# Effects of Increased Rainfall on Native Forage Production in Eastern Montana

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**Abstract**

**Basal area data, collected from five sites in 1963 and 1976, were compared to determine the effects of 13 years of above-average rainfall in the growing season (April through September) on native range vegetation of the northern Great Plains. Changes in basal area, composition, and forage production were analyzed for five major grass and grass-like species. During the 13-year above-average rainfall period, western wheatgrass *(Agropyron smithii)*, needleandthread *(Stipa comata)*, and prairie junegrass *(Koeleria cristata)* established or increased on all sites. Threadleaf sedge *(Carex filifolia)* increased on the silty thin hilly range sites but decreased on the sandy range sites. Blue grama *(Bouteloua gracilis)* decreased on all sites. Calculated forage yield of these five species more than doubled on the silty (110%) and thin hilly (109%) range sites and increased 61% on the sandy range sites. The increase in forage yield decreased the amount of land needed for grazing by 1.6, 0.7, and 2.4 ha/cow-month for the silty, sandy, and thin hilly range sites, respectively.**

It is well known that changes in precipitation will alter the floristic composition of short and midgrass prairies in the northern High Plains (Perry 1976). Many investigators have discussed the effects of droughts upon rangeland vegetation but, as Coupland (1959) and Perry (1976) have stated, little information has been published correlating the effects of many years of near-normal or above-normal precipitation upon this vegetation.

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The short and midgrass prairies are continually changing, with climatic variables determining the degree of dominance of each species. Generally, during extended dry periods, total basal area decreases and species composition shifts toward domination by the short grasses. During the drought of the 1930's, blue grama *(Bouteloua gracilis)*, western wheatgrass *(Agropyron smithii)*, and needleandthread *(Stipa comata)* were reduced approximately 90% in eastern Montana (Ellison and Woolfolk 1937; Hurtt 1951; Reed and Peterson 1961). This drought reduced threadleaf sedge *(Carex filifolia)* only 12 to 55%. In southern Alberta, Clarke et al. (1947) reported that total basal cover was reduced from 26% in 1929 to 21% in 1936 and then to 14% by 1939. In eastern Montana, needleandthread and prairie junegrass *(Koeleria cristata)* appear to be the least drought-tolerant species, whereas blue grama and threadleaf sedge seem to be the most drought-tolerant species (White et al. 1978).

During extended periods of above-normal precipitation, total ground cover may increase, and range vegetation may shift toward a more mesic type in which the midgrasses play the more dominant role (Coupland 1958). Coupland (1959) reported that precipitation averaged about 20% above normal and temperature 1.7 to 2.8 C below average between 1950 and 1954 in Alberta and Saskatchewan, Canada, and that total basal area of grasses on ungrazed to moderately grazed sites in the mixed grass prairie doubled between 1944 and 1954 and the calculated forage yield increased by 137%. The two principal species in this region, porcupine needlegrass (*Stipa spartea* var. *curiseta*) and thickspike wheatgrass *(Agropyron dashystachyum)*, increased from 15 to 31% in total composition and forage yield increased from 29% to 50%. In contrast, the two principal species of drier situation, needleandthread and blue grama, declined from 62% to 44% in total composition and the calculated forage yield declined from 54 to 38%.

Five permanent sites, representing the native range vegetation near Mildred, in southeastern Montana, were mapped by basal area in 1936, 1938, and 1963. These sites provided us an excellent opportunity to document changes in range composition because the growing season precipitation (April-September) in this area between 1963 and 1976 averaged 23% higher than the mean of the previous 13 years (1949-1962). We believed that changes in vegetation occurring under natural conditions might be a good predictor of the possible long term consequences of many years of successful spring-early summer cloud seeding. Evidence to date indicates that cloud seeding may result in precipitation increases of 10–70% (Cleveland et al. 1978). Therefore, the objective of this study is to document changes in basal area between 1963 and 1976 after 13 years of above-average rainfall and relate this to changes in forage yield.

## Site Descriptions

Within each of the five permanent sites, five 30 × 152-cm (1 × 5 ft) permanently marked plots were originally located about 130 m (426 ft) apart. All plots have a north-south orientation and location was restricted to similar type range. Some plots were lost over the years, leaving five plots each at sites 1 through 4 and three plots at site 5 in 1976.

