EVAPOTRANSPIRATION CONTRASTS BETWEEN SOUTH-FACING BLUFF PRAIRIES AND NORTH-FACING FOREST

CHRISTOPHER R. RANFT and PAUL D. KILBURN
Principia College, Elsah, Illinois

ABSTRACT. — A short term study was set up to test the suitability of the evaporimeter and transpirometer for the measurement of ecological differences as well as their ability to measure evaporation and transpiration differences quantitatively under three habitats. The correlation between the evaporimeters and transpirometers indicate that one might be able to predict transpiration rates from evaporimeters with sufficient data. However certain difficulties were encountered with the two systems of measurement.

Along the exposed south and southwest facing bluff slopes of the Mississippi, small bluff or hill prairies occur frequently, despite the dominance of oak-hickory forest throughout this river-border area (Vestal, 1931). The southerly slopes, being hotter and drier, support grassland and open forest; while on the northerly slopes dense forest prevails.

The floristics of these xeric grasslands, usually dominated by little bluestem (*Andropogon scoparius* Michx.) have been detailed by Evers (1955), while the vegetation-soil relationships have been discussed by Kilburn and Warren (1963) and Bland and Kilburn (1966).

Microclimatic studies at Principia College, Jersey County, Illinois, indicate far different climatic regimes in several aspects between these exposed sites and the more protected forest habitat: higher soil maxima, higher air maxima in all months, lower relative humidity and far stronger wind velocities. All of these features result in increased transpiration rates, probably the primary factor in the encouragement of grasses and discouragement of trees.

In order to assess quantitatively evapotranspiration differences between these habitats two inexpensive, yet readily comparable techniques for the measurement of evaporation and transpiration were selected. These have been used successfully by Davenport (1965) in England. The techniques include "evaporimeters," shallow glass dishes measured daily for water loss, and "transpirometers," small sealed flowerpots of grass. A short term study was set up at Principia College to test the suitability of the evaporimeter and transpirometer for the measurement of ecological differences and to test the ability of these techniques to measure quantitative differences in evaporation and transpiration in three differ-

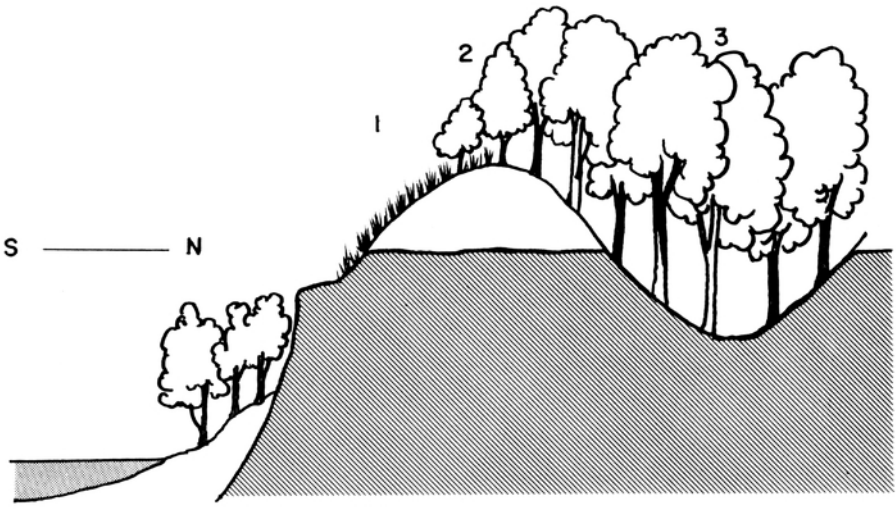

FIGURE 1. — Location of Stations. The prairie station (1) faces south overlooking the Mississippi River; the ecotone station (2) is at the crest of the bluff; and station (3) is in the north-facing ravine forest. The shaded subsoil is limestone bedrock; the upper unshaded portion above the limestone is loess.

ent habitats. This paper reports the results of this study.

MATERIALS AND METHODS

Three field stations were set up for this study and they were designated 1, 2, and 3 on Figure 1. Station 1 was on the bluff prairie, station 2 was located on the crest (ecotone), and station 3 was located in the deep ravine immediately adjacent, in Sec. 21, T. 6N., R. 11W. of Jersey County.

Each station was set up with nine transpirometers and two evaporimeters. Three transpirometers were at ground level while the remaining transpirometers and the evaporimeters were placed in iron rings which were attached to a metal post standing six feet above ground level. An evaporimeter was placed at the three and five foot levels while two transpirometers were placed at the two, four and six foot levels.

