Snow Amount in Relation to Streamflow and Herbage Production in Western Colorado

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Highlight: A 10% increase in peak snowpack, due to cloud seeding or natural events, is partly returned as runoff but has little, if any, immediate effect on the productivity and use of mountain grasslands.

Public concern over the consequences of augmenting the mountain snowpack by cloud seeding has set researchers to reworking data in an effort to determine the influence of modest increases of snow on the environment. One such set of precipitation, runoff, and vegetative production data from the Black Mesa Experimental Range has been analyzed statistically to quantitatively define relationships of peak snowpack to hydrologic characteristics and herbage production.

The experimental area is located west of Gunnison, Colo., on National Forest land at an elevation of 9,800 ft. The vegetative cover is broadly classified as aspen, spruce-fir, and herbaceous. The last, commonly referred to as Thurber fescue grassland, comprises approximately 50% of the area. A mixed grassweed complex occupies the largest area within the herbaceous type. Needlegrasses (*Stipa lettermanii* Vasey and *S. columbiana* Macoun) and Idaho fescue (*Festuca idahoensis* Elmer) are frequently found components. Hummocky areas, termed mima mounds, support a variety of cover types. On some, Thurber fescue (*Festuca thurberi* Vasey) predominates; on others, hairy goldaster (*Chrysopsis villosa* [Pursh] Nutt. ex DC) is the major species. These small parks are grazed extensively by cattle in summer.

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Manuscript received May 9, 1972.

Methods

Records for this paper were obtained from long-term grazing and watershed studies on Black Mesa. The studies have been generally described in a progress report (U. S. Forest Service, 1959), and certain preliminary findings were reported by Paulsen (1969). Additional records are on file at the Rocky Mountain Station.

Since 1954, two fenced pastures have been sampled each year to estimate total production of grasses, forbs, and shrubs. Thirty transects were established per pasture in the herbaceous type. Three 2.5 ft² plots per 50-ft transect were used to estimate production by the weight estimate method (Pechanec and Pickford, 1937), usually late in July.

Five snow courses were established on three experimental watersheds at Black Mesa in 1956. One or more of these were sampled two or more times in the spring each year, usually near April 1 and May 1. Peak snowpack data are based on the average of the five snow courses. There is some chance peak snowpack was missed because of the infrequent sample, but the five-course-average peak and the one-course peak agree as to date in all but one year.

Runoff data, including total and peak flow, were measured by a 90° V-notch weir on watershed 6. The snow courses cover an area greater than this watershed and are only an index of the precipitation received; even so, they are highly correlated with water yield.

Herbage production data are from two moderately grazed pastures, 1 and 6 (Fig. 1). Watershed 6 makes up 69% of the area and contains 22 of the 30 transects making up pasture 6. Pasture 1 is approximately 2 miles from the precipitation-measuring area.

Results

Several linear regression equations were computed from the basic data (Table 1), and the correlation coefficients were tested for significance. As is commonly found, runoff parameters correlated well with the precipitation variable. The correlation coefficient "r" is 0.94 for the peak snowpack-water yield relationship. For the sample size of 13 years, "r" is significant at the 1% level.

The steep slope of the peak snowpack-water yield regression indicates a substantial return in snowmelt runoff for any additions to peak snowpack.

The regression equation, $Y = 0.73X - 6.4$ (Y is water yield in inches and X peak snowpack water equivalent in inches), was used to predict the increase in water yield expected from a 10% increase in peak snowpack by substituting X and X + 0.10X in the equation. Subtracting the first yield from the second gives the expected increase. At the mean annual peak snowpack a 10% addition (1.8 inches water equivalent) results in a 1.4-inch increase in water yield; however, due to the large standard error of estimates (1.4 inches), the confidence interval at the mean is ±0.9 inch of runoff for an average year.

Similarly the increase in runoff for a 10% increase in peak snowpacks ranging from 10 to 30 inches was computed (Fig. 2). For this range of data, the confidence interval is ±1.5 and ±2.3 inches at the minimum and maximum annual peak snowpack.

