EVAPORATION AND SOIL MOISTURE ON THE PRAIRIES OF ILLINOIS.

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I. Introduction.

The prairie association is quite common in the Chicago region, where it occurs both as small isolated patches and in rather extensive and continuous areas. The association seems to hold here, at least, the position of a very persistent stage in the succession following the sedges in the filling up of ponds and lakes. (1) Although it is to be considered as decidedly different in many ways from the Western prairies, it gives very much the same aspect, this being emphasized by the characteristic coarse prairie herbs such as species of Rudbeckia, Liatris and Amorpha together with Solidago rigida, Eryngium yuccifolium, Silphium laciniatum, S. terebinthinaceum and others that occur here. Whatever may be the final history of these prairies as regards succession, it is noteworthy that they are maintained for extended periods against the encroachment of the forests of the region.

Since the above general problem, and others are presented by these edaphic prairies, it seems highly desirable that any quantitative measurements of environmental factors be brought forward.

During the summer of 1911 a series of evaporation and soil moisture determinations were carried out at Chicago Lawn, an undisturbed prairie area within the city limits of Chicago. The work was made to conform more or less with similar, though more extensive studies of Fuller (2) on the forest associations of the south shore dune region of Lake Michigan, and those of McNutt and Fuller (3) on the oak-hickory forest at Palos Park, Ill.

II. Evaporation.

Evaporation determinations were made by means of the Livingston standard atmometer (4) and the methods of operation suggested by him were carefully followed. During the early part of the season, including the months of May and June, the cups were equipped with the rain-correcting device.(5)

Two stations were established and maintained throughout the season, while at times, three, and during one week, four stations were in operation. The two principal stations, Nos. one and two, were located in the midst of the association, about 250 meters apart, the instruments being placed in similiar relation to the vegetation with the cups just below the general level of the grasses at a height of about 30 cm., above the surface of the soil. During the latter part of the season a third instrument was set up with the cup placed about 25 cm., above the level of the surrounding vegetation (i. e. about 60 cm. above the surface of the soil). Readings were made at intervals of one week or ten days throughout the season. The average daily loss for the intervening days was computed from these data. And finally the mean was taken from the results of stations one and two.

The records show the maximum evaporation, for the season, of 37 c. c. per day to occur about the 20th of May. This extreme rate of evaporation might be considered very abnormal on the supposition that May 1911 was an unusually hot and dry month, as noted by McNutt and Fuller (3) in their work of the same spring. However, Miss Newlon finds the same situation in her studies on Chicago Lawn during the season of 1912. It seems not improbable that this high rate of evaporation is the usual condition at the beginning of the season before vegetation becomes well developed, and may be a factor of considerable importance in the growth of these plants. An examination of graph **a**, fig. 1, will show the presence of two summer maxima, one in July, of 15.8 c. c. per day, and the other in August, of 16.0 c. c. per day. The minimum evaporation recorded is 5.9 c. c. per day, occuring in the latter part of September. The mean daily rate for the entire season of 168 days is 12.5 c. c. Also from fig. **1b**, it