Temperatures were recorded by a Taylor maximum-minimum thermometer checked daily at 5:30 p.m. Glass dishes 10 cm. in diameter and 4 cm. in depth were used as evaporimeters. These glass dishes were placed on platforms painted black in the center and white on the outside, the scheme used by the more streamlined English models. At the beginning of each 24 hour measuring period, the evaporimeters were filled with 200 ml. of water. The amount of water lost over the 24 hour period was considered the amount evaporated.

Grass transpirometers were patterned closely after those used by Davenport (1965). The drainage holes of plastic pots (12.5 cm. in diameter x 12 cm. deep) were plugged and the pots were then filled to within 2 cm. of the rim with soil. The soil was wetted down and sown with 1.5 g. of commercial red top grass seed (*Agrostis* sp.). Germination began six days after sowing and fourteen days later the seedlings were clipped for the first time level with the rims of the pots. They were clipped to the same height every other day thereafter. Field capacity for these pots was established by noting the weight of an unplugged pot containing saturated soil that no longer drained. At the beginning of each 24 hour measuring period each transpirometer was brought up to a field capacity of 1300 grams by adding water. The dense cover of the grass in the transpirometer reduced soil evaporation to a negligible amount so that weight losses were assumed to result entirely from transpiration, a conclusion reached also by Davenport (1965).

TABLE 1.—Maximum temperature differences (means) between north and south slopes. In each month south slope values were higher.

Month	Mean Values, F°
January-February	8.1
March-April	3.7
May-June	19.9
July	13.1
August	18.2
September	20.2
October	8.1
November-December	6.5
Average, May through September	17.8

RESULTS

The maximum temperatures shown in Table 1 reveal a striking contrast between the higher maxima of the exposed bluff region and the protected woody ravine in every month. These differences, with a mean exceeding 20 degrees (F) in September were recorded in an intensive study in 1960-61, and are known to be typical from frequent intermittent measurements since that time. Minimum temperatures from the two habitats, in contrast, show far greater similarity and no consistent pattern. All temperatures were recorded in the shade 1″ above ground level. It is clear that the exposed bluff habitat is not simply warmer; rather it exhibits a far more extreme climatic variation.

Figure 2 (B and C) illustrates the way in which transpiration and evaporation rates from the transpirometers and evaporimeters correspond with the maximum temperature changes. The correspondence of the peaks on the 15th of April is indeed striking, while those on the 28th are also very similar. At the same time, the readings from station 2 (ecotone) and station 3 (north-facing forest) are consistently lower than station 1. In part this reflects the lower temperatures there, but it also reflects the lower wind velocity and higher humidity found there. Recent readings made since the study indicate that wind velocities at station 3 are on the average about 1/10 that of station 1; humidities are consistently lower as well as station 1.

Quantitative comparisons of evaporation can be made from Table 2. Here it can be seen that evaporation from the evaporimeters at station 1 was about 4 times as great in hot days of April and May as station 3, slightly less than this on cooler days, and perhaps even greater than this on cool days in May, after foliage had come out fully on the trees. Data from the transpirometers do not reveal quite such extreme differences. On the hottest days transpiration was nearly three times as great at station 1 as at station 3. Differences between pots at different heights were not consistent and are not shown. This is undoubtedly because of both the variability in the transpirometers, and the small number of them used in the study.

DISCUSSION

It is well known (cf. Meyer and Anderson, 1952) that evapotranspiration is correlated with air temperatures. Therefore, the close correlation between the maximum temperature curves and losses from both the evaporimeters and transpirometers indicates their potential value as tools in comparative ecology. At the same time it is clear that the rates of both are affected by humidity and wind