Peak discharge and peak snowpack are also highly correlated ($r = 0.82$, significant at 16.1% level). Using the prediction equation, $Y = 1.11X - 5.0$, as outlined for water yield a 10% increase in mean snow water equivalent yields a predicted increase of approximately 2 ft³/second

Fig. 1. Black Mesa Experimental Area.

per square mile (csm) in the mean peak flow of 15 csm (Fig. 3). The confidence interval at maximum peak pack is ± 7 csm and at minimum ± 4 csm.

The correlation between (1) peak snowpack and (2) days from the start of runoff until the day of peak discharge is not significant until the probability level exceeds 50%. Another snow-duration analysis produced a significant correlation between peak snowpack and days from start of runoff until snow disappears from the herbaceous and aspen types. Snow disappearance was estimated from photographs, cessation of flow on watershed 5, and the day-to-day observations of the range technician working at Black Mesa. April 26 was the average start of runoff. Snow cover then lasted another 16 to 40 days. For 6 of the 10 years, snow cover lasted within ± 2 days of the mean duration of 26 days. A 10% increase in mean pack would increase the duration of snow cover 1.5 days.

Relationships between peak snowpack and herbage production do not reach significance at the 5% probability level. A linear regression fitted to the current year's peak snowpack and that summer's grass production does show a weak negative correlation, however. While the correlation coefficient is significant at the 14% level (1 in 7 chance instead of the traditional 1 in 20), only 17% of grass production variance is attributable to peak pack. The regression equation predicts a 25 lb./acre decrease in grass production for a 10% increase in peak snowpack. This is less than the "15% of the mean" criterion used to estimate grass production, and within the confidence interval at mean grass production on the regression line. The linear analysis shows

Fig. 2. Predicted increase in water yield from a 10% increase in peak snowpack.

no determinable effect on grass production and a plot of the variables does not indicate a curvilinear fit. Linear analysis of forb data was not significant at the 5% level.

When peak snowpack from the pre-

vious year and the current year's grass production are plotted, they appear to be positively correlated, but the relationship is not significant.

Discussion

On a mountain grassland-timber range of the mesa country on the western slope of Colorado, peak snowpack correlates well with water yield and peak discharge. Snow cover lasts almost a month, once spring runoff starts late in April. Increasing the snow precipitation input by 10% would lengthen the duration of snow cover less than 2 days.

Relationships of herbage production to peak snow water equivalent were not significant at the 5% level. Grasses have frequently been observed to be greening up under the snow cover. According to Paulsen (1969), rapid herbage growth begins soon after snowmelt, and reaches its maximum 6 to 8 weeks later. Heavy snow may delay peak production until August, but seeds ripen by September and the grasses and forbs are capable of completing their cycle in all but the most

Fig. 3. Predicted increase in peak discharge from a 10% increase in peak snowpack.

Table 1. Hydrologic and range production (lb./acre) data.

Year	Peak snowpack water equivalent, (inches)	Runoff (inches)	Peak dis- charge (c.s.m.)	Duration of snow (days)	Production ¹	
					Grasses	Forbs
1956	16.1	4.8	12	—	512	527
1957	28.2	16.2	27	40	529	865
1958	26.5	13.0	22	25	584	826
1959	13.3	3.3	10	16	586	701
1960	17.6	6.2	25	32	484	677
1961	13.8	3.3	7	22	622	1069
1962	20.2	7.9	15	27	751	814
1963	13.9	1.7	5	24	683	683
1964	17.9	6.2	19	25	510	546
1965	20.2	8.6	18	26	828	912
1966	13.8	6.3	14	25	1032	—
1967	9.7	2.0	4	—	955	—
1968	22.5	7.9	17	—	563	—
1969	18.2	—	—	—	854	—

¹Paulsen (1969) for 1956-65 data; 1966-69 data on file at Rocky Mountain Forest and Range Experiment Station, Project RM-1701.

unusual years, where very heavy spring snowpacks are followed by early fall frost. In spring, the moving of cattle up to their summer range is not restricted by snow cover, but by the growth stage of poisonous larkspurs (*Delphinium* sp.). Duration of snow cover could influence the phenology of larkspurs, but data are not available from Black Mesa to test this

hypothesis.

These observations and analyses indicate that a 10% increase in snowpack due to cloud seeding would have little, if any, immediate effect on the productivity and use of mountain grasslands.

Literature Cited

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mountain grassland-aspen range in western Colorado. J. Range Manage. 22: 102-107.

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