratum due largely to the great amount of humus. In this association the wilting coefficient was reached only once during the season.

In the wheat field the upper stratum shows a marked response in soil moisture due to periodic rainfall. In this association the soil moisture falls decidedly below the wilting coefficient after the wheat is harvested.

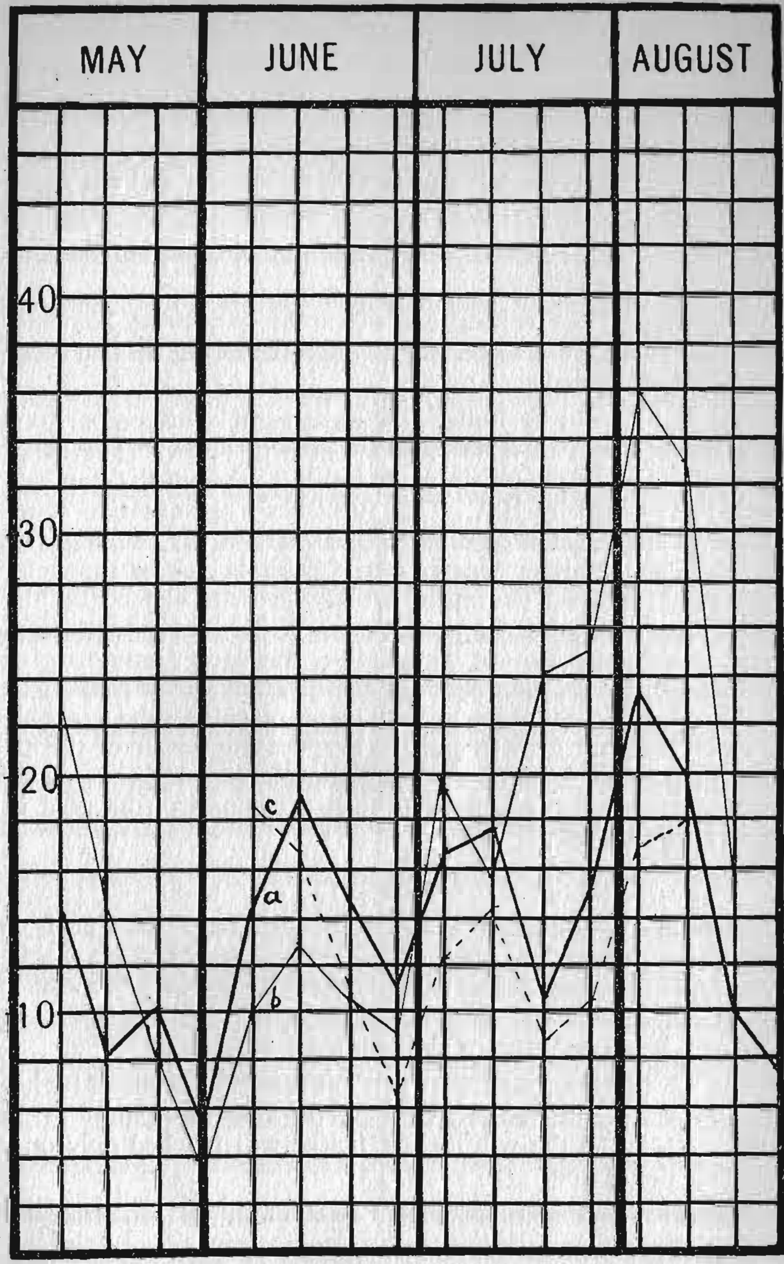

Figure 3: Graphs representing the average evaporation of three stations each in (a) beech-maple forest, (b) wheat field, and (c) oat field. ("1" represents the time of harvesting wheat).

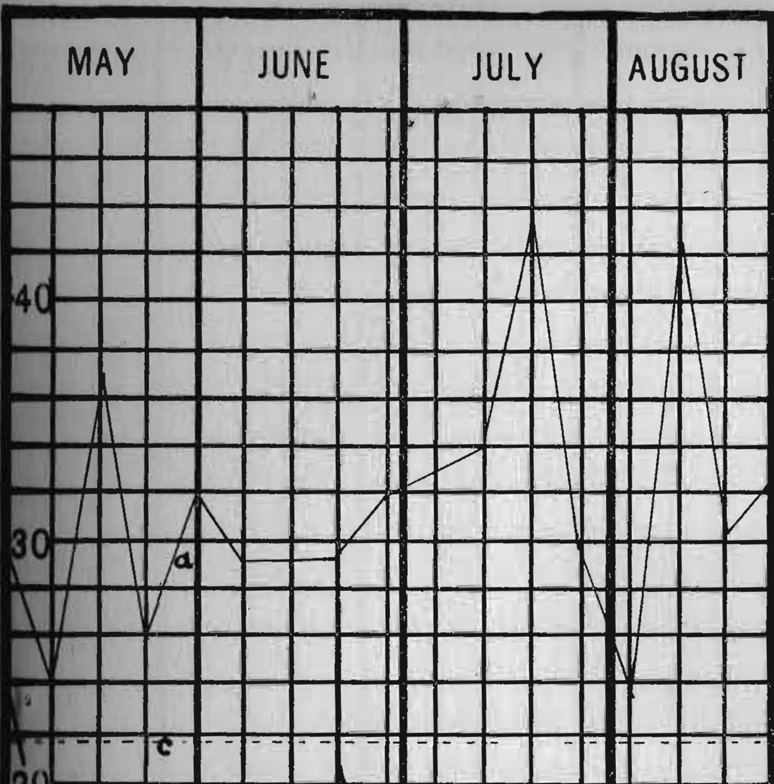

Figure 4: Graphs representing soil moisture in beech-maple forest at (a) 7.5 cm., (b) 25 cm. below surface. Also wilting coefficient of soil moisture at (c) 7.5 cm. and (d) 25 cm.

