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EFFECT OF TOPOGRAPHY ON MICROCLIMATE IN SOUTHWESTERN WISCONSIN

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That microclimate is important to forest growth is well known. Because microclimate influences soil freezing and snow accumulation and melt as well as evapotranspiration rate, microclimatic differences on a watershed may also affect its hydrologic behavior.

Topographic variables that may affect microclimate are elevation, steepness and direction of slope, and position on the slope. Although topographic effects on microclimate are more pronounced in mountain areas because of the greater range in the variables, these effects can be important wherever the landscape is rough. How southwestern Wisconsin's ridge and valley topography affects microclimate is discussed here. All data are from the Coulee Experimental Forest near La Crosse.

The terrain here is neither mountainous nor hilly, but it is extremely rough. It is best described as a dissected plain. The landscape consists of dolomite-capped ridges of relatively uniform elevation and narrow valleys or "coulees." The coulees lie about 400 feet below the ridgetops and are separated from them by steep wooded slopes (fig. 1). Mean slope of the forest zone is about 40 percent, but individual slopes may range up to vertical scarps.

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Figure 1. — *Typical Driftless Area landscape as seen from ridgetop.*

PRECIPITATION

From a rainfall study (Sartz 1966) I found that the dissected terrain of the area has little effect on point rainfall. Rain gages on the windward side of a steep slope caught only 3 percent less rain than gages on the leeward side; and the amount of rainfall caught by ridge gages was little more than that caught by valley gages. However, snow accumulation and melt are affected by degree of slope and by aspect.

Steep (greater than 45-percent slope) "goat prairies," which generally slope to the south, never accumulate a snowpack, even in heavy snow years. Sublimation and wind keep these slopes bare most of the time. On less steep slopes where snow does accumulate, south slopes may lose their snowpack 2 to 3 weeks earlier than north slopes. This difference in melting time is beneficial from a flood-runoff standpoint because it tends to even out the flow and reduce the peak. However, the difference does not appear to affect the timing of snowmelt accretions to ground water. Springs on the Coulee Experimental Forest rise and peak at the same time on both north- and south-facing watersheds during snowmelt. However, we are not certain that the ground water tables conform to the surface terrain.

How aspect affects snowpack accumulation on more moderate slopes is shown by meaurements of the late winter snowpack on north and south slopes of 25 percent on the Coulee Experimental Forest (table 1). During a 6-year period, depth and water content of the south slope snowpack were 51 percent and 59 percent, respectively, of the corresponding north slope values. Topographic shading in the ridge and coulee terrain of the area also affects snowmelt, a factor discussed by Lee and Baumgartner (1966). Bottomland on the south side of east-west oriented coulees is shaded by the ridges to the south, so snowmelt in these coulees progresses at a gradually diminishing rate from north to south.

SOIL WATER

Theoretically, the rate of soil water depletion will vary with steepness and direction of slope because of their effect on the radiation balance (Nash 1963). Stoeckeler and Curtis (1960) reported that a forested north slope in southwestern Wisconsin held about twice as much water in the upper 2 feet of soil as a forested south slope. However, soils on an adjacent ridgetop held much more water than the north slope soils; and the amount of depletion in a 90-day summer period on middle and upper slope soils was about the same for both north and south aspects.

Table 1. — *Accumulated snowpack on north and south slopes of 25 percent*

Year	Depth			Water content		
	North	South	S/N	North	South	S/N
	Inches	Inches	Percent	Inches	Inches	Percent
1965	9.1	4.4	48	2.0	1.1	55
1967	17.0	5.8	34	4.3	2.0	47
1969	17.2	12.9	75	4.6	3.5	76
1971	21.7	10.0	46	6.2	3.6	58
Mean	16.2	8.3	51	4.3	2.5	59

Measurements with a neutron meter from 20-24 soil water tubes on the Coulee Experimental Forest showed the following average amounts of soil water depletion in the top 3 feet of soil over a 51-day summer period: ridgetop, 3.2 inches; north slope, 3.3 inches; south slope, 4.0 inches. The north and south sites are on lower, 25-percent slopes and the soil and old-field vegetation are similar on the three sites. Mean water contents for the three sites at the beginning of the depletion period were: ridgetop, 12.6 inches; north slope, 11.8 inches; south slope, 12.1 inches. From a study on upper slopes, where the soil is generally shallower, depletion by oak-hickory forest in the top 2 feet of soil over a 113-day summer period on the four major aspects was: north, 3.71 inches; south, 3.09 inches; east, 3.38 inches; west, 3.02 inches. The values are means from 12 soil water tubes.

From these data it appears that soil water withdrawal by similar vegetation on similar soils is not strongly affected by direction of slope.