The soils at these sites were classified by the Soil Conservation Service (Table 1). Sites 1 and 2 were classed as silty, site 3 as sandy, and sites 4 and 5 as thin hilly range sites. To minimize the effects of different soils, the basal area data on similar range sites were combined.

Grazing was heavy on all sites until allotments were formed in the late 1940's. Since then, the Bureau of Land Management records in Miles City show that the grazing pressure at each site between the two periods (1949-1962 and 1963-1975) was relatively constant. Sites 1 and 3 have been grazed lightly to moderately by cattle from April to October. Site 2 has been grazed only occasionally although heavily by cattle and sheep. Site 4 has received only moderate grazing by cattle and sheep during the winter and early spring since 1940. Grazing on site 5 has varied from moderate to heavy from April to October.

## Methods

Precipitation and temperature from 48 years of records at the National Weather Service Cooperative Station located near the study sites in Mildred, Montana, were analyzed. Growing season rainfall (April through September), water-year precipitation (October through September), and monthly precipitation and temperature averages between 1963 and 1976 were compared statistically to the previous 13 and 35 year averages (one-tailed Student's $t$-test). Since we are interested in major effects of above-average precipitation, data obtained in 1963 were compared with the data from 1976, after 13 years of above-average precipitation.

**Table 1. Characteristics of study sites.**

| Site No. | Range site classification | Soil texture | Soil depth (cm) | Slope (%) | Physiography |
|---|---|---|---|---|---|
| 1 | Silty | Loam | 90 | 1 | Terrace along upland creek |
| 2 | Silty | Loam | 80–100 | 5 | Slope of rolling upland |
| 3 | Sandy | Fine sandy | 90 | 4 | Slope of rolling upland |
| 4 | Thin hilly | Loam & fine sandy loam | 30–70 | 7 | Slope of steeply rolling upland |
| 5 | Thin hilly | Loam & clay loam | 13–70 | 1 | Ridge crest of steeply rolling upland |

The vegetation was charted using a 30 × 152-cm frame strung with wire forming 5 × 5-cm grids. Basal area of plant species, ant hills, cow chips, and other materials occupying area within the frame were mapped on graph paper at ½ scale and then planimetered at least twice to assure accuracy. The basal area data were used in determining composition changes during the study period of all grasses, shrubs, half shrubs, and forbs. A one-tailed paired comparison $t$-test was used to statistically compare basal area changes on the range sites. Because western wheatgrass, blue grama, needleandthread, prairie junegrass, and threadleaf sedge are the important grasses or grass-like species for forage production in this region, the data for these species were analyzed further for changes in percent total ground cover between 1963 and 1976.

To obtain a relative estimate of forage yield, percent basal area for these five species was converted to *Stipa* equivalents (Brown 1954; Clarke et al. 1947). Forage yield is first converted in terms of needleandthread cover by multiplying the figure for relative yielding capacity (relative production) of each species by its percentage basal area. A stand of needleandthread (the standard) with 100% cover yields 2,268 kg of air-dry forage per acre in southeastern Alberta (Clarke et al. 1947). This standard was used in calculating forage yield. These values were then used to calculate an estimate of grazing capacity for cattle, assuming that a 453.5 kg (1,000 lb) grazing beef cow: (1) may graze 55% of the available forage and (2) will use 299 kg (660 lb) of forage per month on a dry-weight basis (Brown 1954). Since the relative yielding capacity figures used were those developed for the Canadian grasslands, the actual yield of various species under the conditions encountered in eastern Montana may be different. However, for a comparative study (1963 production vs. 1976 production) use of the Canadian relative yielding capacity figures is quite justified.

