Effect of precipitation on mixed grass plant communities of southeastern Montana and its implications for grazing intensity

by Kenneth Clark Olson

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Range Science
Montana State University

Abstract:
Data were compiled for a grazing study over a 24 year period between 1932 and 1956 at the Livestock and Range Research Station, Miles City, Montana. Previous research based on these data suggests that climate is the major controlling factor of range condition and production.

The objectives of this study were: (1) to investigate the correlation between plant community composition and precipitation, (2) to examine the effect of grazing intensity on the correlation between plant community composition and amount of precipitation, and (3) to examine management alternatives that maximize desirable plant communities for livestock production under variable climatic conditions.

Basal cover data were collected annually from permanent meter square chart quadrats by using the pantograph method. Data analysis employed multiple regression techniques with basal cover as the dependent variable and precipitation parameters as independent variables. A series of predictive equations were obtained to evaluate relationships among factors such as annual precipitation, preceding annual precipitation, cumulative precipitation, and growing season precipitation. A total of 142 species were recorded from 1932 to 1 956. Of these, predictive equations were developed with a coefficient of determination (r2) of 0.70 or greater for twelve species. These included western yarrow, western wheatgrass, fringed sagewort, red threeawn, blue grama, buffalograss, threadleaf sedge, needleleaf sedge, tumbllegrass, scarlet globemallow, needle-and-thread, and green needlegrass.

Predictive equations were developed for three grazing intensities, for exclosures, and for all quadrats combined. Cover was predicted for several precipitation regimes using each predictive equation. These predicted cover values were then used to develop three dimensional graphs, which were used to examine the precipitation regime that determines cover for a particular species. The response of each species to precipitation is discussed. Each species responds to a different precipitation regime, indicating that fluctuations in the precipitation regime will cause fluctuations in species composition of the plant community By comparing graphs for the same species under different grazing intensities, the effect of grazing upon plant cover is also discussed. Moderate grazing (.92 ha or 2.3 acres/AUM) was recommended as the optimum for maintaining a composition most conducive to livestock production.

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A thesis submitted in partial fulfillment
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Range Science

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May, 1982

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Dr. R.S. White and Dr. B.W. Sindelar for the support and advice that they have given throughout my graduate program, and to Dr. C.B. Marlow, Dr. R.W. Whitman and Dr. P.O. Currie for their assistance.

Special thanks are extended to Mr. Brad Knapp for his invaluable assistance with my data analysis and Jeanne Blee for her teaching skills on the word processor. I express my appreciation to Laura Zook and Laurel McCoy for pasting figures in the final draft. I also thank the staffs of the Livestock and Range Research Station and the Animal and Range Sciences Department for their support.

I would like to thank the Livestock and Range Research Station and the Montana Agricultural Experiment Station for financial support.

I owe very special thanks to my parents, Bob and Doris Olson, and my wife's parents, Bud and Lil Lawrence. Most of all, my deepest gratitude goes to my wife, Joni, who postponed her education to allow me to continue mine.

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ABSTRACT

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INTRODUCTION

Climate appears to be the major controlling factor of plant growth in the Great Plains. Reed and Peterson (1961) and Hurtt (1951) stated that major trends in vegetation characteristics are determined by fluctuations in climatic conditions, and that changes within these major trends are influenced by grazing intensity.

At the present time, there are generalized ideas of the influence of precipitation and grazing intensity on rangeland plant communities, but little effort has been made to quantitatively describe changes in these plant communities as influenced by fluctuating precipitation regimes. Researchers have developed models to predict or estimate forage production, but literature has not been found which attempts to predict plant cover under fluctuating precipitation regimes. Predictions of forage production are very useful for determining stocking rates. However, by determining changes in basal cover of the plant species present, a more concise understanding of the changing ecological roles of the species can be achieved, and hence a better understanding of community dynamics of the range ecosystem can be realized.

The purpose of this thesis is to quantitatively describe changes in basal cover of vegetation in response to variation in precipitation and grazing intensity.