TEMPERATURE AND RADIATION

Surprisingly, temperature did not appear to be strongly affected by aspect, at least on moderately steep slopes. Exposure to the wind may have more effect than direction of slope. Temperatures on north and south slopes of about 25 percent were recorded at two places on the Coulee Experimental Forest — Russlan Coulee and Shelmidine Coulee. In Russlan Coulee, thermographs and maximum-minimum thermometers were housed in small instrument shelters mounted 1 foot above the ground. In Shelmidine Coulee, they were mounted in standard National Weather Service type shelters. Steepness of slope at the gage locations is about the same at both places. In Russlan Coulee, daily maximum and minimum temperatures from the thermograph charts were compared for 20 days in June and July and for 20 days in December and January with the following result, in degrees Fahrenheit:

	June-July		*December-January*	
	North	*South*	*North*	*South*
Maximum	82.0	82.5	22.5	24.3
Minimum	58.6	58.3	5.2	6.2

North-south differences were statistically nonsignificant for June-July but were highly significant for December-January. From 311 daily maximum and minimum temperatures, the mean maximum was 1.2° F. higher and the mean minimum, 0.5° F. higher on the south slope. Both are statistically highly significant.

In Shelmidine Coulee, the north slope had higher maximums but lower minimums than the south slope. From 33 weekly maximum-minimum thermometer readings in standard instrument shelters the means were:

	North	*South*
Maximum	85.2	84.2
Minimum	43.3	44.5

Maximum differences are statistically nonsignificant but minimum differences are highly significant. In one 10-day period in August 1971, the daily maximum temperature on the north slope averaged 3.9° higher, while the daily minimum averaged 2.0° lower than on the south slope. These data are from maximum - minimum thermometers mounted 1 meter above the ground on wooden stakes. The thermometers faced north and were shielded only by the plastic thermometer housing and the 1- by 3-inch wooden stake. Both differences are statistically highly significant. The cooler daytime temperatures on the south slope apparently resulted from its greater exposure to the wind.

Although aspect alone appears to exert a minimal influence on temperature, it does

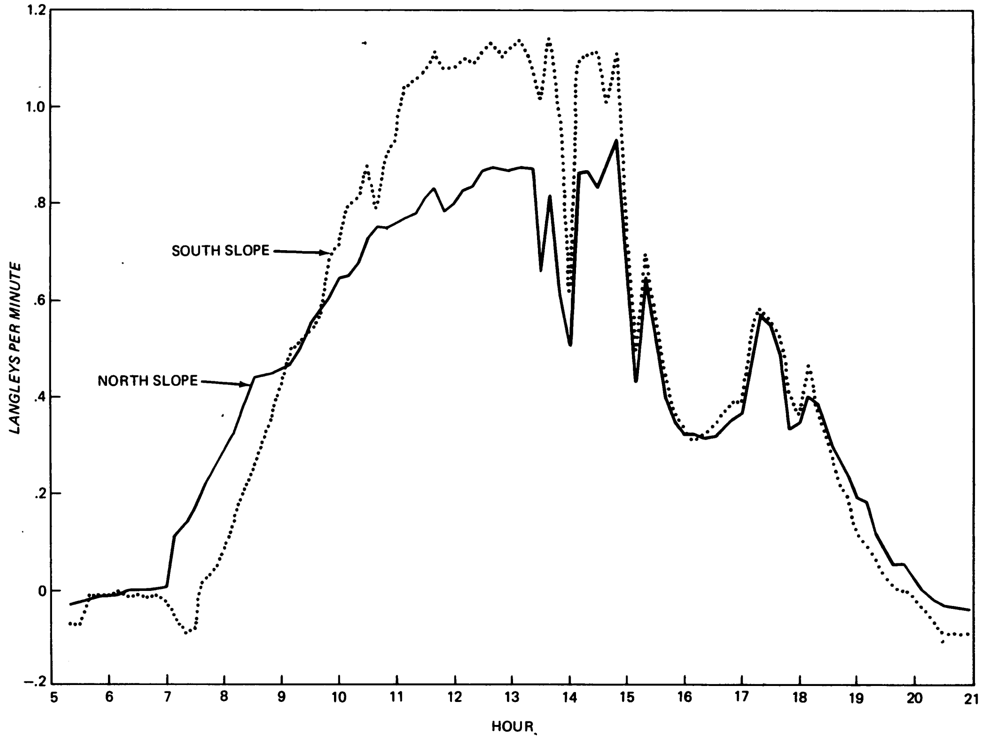

Figure 2. — *Net radiation on north and south slopes, June 25, 1965.*

have a pronounced effect on daytime net radiation (fig. 2). The data plotted in figure 2 are from totalizing net radiometers (Goodell 1962) that were operated on the Shelmidine Coulee slopes where the temperature measurements were taken. The two previously calibrated radiometers were mounted 3 feet above the ground parallel with the slope. The vegetation at both sites was bluegrass and weeds that had been clipped. Radiation, temperatures in a shelter and on the ground surface, and anemometer counts were taken at 10-minute intervals for the period shown. Ground surface temperature was measured with mercury-in-glass thermometers placed unshaded on the clipped grass surface (fig. 3). Ground temperature followed the radiation pattern much more closely than did shelter temperature. Shelter temperature was higher on the north slope most of the day, reflecting the difference in wind. Based on anemometer counts, wind movement on the south slope was about 2½ times that on the north slope.