## Results

### Weather Conditions during the Study

Growing season precipitation and the water-year precipitation during the recent 13-year period averaged 23% and 21% higher, respectively, than that of the earlier 13-year

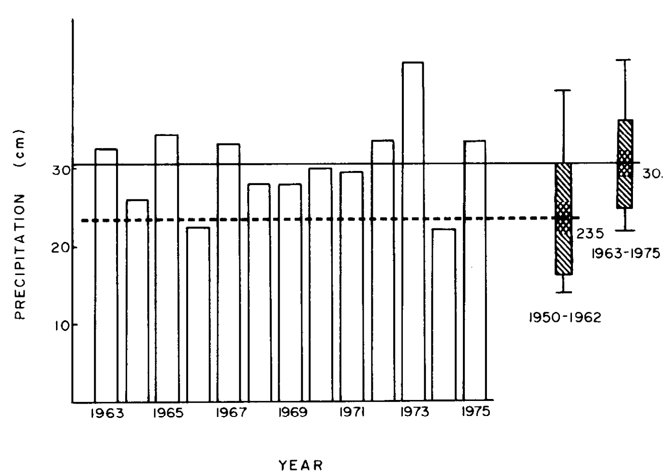


**Fig. 1.** *Growing season (April-September) precipitation for 13 consecutive years (1963-1975) at Mildred, Mon. (histograms). Two rectangular blocks (far right) represent the 1950-1962 and 1963-1975 growing seasons (average, standard error of the mean, standard deviation, and range). Solid and dashed horizontal lines represent the 1963-1975 and 1950-1962 means, respectively.*

period. The months of April and June accounted for most of the difference.

Figure 1 illustrates the variation in growing season precipitation at Mildred, Montana, for the 13 years between 1963 and 1975. Eleven of these exceeded the average value of 23.5 cm calculated from the prior 13 growing seasons (1950-1962), which was not significantly different from the 24.4 cm average for the 1928 (beginning of record) to 1962 period. The average of 30.5 cm determined from the recent 13 growing seasons was significantly higher ($P<0.01$) than that of both these earlier periods.

The water-year precipitation between 1929 and 1962 and between 1949 and 1962 averaged 31.4 cm and 29.7 cm, respectively, and was significantly less ($P<0.05$) than that of the 1962-1975 period (37.5 cm). Water-years, rather than annual years, were analyzed because fall-winter precipitation can affect forage production the following summer.

April and June had significantly more rainfall ($P<0.01$) during the 1962-1975 period than during the earlier period (1949-1962), with June showing the greatest increase (3.86 cm) (Fig. 2). Precipitation in the remaining months did not differ significantly ($P>0.01$).

Average monthly temperatures for the two 13-year periods (1949-1962 and 1962-1975) did not differ significantly ($P>0.01$).

### Changes in Basal Area

Total basal area at all range sites increased 61% between 1963 and 1976 with the silty, sandy, and thin hilly range sites increasing 58, 34, and 101%, respectively. Basal area at the silty and thin hilly range sites increased significantly ($P<0.05$). The sample size at the sandy site was too small for