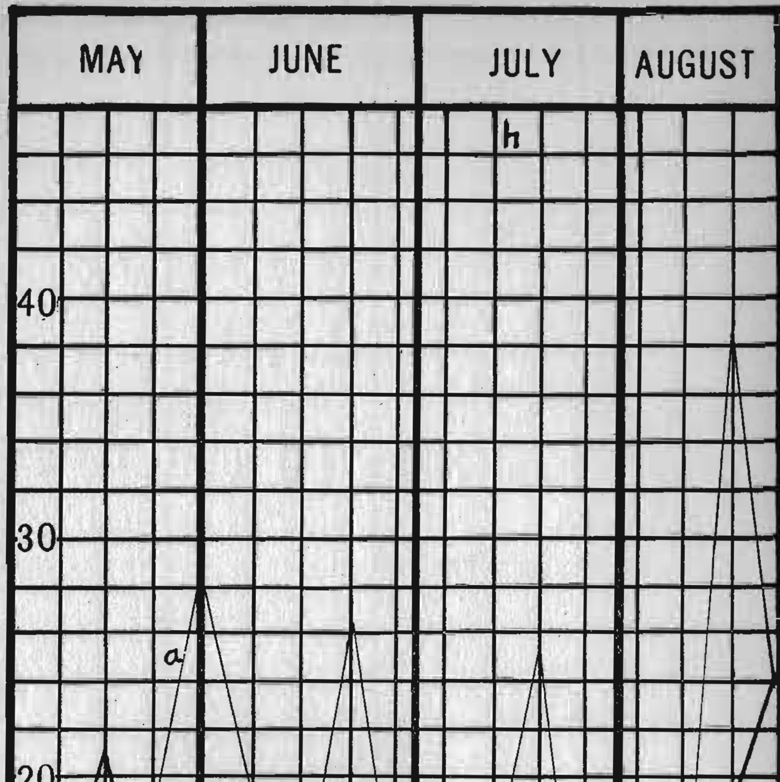

Figure 5: Graphs representing soil moisture in wheat field at (a) 7.5 cm., (b) 25 cm. below the surface. Also the wilting coefficient of soil at (c) 7.5 cm. and 25 cm. Weekly rainfall at bottom graph.

The upper stratum of the oat field also shows considerable variations which correspond more or less to those in the wheat field.

In order to determine the relation of climatic conditions to crop production the work on soil moisture and evaporation should be extended to deeper strata of soil and to higher strata of the atmosphere. Soil and air temperatures should also be recorded in these extended strata since such temperatures probably are directly effective on plant growth. The amount of precipitation and of irrigation water should also be recorded throughout the year, together with the soil conditions which effect the conservation of the same. The distribution and stages of development of the stem and root systems should be determined from time to time as the crops progress. The osmotic force of the roots of various crops in comparable stages of development may also be of interest in this connection.

The above methods of determination can be profitably applied to any crop at different stages in its development and under different methods of cultivation in order to obtain a quantitative statement of the relative effectiveness of methods of cultivation.

I wish to acknowledge many helpful suggestions by Doctor George D. Fuller, under whose direction this work has been done.

TABLE I.

Wilting Coefficients and Mean Percentage of Growth-Water in Various Associations from June 1 to August 16, 1913

Name of Association	Depth in cm.	Wilting Coef.	Growth-water			Ratio of Evap. & growth-water
			Per cent	Mean %	Comp. Amts.	
Wheat field........	7.5	13.6	6.3	3.65	55.	5.25
1913	25.0	13.7	1.4			
Oat field	7.5	14.1	9.6	6.00	90.	2.17
1913	25.0	10.5	2.4			
Beech-Maple	7.5	21.8	10.4	7.35	100	2.02
1913	25.0	10.6	4.3			
*Beech-Maple	7.5	13.5	5.5	4.25	100.	2.00
1911	25.0	9.5	3.3			
*Beech-Maple	7.5	13.5	5.0	4.5	100.	1.18
1912	25.0	9.5	4.0			

*Taken from Fuller's data in the same region.

LITERATURE CITED

1. Fuller, George D., "Evaporation and Soil Moisture in Relation to the Succession of Plant Association." Bot. Gaz. 58; September, 1914.

2. Livingston, B. E., "Operation of the Porous-Cup Atmometer." Plant World, 13: 111-119, 1910.

3. Briggs, L. J. and Schantz, H. L., "The Wilting Coefficient for different Plants and its Indirect Determination." U. S. Dept. of Agr., Bureau of Plant Industry, Bul. No. 230, 1912.