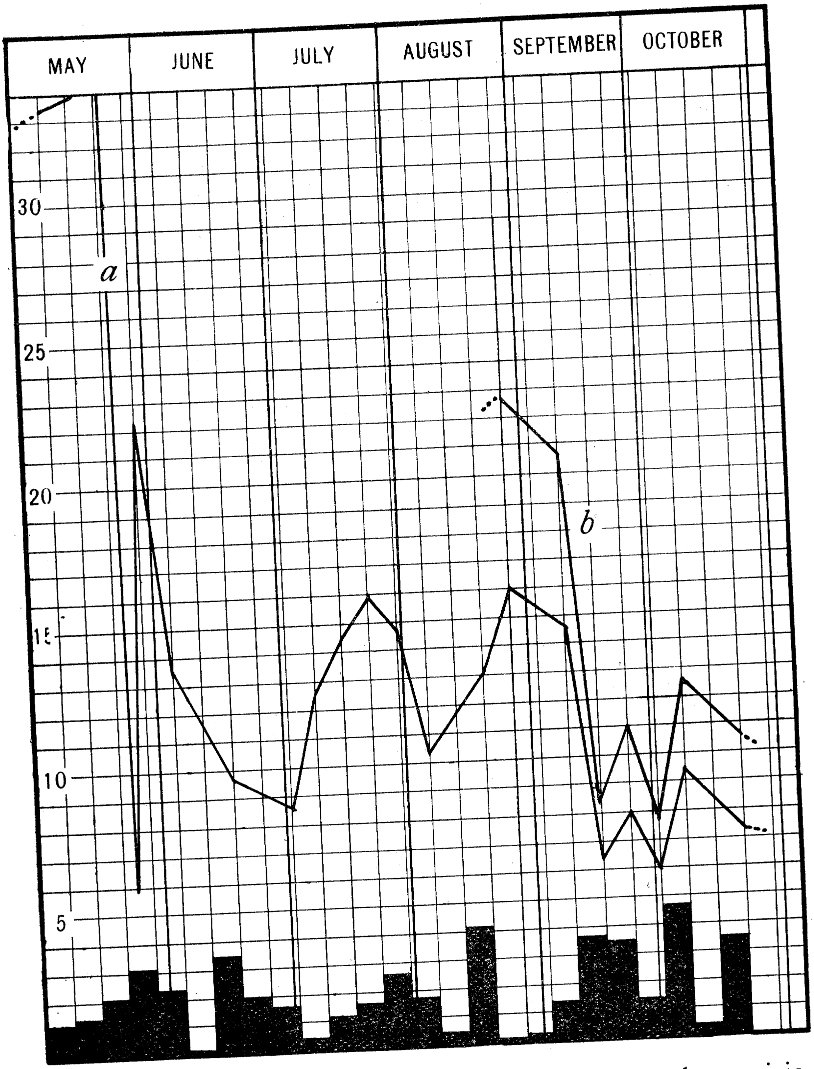

Fig. 1. Graphs showing the evaporation on the prairie, summer 1911. **a**:. Mean at stations 1 and 2. **b**: at station 3, cup above vegetation. Weekly rain-fall in cm. shown at base of figure.

may be seen that station 3, the one having the cup above the vegetation, gave the same fluctations as did the other stations and differed only in that the rate for each period was always 25 to 30 per cent greater.

It may be instructive to compare the results here with those reported by Fuller (2) for the cottonwood dune, the pine dune, the oak dune and the beech-maple forest, and also those of McNutt and Fuller (3) for the oak-hickory forest. Though the figures themselves are not repeated, fig. 2 will show the relative average evaporation of these different associa-

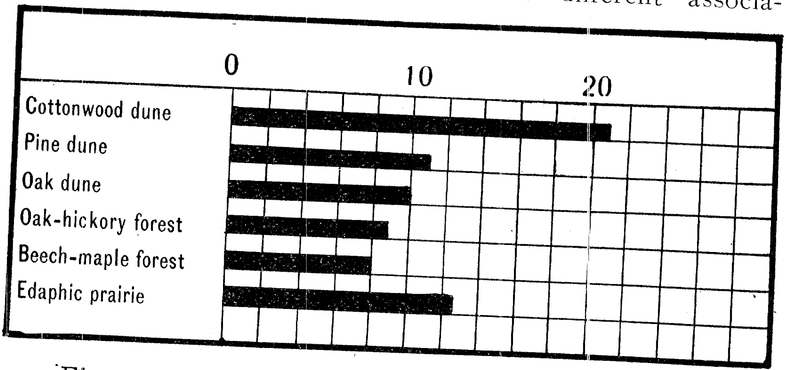

Fig. 2. Diagram showing average daily rates of evaporation in various plant associations of the Chicago region.

tions. It is evident at once that the evaporation conditions of this edaphic prairie are between those of the cottonwood dune and the pine dune, though more nearly equivalent to the latter. But the summer maximum of evaporation on the prairie is as low as the corresponding maximum of any of the forest associations yet studied in this region, excepting the beech-maple forest which has a maximum of only 13.2 c. c. per day. It corresponds rather closely in this respect to the pine dune, the oak dune, and the oak-hickory forest that has not been pastured. It seems somewhat surprising that the summer maximum on this prairie should be found so low as compared with the forest types, considering how slight is the apparent protection here from wind and sun. So the results would tend to show that, contrary to what one might expect, there must be a considerable resistance offered by the covering of grasses to the movement of air, this becoming evident in the stratum in which the cups were placed. The moist air blanket, thus tending to develop among and just above the grass covering, would largely account for the rather unexpected low summer maximum rate of evaporation.

III. Soil moisture.

The determinations of the water content of the soil were made weekly from April 11 to October 25 from samples of about 200 grams taken at the depth of 7.5 cm. and 25 cm. at each of the stations 1 and 2. The soil was brought into the laboratory in sealed vessels and dried at 104 degrees, C. The percentage of water was calculated in terms of the dry weight of the soil.