**Table 2. Status of species in 1976 compared to 1963.**

| Scientific name | Common name[1] | Sites | | |
|---|---|---|---|---|
| | | Sandy | Thin hilly | Silty |
| Grasses and grass-like species | | | | |
| *Agropyron smithii* | western wheatgrass | N[2] | ↑[3] | ↑ |
| *Agropyron spicatum* | bluebunch wheatgrass | —[4] | ↑ | — |
| *Aristida longiseta* | red threeawn | — | N | |
| *Bouteloua curtipendula* | sideoats grama | — | ↑ | — |
| *Bouteloua gracilis* | blue grama | ↓[5] | ↑ | ↑ |
| *Bromus japonicus* | Japanese brome | N | — | — |
| *Buchloe dactyloides* | buffalo grass | ↓ | N | ↑ |
| *Calamagrostis montanensis* | plains reedgrass | — | N | N |
| *Calamovilfa longifolia* | prairie sandreed | — | — | ↑ |
| *Carex eleocharis* | needleleaf sedge | N | ↓ | |
| *Carex filifolia* | threadleaf sedge | ↓ | ↑ | ↑ |
| *Carex heliophila* | sun sedge | — | — | N |
| *Vulpia octoflora* | common six weeksgrass | N | — | N |
| *Koeleria cristata* | prairie junegrass | N | ↑ | ↑ |
| *Muhlenbergia cuspidata* | stoneyhills muhly | — | ↑ | — |
| *Poa secunda* | sandberg bluegrass | — | N | ↑ |
| *Andropogon scoparius* | little bluestem | — | N | — |
| *Sporobolus cryptandrus* | sand dropseed | N | — | — |
| *Stipa comata* | needleandthread | ↑ | ↑ | ↑ |
| *Stipa viridula* | green needlegrass | — | — | ↓ |
| Shrubs and half shrubs | | | | |
| *Artemisia cana* | silver sagebrush | — | — | ↓ |
| *Artemisia frigida* | finged sagewort | — | ↑ | ↓ |
| *Eurotia lanata* | common winterfat | — | ↓ | — |
| *Gutierrezia sarothrae* | broom snakeweed | — | ↓ | — |
| *Yucca glauca* | small soapweed | — | N | — |
| Forbs | | | | |
| *Arenaria congesta* | ballhead sandwort | — | — | ↓ |
| *Cirsium undulatum* | wavyleaf thistle | — | — | ↑ |
| *Echinacea pallida* | pale echinacea | — | ↑ | ↑ |
| *Lappula redowskii* | bluebur stickseed | — | — | N |
| *Liatris punctata* | dotted gayfeather | — | N | — |
| *Lygodesmia juncea* | rush skeletonplant | ↑ | ↑ | N |
| *Mammillaria vivipara* | purple mammillaria | ↑ | — | ↑ |
| *Melilotus officinalis* | yellow sweetclover | — | — | N |
| *Opuntia polyacantha* | plains pricklypear | N | — | ↓ |
| *Petalostemon purpureum* | purple prairieclover | — | — | N |
| *Phlox hoodii* | Hoods phlox | — | ↑ | — |
| *Plantago purshii* | woolly plantain | N | ↑ | — |
| *Polygala alba* | white polygala | — | N | — |
| *Psoralea argophylla* | silverleaf scurfpea | — | — | N |
| *Ratibida columnifera* | prairie coneflower | — | N | ↑ |
| *Solidago missouriensis* | Missouri goldenrod | — | — | N |
| *Sphaeralcea coccinea* | scarlet globemallow | N | ↑ | ↑ |
| *Taraxacum officinale* | common dandelion | — | — | N |
| *Tragopogon dubius* | yellow salsify | N | N | N |

[1]Plant names follow those recommended by Beetle (1970).
[2]N = species present in 1976 but not in 1963.
[3]↑ = increase in % composition by basal area
[4]species not present in 1963 and 1976
[5]↑ =Decreases in % composition by basal area.

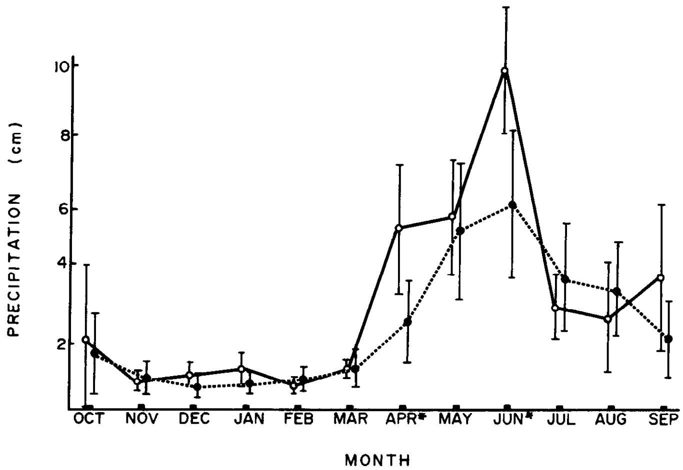


**Fig. 2.** *Average monthly precipitation at Mildred, Mon. Solid line represents 1962-1975 average (open circle ±2 standard error of the mean) and dashed line represents 1949-1962 average (dark circle average ±2 standard error of the mean). Months of significant differences (P< 0.01) are indicated by *.*

statistical comparison because some of the plots were lost over the past 40 years. The status of all species present in 1976 compared to 1963 are summarized in Table 2.