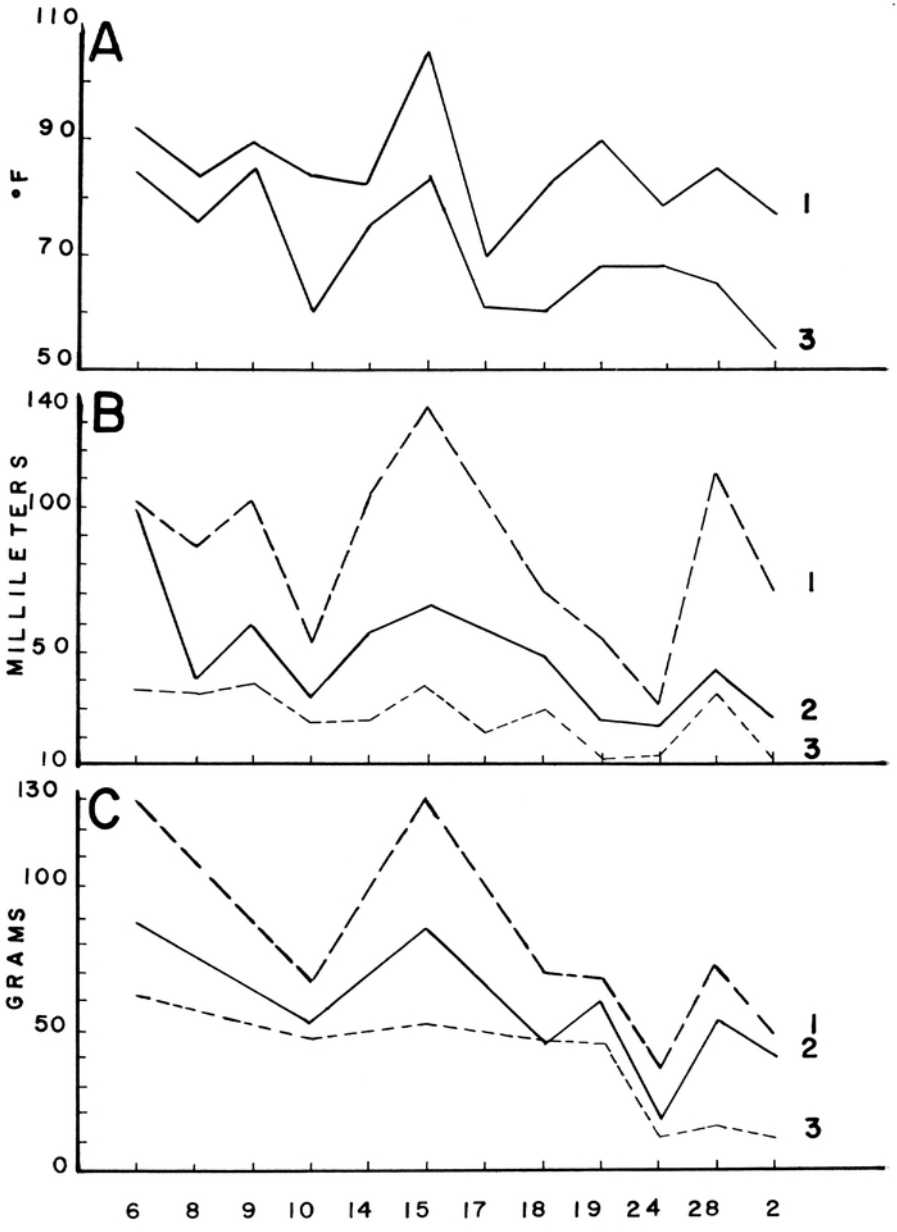

FIGURE 2. — Comparisons of maximum temperatures (A), evaporimeter losses in milliliters (B), and transpirometer losses in grams (C). Readings represent results during April-May 1967. Line 1 based on readings from station 1 in the south-facing hill prairie; line 2 is from station 2; line 3 represents readings from station 3 in the north-slope forest.

TABLE 2.—Evaporimeter losses at various temperatures. Figures represent daily loss in milliliters.

Month	Temperature range	Number readings	Station 1	Station 2	Station 3
April	85° +	7	123.3	74.9	33.7
	71 — 84°	6	55.1	32.9	22.3
	70° + below	0		Rained out	
May	91° +	7	102.0	36.0	24.5
	81 — 90°	4	76.0	31.5	19.4
	80° below	3	74.5	30.3	12.7

velocity as well. Indeed the highest values for both were obtained during a hot, dry and unusually windy period in April. Averages for the entire period reveal that evapotranspiration rates on the southerly prairies are three to four times those of the northerly woods.

It will be noted that the highest rates in Table 2 are for April. This was due both to the abnormally high temperatures recorded during this month and also to the extreme windiness of several periods in this month. Although no anemometer readings were taken, visual estimates showed that these strong winds did not occur in May, even though many of the days were hotter.

The correlation between the evaporimeters and transpirometers was good enough to encourage us to conclude that we might be able to predict transpiration rates from evaporimeters with sufficient data. This would be helpful inasmuch as the latter are much easier to use. Readings from evaporimeters can be taken much more quickly inasmuch as water loss is measured rather than weighed. Surprisingly, the evaporimeters rarely showed water loss by water blowing out, even in high winds. Apparently, the stability in a small container, and the lip of the dish, prevented loss of water from what would appear to be a probable source.

The transpirometers also revealed some problems. The major difficulty with their use, as with the evaporimeters, is that they cannot be used when it rains. At such times rain is added to the containers in different amounts, and the data taken must be discarded. Thus, about a quarter of the readings in this study were wasted.

The transpirometers also revealed the problem of differential growth at the different stations. Those kept in the shade at station 3 eventually became unusable as the grass in them sickened and died, owing to an extended rainy period that kept them over-saturated. It became clear to us that double the number of transpirometers must be prepared, and a rotation scheme utilized in future studies.

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Manuscript received May 11, 1968.