Since the mere knowledge of the water content of the soil is of little value toward the understanding of the real water conditions to which the plant is being subjected, it becomes necessary to relate such facts to the plant directly in some manner that they may be at all significant. On the whole, the most satisfactory methods yet devised for getting at this difficulty are probably those described by Briggs and Shantz, (6) by which they were able to show a definite relation between the plant and the water content of any given soil. Their method of determining the wilting coefficient directly, by the wax seal method, and indirectly by means of the centrifuge, etc., are now well known. However, it may not be amiss to recall that in one of their indirect determinations of the wilting coefficient they employed the following formula which they found to hold, apparently, for all types of soils investigated. (*)

Wilting coefficient equals moisture equivalent divided by 1.84. The moisture equivalent here being that amount of water which the soil has the power of holding against a given high centrifugal force. The number 1.84 is a constant.

In the autumn of 1912 a centrifuge of the type used by the government workers in the soil investigations was installed in the Botanical laboratory. By means of this apparatus the moisture equivalents of the various soils brought in from Chicago Lawn were determined. The force used was always 1,000 gravities, acting during 30 minutes.

By the above method the soils of the two stations were found to have the following wilting coefficients: station 1, the 7.5 cm. depth, 28 per cent and the 25 cm. depth, 20 per cent; station 2, the 7.5 cm. depth, 23 per cent and the 25 cm. depth, 19 per cent.

Fig. 3 gives the graphs of the water content of the soils from station 1 for the entire season, plotted with percentage of water as ordinates and weekly intervals as abscissae. The soil at the 7.5 cm. depth represented by graph **a**, and at 25 cm. by graph **b**. The horizontal dotted lines, **c** and **d**, mark the wilting coefficients of these soils respectively, as calculated by the method described. The water content and the wilting coefficients of the two soils of station 2 are represented in fig. 4, exactly in the manner as are those of sta. 1, in fig. 3.

(*) For important contrary data see Caldwell, J. S. The relation of environmental conditions to the phenemonon of permanent wilting in plants. Physiol. Researches 1:1-56, 1913.

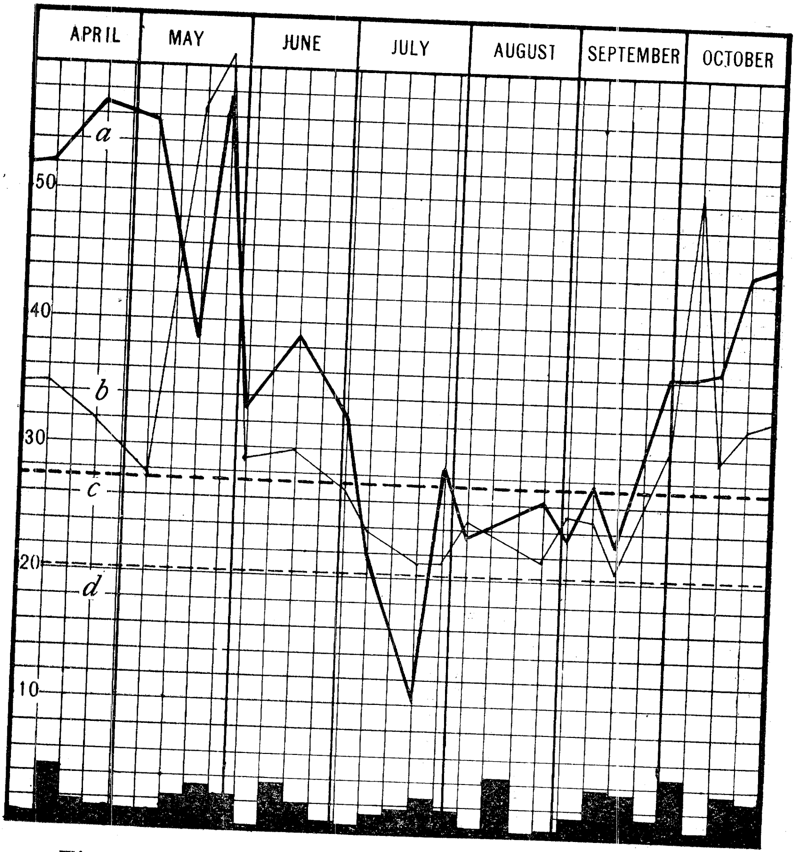

Fig. 3. Graphs showing soil moisture at station 1. **a**: of soil at the 7.5 cm. depth. **b**: of soil at the 25 cm. depth. **c**: wilting coefficient for the former and **d** for the latter soil. Weekly rain-fall in cm. shown at base of figure.