The following five species comprised approximately 85% of the basal area at the range sites: western wheatgrass, blue grama, prairie junegrass, needleandthread, and threadleaf sedge (Table 3). By 1976, western wheatgrass, needleandthread and prairie junegrass had increased on all range sites, whereas, blue grama and threadleaf sedge increased on the silty and thin hilly range sites but decreased on the sandy site. These five species increased the most on the thin hilly range (97%), followed by the silty range sites (64%) and lastly, the sandy range site (34%).

**Table 3. Percent basal area at the three range sites in 1963 and 1976.**

| | Range Site | | | | | |
|---|---|---|---|---|---|---|
| | Silty | | Sandy | | Thin hilly | |
| Plant species | 1963 | 1976 | 1963 | 1976 | 1963 | 1976 |
| Western wheatgrass | 0.1 | 0.2 | 0.0 | 0.1 | 0.0 | 0.1 |
| Blue grama | 5.4 | 6.6 | 4.8 | 4.2 | 1.8 | 3.5 |
| Needleandthread | 0.– | 2.1 | 2.4 | 5.7 | 0.3 | 1.3 |
| Prairie junegrass | 0.0 | 0.5 | 0.0 | 0.3 | 0.0 | 0.4 |
| Threadleaf sedge | 0.7 | 2.1 | 1.4 | 1.3 | 1.4 | 2.0 |
| Subtotal | 6.2 | 11.5 | 8.6 | 11.6 | 3.5 | 7.3 |
| All other grasses and sedges | 0.5 | 1.2 | 0.2 | 0.3 | 0.5 | 1.1 |
| All forbs | 0.4 | 0.3 | 0.0 | 0.1 | 0.2 | 0.5 |
| All shrubs | 0.4 | 0.2 | 0.0 | 0.0 | 0.0 | 0.1 |
| Percent total basal area | 7.5 | 13.2 | 8.8 | 12.0 | 4.2 | 9.0 |

All other grasses and sedges accounted for less than 6, 3, and 12% of the total basal area on the silty, sandy, and thin hilly range sites, respectively, in 1963 (Table 3). Basal area of these species had more than doubled on the silty and thin hilly range sites but increased only 23% on the sandy site by 1976.

Forbs and shrubs (representing less than 1% of the total basal area on all sites) increased on the sandy and thin hilly range sites and decreased on the silty range site (Table 3).

Percentage of bare ground decreased at all sites; from 92 to 87% at the silty range sites, from 93 to 90% at the sandy site and from 95 to 90% at the thin hilly sites (Table 3). Since basal area is an estimate of the ground area actually occupied by plants rather than the area covered by the combined aerial parts of plants and litter (as in foliage cover), the amount of bare ground estimated by basal area will be higher than that estimated by foliage cover.

**Changes in Percent Composition Based on Basal Area**

In 1963 the dominant plant was the low growing, perennial blue grama, but in 1976 the trend appeared to be changing slightly toward more midgrass species such as needleandthread and prairie junegrass (Fig. 3). Dominant in this case refers to the area occupied by the various species. In terms of forage yield, blue grama was never a dominant grass with the exception of the silty sites in 1963 (Fig. 4).