The effect of ridge and coulee terrain on cold air drainage is shown by the temperature record from thermographs in standard instrument shelters at a ridgetop and a coulee bottom site, both in the open. The two sites are 2,100 feet apart and differ in elevation by 360 feet. Minimum differences for November through March are statistically nonsignificant, but all other minimums and all maximums are highly significant (table 2). The lower minimum temperatures at the valley site result from cold air drainage down the slope. The effect of air drainage is greatest during the growing season, thus it could influence forest site quality as well as survival of planted trees following late spring frosts (Stoeckeler 1963).

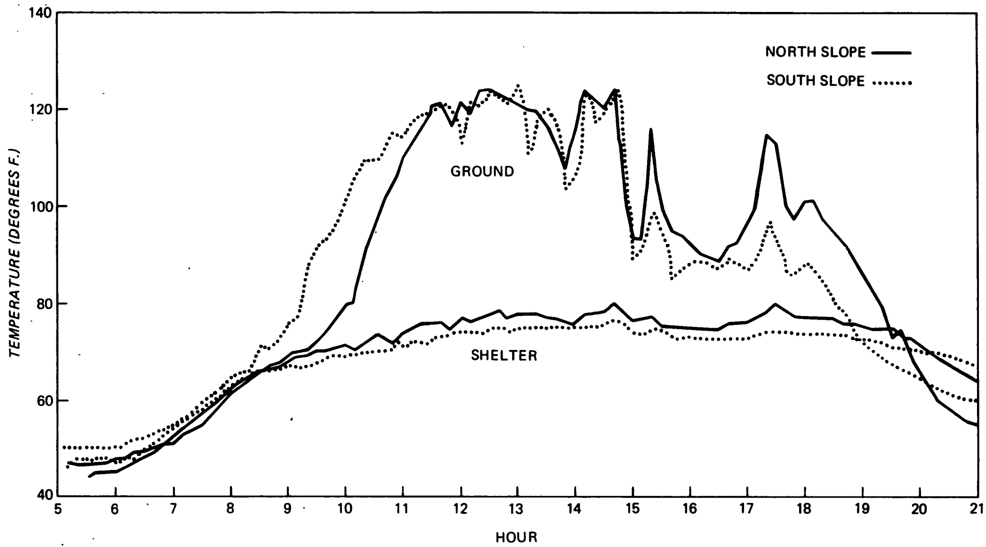

Figure 3. — *Temperature in a standard weather instrument shelter and at the ground surface on north and south slopes, June 25, 1965.*

Table 2. — *Difference in mean daily maximum and minimum temperatures at a ridgetop and a valley site*

Month	Number of observations	Temperature difference[1/] Maximum	Temperature difference[1/] Minimum
		Degrees F.	Degrees F.
January	31	3.0	-0.1
February	25	4.6	.8
March	29	4.3	-1.0
April	52	3.7	-2.6
May	93	4.2	-3.6
June	89	3.3	-3.5
July	92	3.4	-5.0
August	83	3.6	-4.1
September	60	4.5	-3.4
October	62	3.6	-3.4
November	30	6.4	.1
December	31	3.8	-0.1
Total or mean	677	4.0	-2.2

[1/] Valley reading assumed to be higher.

I also compared the temperature records from the open ridgetop site with those from another ridgetop site that was located in a small (0.1-acre) clearing in the native hardwood forest. The two sites are 2,100 feet apart and the forest site is about 30 feet lower in elevation. Maximum mean daily temperatures were 3.3° F. higher and minimum mean daily temperatures were 2.0° F. higher in the forest clearing than in the open. The values are from 456 daily observations from all months of the year. The means for individual months did not show any seasonal trend.

CONCLUSIONS

Driftless Area topography affects point rainfall only slightly, but it affects snowpack buildup substantially because of the effect of slope climate on sublimation. Although south slopes appear to lose more water, soil water depletion by similar vegetation on similar soils does not vary greatly by aspect. South slopes receive more insolation, but temperature differences between north and south slopes are slight, and may be more affected by differences in wind than in slope direction. Based on temperature measurements in standard instrument shelters, coulees are warmer than ridgetops in the day but cooler than ridgetops at night because of differences in wind and because of downslope air drainage.

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