The specific objectives of this study were:

1. To investigate the relationship between plant community composition and amount of precipitation.
2. To examine the effect of grazing intensity on the relationship between plant community composition and amount of precipitation.
3. To examine management alternatives that maximize desirable plant communities for livestock production under variable climatic conditions.

LITERATURE REVIEW

Factors Controlling Vegetation Growth

Climate appears to be the major factor controlling plant growth in the Great Plains. Reed and Peterson (1961), Hurtt (1951), and Clark, Tisdale and Skoglund (1943) stated that major trends in vegetation characteristics are determined by major changes in climatic conditions and that changes within these major trends are influenced by grazing intensity. Whitman, Hanson and Peterson (1943) stated that drought is the primary influence of vegetational change. Forage production may decrease due to abnormal climatic conditions and increased grazing intensity (Albertson, Riegel and Launchbaugh 1953). Climatic conditions greatly affect the quantity, quality, and availability of forage (Clark et al. 1943).

Soil moisture content has also been considered the major factor controlling plant growth, whether it be biomass production or tillering, which increases basal area (Clark et al. 1943; Schumacher 1974; Coupland 1958). However, fluctuation in soil moisture is due to variation in precipitation (Schumacher 1974). Therefore, precipitation, which is an element of climate, appears to be a major controlling factor of plant growth. There is a direct relationship between the amount of precipitation and forage production (Albertson, Tomanek and Riegel 1957).

Other climatic factors have been reported in the literature as limiting vegetational growth. These include high temperature, low humidity, high winds, and burial by dust, along with low soil moisture (Weaver and Albertson 1936). Clark et al. (1943) stated that temperature is a controlling factor in the early spring, insofar as determining when plant growth begins. This is also a period when soil moisture is usually plentiful. It appears that other climatic factors also affect availability of moisture and the plant's ability to use it, so available moisture remains the major controlling factor.

Several authors have discussed soil related factors that control plant growth. Young (1956) stated that plant death loss due to drought can be related to soil type and land management. Ballard and Ryerson (1973) stated that forage production varies more due to range site and condition than precipitation. They reported that, in northern Montana, only four of ten grass species showed a significant relationship between forage production and precipitation using regression and correlation techniques. When considering sandy soils, Herbel, Ares and Wright (1972) reported a direct relationship between drought damage and depth of soil. They stated that a shallow soil is better because it holds moisture closer to plant roots, where it is more readily available. Cook and Sims (1975) stated that soil type and past grazing use determine changes in species composition, with dry years emphasizing these changes. In contrast, Abel, Rosenfield and Stephens (1962) refute this, stating that precipitation has the major influence on plant growth, with other climatic factors, soil type, topography, ecological factors, and management practices, such as stocking rate or breeding programs, having less influence. Weaver, Stoddart and Noll (1935) reported similar findings, stating that drought effects are mostly due to reduced soil moisture, with little effect from low humidity or high temperature.

Only two researchers, Johnson (1981) and Craddock and Forsling (1938) stated that grazing effects have a greater influence on the range ecosystem than does climate. Craddock and Forsling (1938) discussed use of spring-fall sheep range in southern Idaho, which may not be comparable to summer cattle use in southeastern Montana.

Effects of drought can also be increased by other factors which occur as a result of the drought conditions. These factors usually intensify adverse effects of drought. Grasshoppers are influential in the deterioration of rangeland during drought (Cook and Sims 1975; Reed and Peterson 1961). Whitman et al. (1943) reported that grasshoppers increased during drought, which greatly increased their use of grasses. Litter cover is also lost from the soil surface during drought by unknown means (B.W. Sindelar, personal communication). Therefore, the insulating and reflective qualities of the litter cover are lost, allowing increased evaporation of soil moisture and heating of the soil profile. Organic matter content of the soil profile is also decreased because less litter is available to be incorporated into the soil.

Precipitation Regime of the Northern Great Plains

Climate of the Great Plains ranges from sub-humid to semi-arid (Coupland 1958). At Miles City, Montana, where this study is located, the climate is semi-arid. Hurtt (1951) reported that average annual precipitation is approximately 325 mm (13 inches), of which 70% typically falls between April first and September 30th. Throughout the Great Plains, precipitation on a monthly or an annual basis varies widely from the long term mean (Clark et al. 1943; Cook and Sims 1975; Craddock and Forsling 1938). Extended periods of drought are common (Cook and Sims 1975). By the same token, extended periods of above average precipitation can also occur. Smoliak et al. (1976) stated that wet or dry years tend to occur in sequence. Thus, drought periods and periods of normal or high precipitation alternate regularly over time to develop weather cycles (Cook and Sims 1975). Vegetation of the short and mixed grass prairie has evolved to react in a relative equilibrium which changes continuously in relation to climatic fluctuations (Clark et al. 1943; Newbauer et al. 1980). Thus, different plants will react differently during wet or dry cycles (Cook and Sims 1975).

Precipitation fluctuations below normal are termed drought (Reynolds 1954). Various definitions have been given for drought.

The USDA Weather Bureau defined drought as a period when precipitation is 30% of the average for 21 days or longer (Ryerson unpublished; Cook and Sims 1975). Another definition is: a period when annual precipitation is 70% of normal or monthly precipitation is 60% of normal (Cook and Sims 1975). The Society for Range Management uses the definition: "prolonged dry weather, generally when precipitation is less than 75% of the average annual" (Bedell and Ganskopp 1980). Hurtt (1951), reporting on drought in southeast Montana, defined it as being when total precipitation is less than 70% of the 229.5 mm (9.18 inch) spring-summer average for the area. This would be less than 160 mm (6.4 inches) of precipitation. He also stated that a serious moisture deficiency in the first four months of the growing season will result in greatly retarded plant growth.

One of the greatest problems with drought is that its occurrence cannot be reliably predicted (Ryerson unpublished; Cook and Sims 1975; Schumacher 1974). The probability of drought can be estimated (Schumacher 1974). The probability of drought in southeast Montana is one year out of every five (Hurtt 1951) and in southern Alberta it is one year out of every four (Johnson 1981). However, the sequence cannot be predicted (Hurtt 1951). Because of this, it has been difficult to manage rangeland for fluctuating climatic conditions (Cook and Sims 1975).

Drought has a deleterious effect on the economy of the ranching industry. Livestock gains are greatly reduced during drought (Reed and Peterson 1961), resulting in lower total production. This has the effect of lowering income. At the same time, in many cases, livestock have to be removed from the range. They may be sold, moved to a region that has not been affected by drought conditions, or fed hay or other supplements. All of these alternatives are costly and incur large economic losses for ranchers. Because of this, drought has received considerable attention, with many reports written on its effects (Newbauer et al. 1980; Coupland 1958). Most of these studies were initiated to investigate the effects of grazing on range, but the effects of climate were superimposed on them (Coupland 1958). In contrast, relatively few reports are available on the effects of above average precipitation on range (Newbauer et al. 1980; Coupland 1958). Recent interest has been shown in above average precipitation to determine the effects of weather modification on the Great Plains range ecosystem (Newbauer et al. 1980). Also, above average precipitation needs to be better understood to make full use of the increased growth that usually occurs with increased precipitation, without lowering range condition.

A comprehensive understanding of the responses of the range ecosystem to weather and grazing is desirable to improve management (Reed and Peterson 1961). As of now, drought cannot be controlled, but its impact can be lessened by proper livestock management. To do this, actual changes in plant communities need to be known so that the effects of drought on the range can be better understood.

Vegetation Response to Climate

Abrupt and fundamental changes in the amount and kind of living plant crown area may result from severe drought and last longer than ordinarily supposed (Reed and Peterson 1961). The frequency and duration of drought are both important in determining the severity of the effect of climate on vegetation (Ryerson unpublished; Cook and Sims 1975; Herbel et al. 1972). There is a close relationship between the time and amount of precipitation and plant growth (Albertson et al. 1953). One wet or dry year will affect production, but two or more wet or dry years are required to change the basal cover (Ryerson unpublished; Smoliak et al. 1976). The magnitude of change will depend upon grazing pressure, fire, small herbivores, and insects (Ryerson unpublished).

Effects of drought years can be carried over into non-drought years, especially in severe droughts. Sarvis (1941) reported that in the drought of the 1930's, 1934 and 1936 were the only true drought years. However, drought effects were recorded throughout the entire period of the 1930's. Also, recovery does not occur immediately after a drought breaks. Coupland (1958) and Cook and Sims (1975) reported two major reasons for this: first, it takes time to produce seed crops and have ideal conditions for seed to germinate and establish; and second, after plants have been dormant for a long time, it may take two years to break dormancy, due to low vigor. Albertson et al. (1957) reported that in 1940, a normal precipitation year which followed a prolonged drought, deterioration continued throughout the summer. In northern Montana, during a drought in the early 1960's, basal cover continued to decrease in 1962, even though it was a year of normal precipitation (Ryerson unpublished). Ellison and Woolfolk (1937) reported that the effect of drought on plant vigor extends into the year following drought.

Native vegetation has developed under conditions of wide climatic variation (Albertson et al. 1957). Marked changes in botanical composition occur, but the plant populations are not destroyed (Cook and Sims 1975). These changes are slow, whether for better or worse (Sarvis 1941). Native grass species will remain dominant in prairies unless they are severely overgrazed or buried by dust (Cook and Sims 1975; Schumacher 1974; Albertson et al. 1957). Reed and Peterson (1961) reported that in southeast Montana, perennial grasses continued to make up most of the plant cover throughout all climatic conditions or grazing intensities. Cover did not deteriorate to weeds or unpalatable grasses. There was no elimination of any component or total destruction of range cover during drought in northern Montana (Ryerson unpublished). Ryerson further stated that composition was comprised of species that can tolerate drought conditions. This indicated high tolerance of such range to adverse conditions. Mixed grass prairie in western North Dakota is highly stable during fluctuating moisture conditions (Whitman et al. 1943). Studies from various areas of the western rangeland indicate that forage production, basal area cover, and species composition may be changed drastically by major weather fluctuations, but usually the dominant species are not completely lost from the stand (Cook and Sims 1975). A few species are temporarily completely killed, but they recover after drought from seed or vegetative spread. Only two reports contradict these statements. Hurtt (1951) stated that a small decline in annual precipitation may result in reduced growth or even in total failure of all but the most drought resistant species. Albertson and Weaver (1946) reported that drought and dust, unaided by grazing, had reduced an area of mixed grass prairie to a disclimax of short grasses. However, it appears that these authors considered only the immediate effects during the very severe drought of the 1930's, and did not consider post drought recovery.

Drought effects range from reduction in vigor, or size, including height growth, basal diameter, and root length, to actual death of the plant (Ryerson unpublished; Cook and Sims 1975). Thus, drought causes a reduction in basal cover by mortality of parts or all of individual plants (Pieper and Donart 1975; Cook and Sims 1975).

Different species have different drought tolerances and therefore significantly different mortality rates (Chamrad and Box 1965). Strategies used to increase drought tolerance include deep rooting, spread by stolons and rhizomes, making maximum use of light showers, greater lateral distribution of roots, or reduced palatability, which will reduce grazing stress during drought stress (Chamrad and Box 1965; Weaver and Albertson 1939; Weaver et al. 1935). Because of inherent differences in drought tolerances, species react and change in different amounts during and following drought (Cook and Sims 1975).

There are several general responses that vegetation undergoes during drought. The earliest response of vegetation is a reduction in forage yield (Weaver and Albertson 1944). Young and shallow rooted plants die first (Coupland 1958). Decrease in cover is more rapid in early years (Albertson and Weaver 1942). If drought persists for an extended period, cover may actually increase slightly due to spread into bare areas by more drought resistant species. During drought, losses of cover seem to be greatest on more densely covered areas (Coupland 1958). However, dominant species that decrease most rapidly during drought appear to increase most rapidly following drought (Cook and Sims 1975).

Vegetation response during drought recovery proceeded through definite seres of secondary succession (Coupland 1958). The initial sere depended upon the amount of deterioration that had occurred. The order of the seres was: annual forbs, annual grasses with perennial forbs, early perennial grasses, and late perennial grasses. Rate of recovery depended on several factors:

1. predrought cover
2. degree of depletion of vegetation during drought
3. plant species remaining
4. dust burial damage
5. grazing intensity before, during, and after drought
6. trampling after drought
7. amount and distribution of precipitation after drought

(Coupland 1958; Ryerson unpublished).

Drought generally causes a decline in basal cover, with species composition shifting toward short grasses (Newbauer et al. 1980). Reed and Peterson (1961) reported on the effects of the 1930's drought in southeast Montana. In 1933, prior to the drought, basal cover of all grasses was 28%, but by 1937, it was reduced to 2%. Most major grass species cover declined, but one, Sandberg bluegrass (*Poa sandbergii*[1]), which increased during the drought period. Recovery to the original amount of basal cover of grasses was completed by 1944. Houston and Woodward (1966) reported on a different phase of the same study between 1945 and 1956. During this period, total basal cover declined. Precipitation was below average for most of this period.

[1]Nomenclature taken from USDA Soil Conservation Service (1982)

This decline included most species, with the only species increasing cover being Sandberg bluegrass, threadleaf sedge (*Carex filifolia*), and big sagebrush (*Artemisia tridentata*). Ryerson (unpublished) reported on a drought occuring from 1960 to 1962 in northern Montana. Total basal cover was reduced from 14.5% in 1960 to 6.7% in 1962, with grass and sedge basal cover reduced from 11.4 to 6.2%. Whitman et al. (1943) reported on the effects of drought in western North Dakota. The effects in North Dakota were not as severe as in Montana. Basal cover decreased from 30% in 1933 to 13% in 1936. Recovery was relatively rapid, with many species attaining greater basal cover than previous to drought. In eastern Wyoming, basal cover decreases of 50% or more can be expected when wet years are followed by dry years (Lange 1945). In southern Alberta, basal cover declined throughout the drought of the 1930's, with a similar amount of decrease in basal cover occurring whether the vegetation was grazed or protected (Clark et al. 1943). Several reports have been written about the effects of drought in the Central Great Plains, mostly in Nebraska and Kansas. By 1936, at the height of the drought, perennial grass basal cover had declined by 20% (Weaver, Robertson and Fowler 1940). By 1939, perennial grass cover had increased to twice what it had been in 1936. Annual grasses increased basal cover profusely (564% increase) immediately after 1936, but had decreased by 96% of this increase by 1939. Weaver and Albertson (1940) reported that basal cover was reduced by two thirds to one half of the original basal cover during drought. Weaver and Albertson (1939) also reported that the major dominant grasses suffered the most loss in basal cover and were also slow to recover. Meanwhile, other perennial grasses that weren't dominant prior to the drought, but had xeric qualities, increased and became dominant during the drought. The fact that these species had increased was evident by the age class structure being characterized by young, newly established plants. Annual grasses increased rapidly during drought, but were replaced rapidly following drought. In mixed grass prairie of the Central Great Plains, midgrasses were lost and the shortgrass blue grama (Bouteloua gracilis) dominated (Coupland 1958). Craddock and Forsling (1938) reported that total basal area decreased 19% from 1923 to 1932 due to drought in southern Idaho. Pechanec, Pickford and Stewart (1937) stated that basal cover of grasses decreased by 60% at the same site during drought.

Coupland (1958) reported that during long periods of above average moisture, which occurred during the 1940's and 1950's in Alberta and Saskatchewan, succession moved toward more mesic communities. This included increased total basal cover and a compositional shift toward midgrasses with proportionately less short grass cover. In southern Canada, total basal cover increased 23% during the previously mentioned period (Coupland 1958). In southeastern Montana, total basal cover increased 61% and composition shifted toward more midgrasses during a 13 year period of above average precipitation (Newbauer et al. 1980).

Response of Individual Species to Climate

Compositional changes due to fluctuating precipitation varied due to location in the Great Plains and type of grass cover (Coupland 1958). Western wheatgrass (Agropyron smithii) basal cover decreased drastically during extended severe drought in southeastern Montana, losing 87.9% of its cover from 1933 to 1937 (Hurtt 1951; Reed and Peterson 1961). In contrast, western wheatgrass increased to be the dominant species during the same period in North Dakota (Coupland 1958), Nebraska, and Kansas (Weaver and Albertson 1940; Weaver and Albertson 1939; Weaver and Albertson 1936). Recovery of western wheatgrass to the pre-drought level of basal cover was slow in southeast Montana (Reed and Peterson 1961). They reported that complete recovery from the 1930's drought had not yet been reached by 1945. Recovery of western wheatgrass was also slow in western North Dakota (Whitman et al. 1943), but it made rapid increases in basal cover following drought in central North Dakota (Sarvis 1941).

Most wheatgrasses (Agropyron spp.) generally increased basal cover during periods of above average precipitation throughout the Great Plains (Coupland 1958). Newbauer et al. (1980) reported similar results during a period of above average precipitation in southeast Montana.

Blue grama basal cover decreased more rapidly during drought in southeast Montana than did midgrasses (Coupland 1958). Blue grama is a warm season species, while most midgrasses are cool season species. Consequently, midgrasses probably had the advantage of using available moisture before blue grama initiated growth. Ellison and Woolfolk (1937) and Reed and Peterson (1961) reported high death losses of blue grama in southeast Montana as a result of drought. Hurtt (1951) reported that blue grama actually lost 95.5% of its basal cover between 1933 and 1937. In northern Montana, basal cover of blue grama decreased from 6.2 to 4.1% over a two year drought period (Ryerson unpublished). In central North Dakota, on range dominated by blue grama, basal cover of blue grama decreased little during drought and recovered quickly (Sarvis 1941). This response was attributed to an ability to respond to light rain showers, making it possible to use any available moisture. In the eastern part of the Central Great Plains, blue grama colonized bare areas that were previously occupied by taller species (Weaver and Albertson 1939; Albertson and Tomanek 1965). Further west in Kansas, where the effects of drought were more severe; even blue grama basal cover decreased (Weaver and Albertson 1940). Blue grama was slow to recover to pre-drought cover levels where it had suffered large losses (Reed and Peterson 1961; Whitman et al. 1943). Pre-drought basal cover of blue grama had not been reached by 1945 in southeast Montana (Reed and Peterson 1961). Newbauer et al. (1980) stated that blue grama appeared to be one of the most drought tolerant species when considering the entire Northern Great Plains.

Under above average precipitation, blue grama basal cover tended to decrease in southeast Montana and southern Canada (Newbauer et al. 1980; Coupland 1958). However, this response varied, depending on the range site being considered.

In southeast Montana, buffalograss (Buchloe dactyloides) lost as much basal cover during drought as blue grama. It was reduced by 95.9% of its cover from 1933 to 1937 (Hurtt 1951; Reed and Peterson 1961; Ellison and Woolfolk 1937). After the drought, buffalograss increased basal cover rapidly. It reached pre-drought amounts of cover by 1942, and achieved 50% greater cover than pre-drought amounts by 1945 (Reed and Peterson 1961). Studies in the Central Great Plains reported various responses of buffalograss to drought. Some studies reported that buffalograss decreased during drought (Coupland 1958; Weaver and Albertson 1940; Albertson and Tomanek 1965). These reports stated that buffalograss generally decreased more than blue grama. These authors also stated that buffalograss increased rapidly following drought. In contrast, Weaver and Albertson (1939) reported that buffalograss increased during drought.

Newbauer et al. (1980) classified threadleaf sedge as one of the most drought tolerant species throughout the Northern Great Plains.