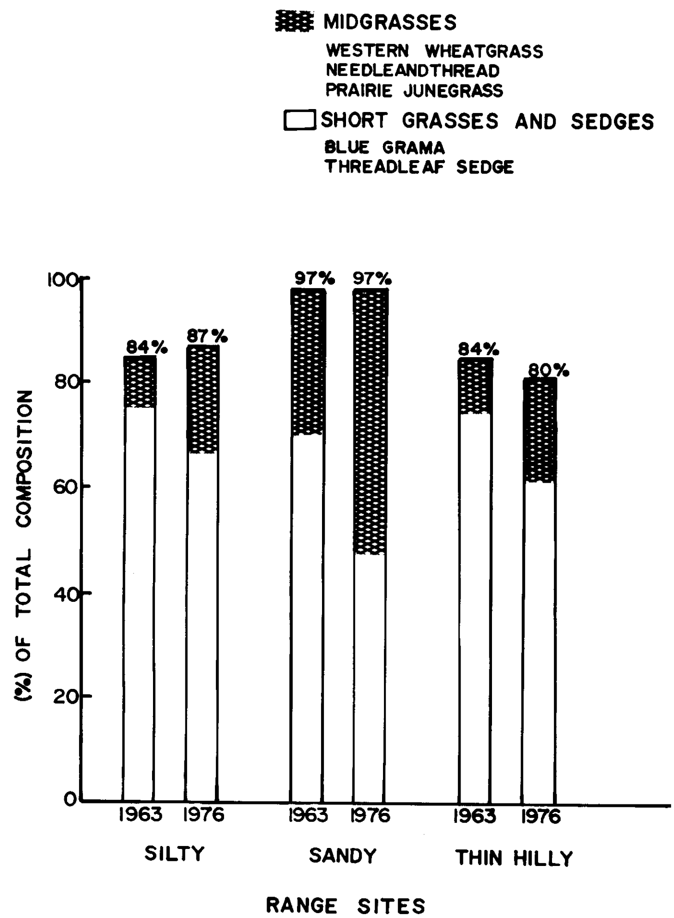


**Fig. 3.** *Change in percent of total composition by basal area of the five major grasses in 1963 and 1976.*

The percentage of total composition comprising the five grass or grass-like species discussed above changed very little at the three range sites between 1963 and 1976 (Fig. 3). Blue grama decreased at all sites: from 66 to 51% on the silty range sites, from 54 to 35% on the sandy range site and from 42 to 39% on the thin hilly range sites. Needleandthread and prairie junegrass increased at all range sites with needleandthread becoming the dominant grass on the sandy range sites by 1976 (27 to 47%). Threadleaf sedge increased at the silty site (9 to 16%), but decreased at the sandy (16 to 11%) and thin hilly range sites (32 to 22%).

The percent total composition of all other grasses and

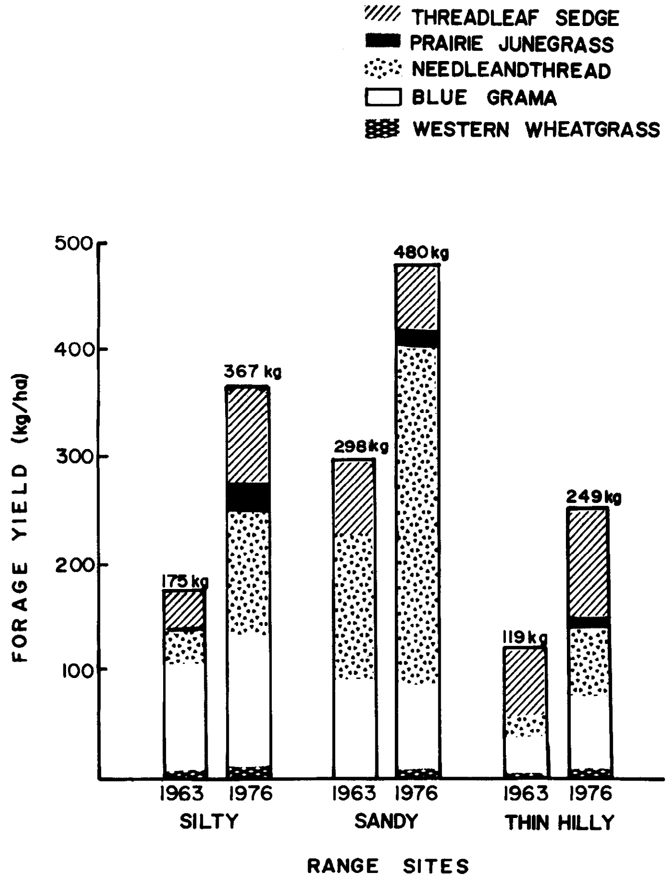


**Fig. 4.** *Calculated forage yield for the five species indicated at the three range sites in 1963 and 1976.*

sedges did not change significantly on sandy (2 to 2%) or thin hilly range sites (12 to 13%), but did show a slight increase on the silty range sites (6 to 9%). This increase was principally due to increases in red threeawn *(Aristida longiseta)* and sandberg bluegrass *(Poa secunda)*.

In 1963, forbs and shrubs comprised less than 5% of the total composition on the silty and thin hilly ranges and less than 1% on the sandy range site. These species decreased at all sites by 1976, except for a slight increase of shrubs (<1%) at the thin hilly site and the establishment of forbs (<1%) at the sandy site.