It will be noted from the graphs that the soil held large amounts of water until late in May when the content fell off rapidly during the rest of the month. This fall coincides with the high rate of evaporation already discussed for May. The general high water contents are at or near the saturation point, and this condition prevails inMay, just before the growing season begins, and again in October after it has closed. In the summer months of July and August the moisture is uniformly low, giving a mean for those months of 24 per cent. There are times during these months that the water content of the soils at the two depths falls below the critical percentage. This is shown for example by the surface soil at station 1 (fig. 3) in July and August and by the deeper layer

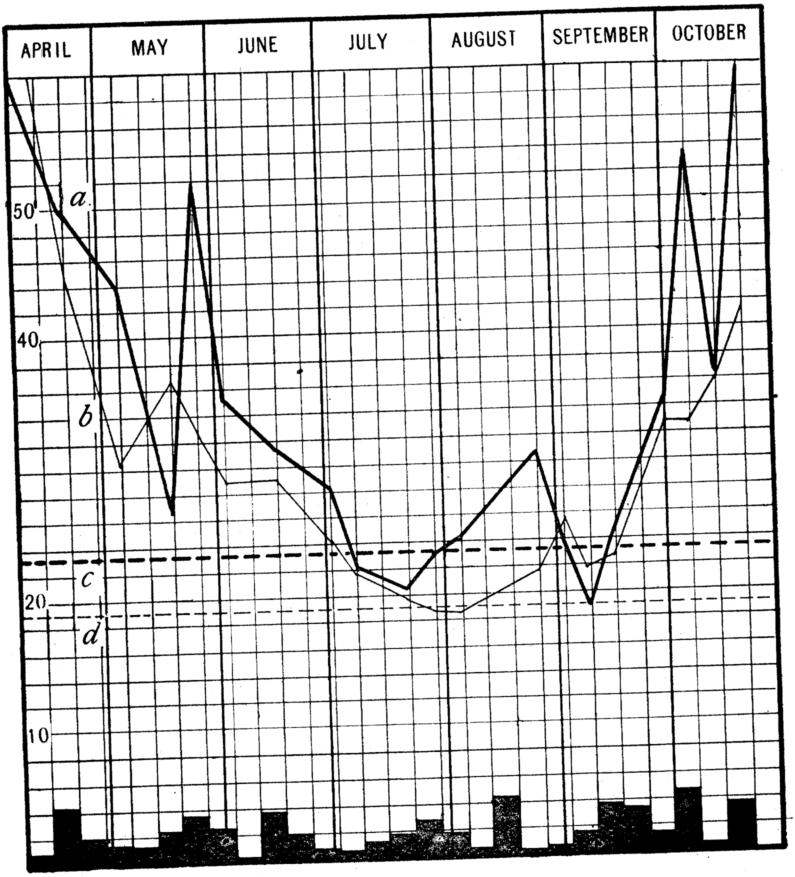

Fig. 4. Graphs showing soil moisture at station 2. **a:** of soil at the 7.5 cm. depth. **b:** of soil at the 25 cm. depth. **c** and **d** the respective wilting coefficient of these soils. Weekly rain-fall in cm. shown at base of figure.

of soil at station 2 (fig. 4) in July. It would also be well to note that at neither of the stations, except in the instance mentioned above, did the water content, at the depth of 25 cm. fall below the critical percentage. However, there must be many days at this period of the summer when the combined action of low water content of the soil and the high rate of evaporation render conditions very severe even for the characteristic vegetation of the association. This may account for the xerophytic aspect of the prairie vegetation in the late summer.

IV. Summary.

This paper presents evaporation and soil moisture records from the edaphic prairie association of the Chicago region for the growing season of 1911.

The data shows a very high rate of evaporation in May, before the grass covering has become developed.

The summer maximum rate of evaporation (i. e. when the grass covering is present) seems lower than that which one might expect, when compared with corresponding data from forest associations.

The mean daily rate of evaporation for the season places the prairie association between the pine and the cottonwood dunes, as regards the atmospheric condition.

Through the summer months the water content of the soil is uniformly low, especially in the surface layer where it often falls below that percentage designated as the wilting coefficient.

On the whole, the data seems to indicate decidely severe mid-summer conditions in the prairie association.

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Legend to figures: