RESEARCH NOTE NC-120

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

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LAKE MICHIGAN SNOW SQUALLS INCREASE ANNUAL PRECIPITATION IN THE UDELL HILLS

ABSTRACT. — Snow squall concentration in the Udell Hills of Michigan illustrates the effects of minor topographic features and the proximity of Lake Michigan on the seasonal distribution of precipitation. Application to water budget studies is indicated.

OXFORD: 111.772:111.784:116.23(774). KEY WORDS: ground water budgets, orographic precipitation, forest watersheds, precipitation measurements, shielding effects.

UDELL HILLS ARE THE FIRST TOPOGRAPHIC RISE FOR WESTERLIES

The study area is located approximately 10 miles inland from the Lake Michigan shoreline (fig. 1). The sand plain that extends eastward from the shoreline has an elevation of about 650 feet near Manistee and rises to about 730 feet on the east side of the study area. An isolated portion of the Port Huron moraine, locally known as the Udell Hills, projects above this surface to a maximum elevation of 1,030 feet. The first major rise in land elevation along the path of prevailing westerly winds, these hills form a partial ring about 2 miles in diameter (fig. 2).

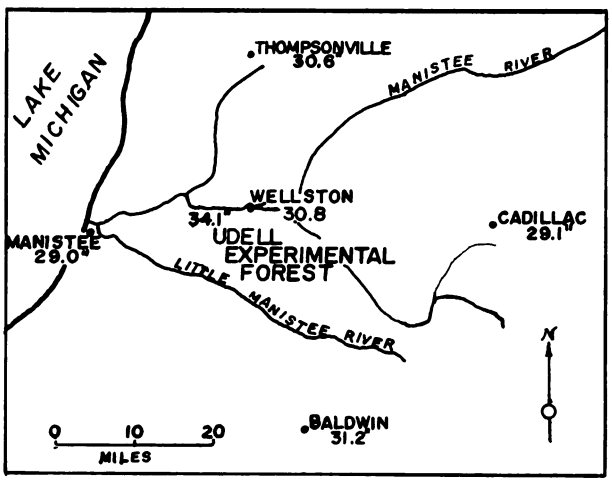

Figure 1. — *Mean annual precipitation at Udell Experimental Forest and at the five nearest Weather Bureau stations from October 1, 1960, to September 30, 1966.*

UDELL PRECIPITATION EXCEEDS SURROUNDING STATIONS

From October 1, 1960, to September 30, 1966, rain gages were measured at weekly intervals at 10 sites on the Udell Experimental Forest (fig. 2). Mean monthly and annual (water-year) precipitation totals for all Udell stations and for the five nearest Weather Bureau reporting stations (Manistee, Thompsonville, Wellston, Cadillac, and Baldwin) are listed in table 1.

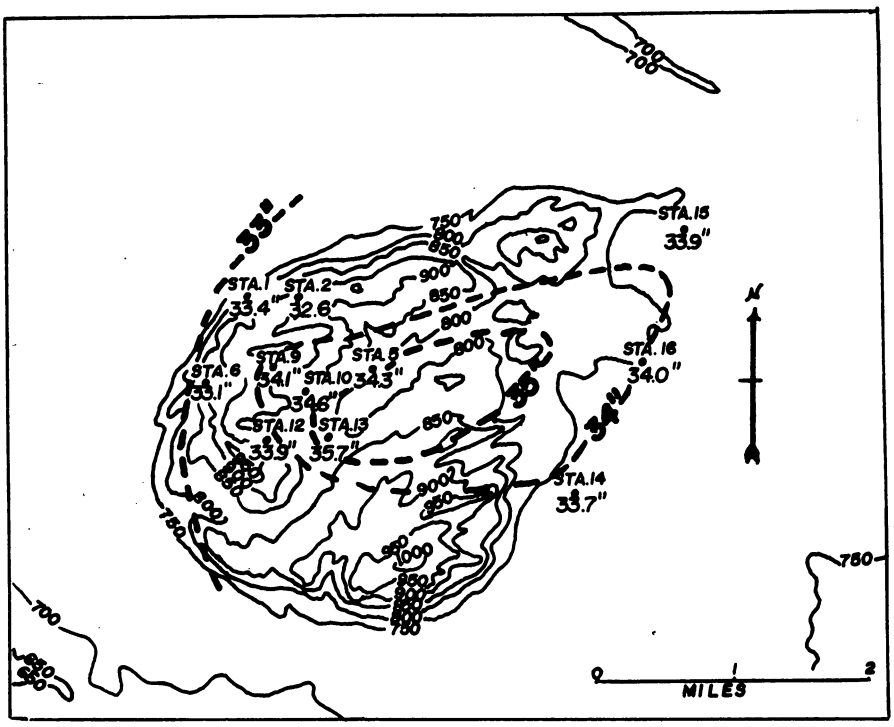

Figure 2. — *Approximate distribution of mean annual (water-year) precipitation over the Udell Hills from October 1, 1960, to September 30, 1966.*

Table 1. — *Mean monthly precipitation in inches at Udell Experimental Forest and at the five nearest Weather Bureau stations from October 1, 1960, to September 30, 1966, showing effect of adjustment for shielding effects on Udell Experimental Forest gages*

Month	Mean of 10 Udell stations	Weather Bureau stations				
		Manistee	Wellston	Cadillac	Thompson-ville	Baldwin
Oct.	2.79	2.13	2.40	2.41	2.32	2.37
Nov.	3.07	2.45	2.65	2.67	2.76	3.80
		[1](2.69)	(2.91)	(2.94)	(3.04)	(4.18)
Dec.	2.90	2.07	1.78	1.41	2.19	1.89
		(2.48)	(2.14)	(1.69)	(2.63)	(2.27)
Jan.	2.80	1.87	1.99	1.57	2.01	1.90
		(2.24)	(2.39)	(1.88)	(2.41)	(2.28)
Feb.	1.84	1.28	1.46	1.13	1.29	1.28
		(1.54)	(1.75)	(1.36)	(1.55)	(1.54)
Mar.	2.24	1.64	2.14	2.21	1.60	2.13
		(1.97)	(2.56)	(2.65)	(1.92)	(2.56)
Apr.	2.94	2.35	2.87	2.79	2.28	2.87
May	2.07	1.99	1.82	2.00	2.26	2.48
June	2.24	1.96	2.40	2.51	1.50	1.63
July	2.89	3.12	2.87	2.92	3.04	2.38
Aug.	3.22	3.28	3.15	2.88	3.70	4.01
Sept.	5.12	4.81	5.30	4.56	5.25	5.03
Annual	34.10	28.95	30.81	29.06	30.19	31.76
		(30.56)	(32.81)	(30.59)	(31.90)	(33.60)

[1]Numbers in parentheses adjusted for lack of shielding after Weiss.[2]

For each of the 6 water-years, the mean annual precipitation in the Udell Hills exceeded that at all surrounding Weather Bureau stations. The greatest differences exceeded 5 inches per year at Manistee and Cadillac. The Thompsonville, Wellston, and Baldwin stations form a generally north-south transect at about the same longitude as the Udell Hills.

LAKE SNOW SQUALLS HEAVIER IN UDELL HILLS

Strommen[1] has described the pattern of snowfall along the Lake Michigan shore where prevailing westerly winds bring lake moisture overland and produce "lake snow squalls." During October and November, the heaviest snow squalls are at some distance from the Lake. During December and January, the heavy snows are quite close to the lakeshore. Located about 10 miles inland, the Udell Hills receive consistently greater precipitation from October through February (table 1) than surrounding areas. The effect of these snow squalls on the annual precipitation pattern of the Udell Hills is shown in figures 2 and 3.

All rain gages on the Udell Experimental Forest were shielded by surrounding forests or by Alter windshields. Regardless of the type of shielding, gage catch was found to be within 10 percent of the accumulation in snowpack measured in the vicinity of each gage. Snow catch is known to be lower in unprotected gages, such as those used at most Weather Bureau stations. Weiss[2] has determined the relationship between the snow catch in shielded and unshielded gages in relation to the exposure to winds. During snow periods, the average correction is 1.2 for moderately exposed rain gages in northwestern Lower Michigan. During rainfall months, the correction is negligible except in very exposed sites. The 120-percent adjustment was made to all monthly values from November 15 to March 31 at the five Weather Bureau stations. The revised monthly totals and the estimated "true" total precipitation for the water-year are shown in table 1.

Monthly precipitation at Cadillac and Baldwin, the two stations most distant from Lake Michigan, was still consistently lower than at Udell during

[1] *Strommen, N. D. Michigan snow depths. Mich. Dep. Agr., Mich. Weather Serv., 17 p. 1969.*

[2] *Weiss, L. L. Relative catches of snow in shielded and unshielded gages at different wind speeds. Mon. Weather Rev. 89(10): 397-400. 1961.*

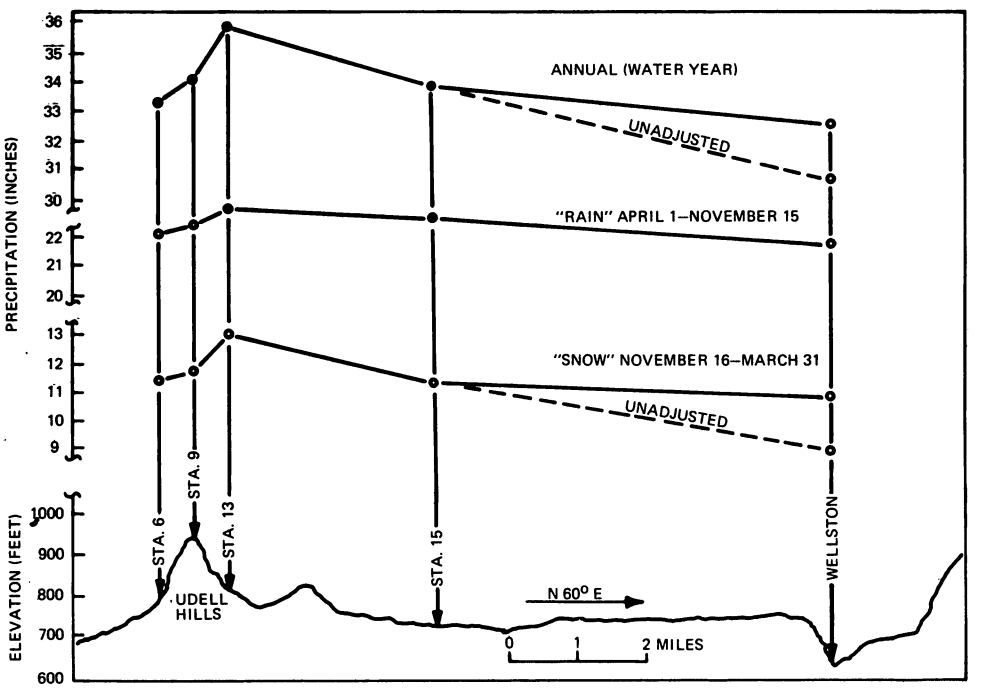

Figure 3. — *Distribution of rain, snow, and annual (water-year) precipitation along a transect N60°E through the Udell Hills.*

December, January, and February. This is the mid-winter period when snow squalls are heaviest near the lakeshore. After adjustment for shielding effects, the annual precipitation at all Weather Bureau stations was still below that measured on the Udell Hills, although the difference at Baldwin was not consistent.

The topographic effect of the Udell moraine is shown by a generally northwest-southeast transect across the hills (fig. 3). Mean water-year precipitation and the rain and snow totals for the period of record are shown at four stations along this transect in the Experimental Forest and at the Wellston Weather Bureau station.

The highest accumulations occurred on the east (lee) slopes. The catch at Station 13 in the leeward cove formed by the Udell Hills exceeded the mean of all gages on the Experimental Area by 1.64 inches.

Precipitation at the Weather Bureau stations during the 6-year study period deviated from the long-term mean precipitation.[3] Annual precipitation at Wellston and Cadillac, the two stations with published 1931-1960 normals, was 1.16 and 2.11 inches below normal, respectively, during the 6-year period. October, November, May, and June precipitation was low, while September rainfall was high. Mean precipitation at Manistee was 1.10 inches below the 33-year average ending in 1938.[4] It is probable that precipitation was also below long-term mean levels in the Udell Hills area. Possibly in periods of normal October and November precipitation, the "lake snow-squall effect" would be greater than that found during the 6 years reported here.

APPLICATION TO GROUND-WATER BUDGET STUDIES

The pattern of precipitation shown in figure 2 was used to determine the density of precipitation measurements needed for water budget studies in various segments of the Udell Experimental Forest. Ideally, the precipitation input should be measured at each study site. Where numerous small (40-acre) study blocks are involved, such intensive measurements are unneeded, especially when the plots are located away from the influence of the uplands. A test of the variability of precipitation measurements made at three stations spaced at 1-mile intervals on the east outwash plain showed that mean monthly precipitation estimates using one, two, or three stations were all within the estimated accuracy of the ground-water analyses techniques (± 0.5 area inch per year). When comparisons were made of water yields on the windward and lee sides of the Udell Hills, differences in annual precipitation and especially of dormant-season precipitation had to be considered. Similar topographic influences may be expected over other morainal hills along the Lake Michigan shore.

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[3] *Eichmeier, A. H. Climates of the States, Michigan. U.S. Dep. Com., Weather Bur., Climatography of the United States 60-20, 20 p. 1959.*

[4] *U.S. Department of Agriculture. Yearbook of agriculture. Climate and man. p. 915. 1941.*

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