### Changes in Relative Production

The calculated forage yield of the five important grass or grasslike species described above increased 192 (110%), 183 (109%), and 130 kg/ha (61%) on the silty, thin hilly, and sandy range sites, respectively, between 1962 and 1976 (Fig. 4). Needleandthread comprised the major increase at these range sites. Forage yield would be somewhat larger if all species on these sites were analyzed.

The increase in forage yield of these species increased the calculated grazing capacity for cattle from 3.1 to 1.5 hectares per cow-month on the silty range sites, from 1.8 to 1.1 on the sandy range site and from 4.6 to 2.2 on the thin hilly range sites.

## Conclusions

The higher April and June precipitation between 1963 and 1976 increased basal area considerably on the silty, sandy, and thin hilly range sites. Species composition changed from a dominant blue grama grassland toward a more mid-grass community. Needleandthread, western wheatgrass, and prairie junegrass became established or increased on all sites. Threadleaf sedge increased on the silty and thin hilly range sites, but decreased on the sandy range site. Concurrently, the calculated forage yield of these species more than doubled on the silty and thin hilly range sites and increased 61% on the sandy range site. The latter range site, however, was more productive than the other two sites. The increase in forage yield of these five grasses decreased the hectares needed per cow-month for grazing by 1.6 (48%), 0.7 (24%), and 2.4 (48%) on the silty, sandy, and thin hilly range sites, respectively.

These results indicate that additional spring-early summer precipitation on moderately grazed rangeland in eastern Montana has benefits for the stockman. The number of cattle that may be properly grazed could almost double with a 23% increase in precipitation, similar to the findings of Coupland (1959) in southern Alberta and Saskatchewan. Whether an increase of this magnitude is consistently obtainable with purposeful cloud seeding remains to be seen.

## Literature Cited

**Beetle, A.A. 1970.** Recommended plant names. Wyo. Agr. Exp. Sta. Res. J. 31. 124 p.

**Brown, D. 1954.** Methods of Surveying and Measuring Vegetation. Commonwealth Agricultural Bureau, England.

**Clark, S.E., E.W. Tisdale, and N.A. Skoglund. 1947.** The effects of climate and grazing practices on short-grass prairie vegetation. Canada Dep. Agr. Tech. Bull. 46. 54 p.

**Cleveland, H. (Chairman). 1978.** The management of weather resources, Vol. I - Proposals for a National Policy and Program. U.S. Dep. Comm., Washington, D.C. 229 p.

**Coupland, R.T. 1958.** The effects of fluctuations in weather upon grasslands of the Great Plains. Bot. Rev. 24: 273-317.

**Coupland, R.T. 1959.** Effects of changes in weather conditions upon grasslands in the northern Great Plains. Grasslands in Our National Lives. (H.B. Sprague, ed.) AAAS Symposium Pub. 53. p. 291-306.

**Ellison, L., and E.J. Woolfolk. 1937.** Effects of drought on vegetation near Miles City, Montana. Ecology 18: 329-336.

**Hurtt, L.D. 1951.** Managing northern Great Plains cattle ranges to minimize effects of drought. U.S. Dep. Agr. Circ. 865. 24 p.

**Perry, D.A. 1976.** The effects of weather modification on the northern Great Plains grasslands: A preliminary assessment. J. Range Manage. 29: 272-278.

**Reed, M.J., and R.A. Peterson. 1961.** Vegetation, soil, and cattle responses to grazing on northern Great Plains range. U.S. Dep. Agr. Tech. Bull. 1252. 79 p.

**Sarvis, J.T. 1941.** Grazing investigations on the northern Great Plains. No. Dak. Agr. Exp. Sta. Bull. 308. 110 p.

**White, L.M. J.J. Newbauer, III, and J.R. Wight. 1978.** Vegetational differences on native range during 38 years in eastern Montana. Proc. of 1st Internat. Rangeland Congress 260-262.

**Whitman, W., H.C. Hanson, and R. Peterson. 1943.** Relation of drought and grazing to North Dakota rangelands. No. Dak. Agr. Exp. Sta. Bull. 320. 29 p.