Soil Moisture and Temperature Changes Following Sagebrush Control[1]

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Highlight

Soil moisture and temperature were measured for a five-year period on a mesic foothill grassland and on an arid cold desert shrub-type in western Wyoming. Herbage production increased on both the arid and mesic sites following the sagebrush and grazing control treatment with the greatest increase occurring on the mesic site. Average annual soil temperature was greatest at the arid site and was warmest in the shrub-dominated areas at both sites. Soil moisture recharge during the spring period was greatest at the mesic site under the non-use treatment but at the arid site grazing treatment did not significantly influence moisture accumulation. Under the shrub control treatment, soil moisture recharge was little influenced at the mesic site and at the arid site greatest soil moisture recharge occurred in the non-controlled shrub area. Soil moisture withdrawal was similar at both the arid and mesic sites in that the least amounts of moisture were taken from the soil under the grazed and non-controlled shrub treatments. Soil moisture accumulation during the spring period was greatest at the mesic site from 24 to 60 inches below the soil surface and the greatest values occurred in the shrub controlled grassland area. At the arid site high moisture levels occurred only down to the 12-inch depth.

Removal of undesirable woody species from native grassland, during the past decade, has become an accomplished fact with the development of selective herbicides. In the western United States large areas dominated by shrubs, principally big sagebrush (*Artemisia tridentata*) have been returned to climax composition by application of the hormonal herbicide 2,4-D (Kearl, 1965). Requisite criteria of time, amount, and method of application are well standardized.

The factors responsible for the vegetational change following sagebrush control, however, are not well understood. The present study was conducted to evaluate soil moisture, soil temperature, and herbage production changes following chemical control and non-grazing treatments of big sagebrush on two study sites, one a mesic grassland and the other an arid shrub type.

Study Areas and Methods

Fenced exclosures were constructed on the two sites in 1962. Big sagebrush was controlled in a portion of each exclosure as well as an adjacent grazing area. Crown cover of big sagebrush on the two areas was similar (approximately 15%) but individual bushes were much more robust on the mesic Granite Mountain site than on the arid Smilo site. Soil moisture was measured with a neutron moisture meter in access tubes set to a depth of 60 inches which were located in treatment sites of shrub control, no shrub control, grazing, and no grazing. Soil temperature was measured with thermister probes placed 1, 8, 15 and 22 inches below the soil surface. These were located only within the non-grazed exclosures but under both shrub control and no shrub control. Precipitation gauges were installed at each location. Basal cover and herbage production of understory vegetation were determined from transects of 20 plots which were read on the same date each year. Both sheep and cattle grazed the areas in spring and fall.

The Granite Mountain exclosure, in the mesic uplands of the Wind River Basin of central Wyoming, was situated at an elevation of 7,000 ft. Average annual precipitation is approximately 12 inches, with much occurring as snow in winter. Summer showers are common on these uplands east of the Wind River Mountain Range. The 8.9 inches average annual precipitation recorded for the 5 years of study is much below the long term average and probably reflects to some extent also, the fact that snowfall is not accurately measured in this type of precipitation gauge.

The Smilo exclosure was located in the Big Horn Basin of North Central Wyoming, a northern cold desert shrub area at an elevation of 4,500 ft, some 2,500 ft lower than the Granite Mountain exclosure. This area receives only about 7.5 inches of precipitation annually. Little snow occurs and summer rains are infrequent, but usually of high intensity. Almost 50% of annual precipitation occurs as rain during the spring from April 15 to June 30. Summer temperatures are much higher at the arid Smilo exclosure than at the Granite Mountain. The effective growing season is severely limited by high temperatures and aridity at the former.

Soils at the Granite Mountain site are classified as Encampment Loam, a deep, strongly developed soil with good drainage which is usually found on old terraces and fans. The Smilo exclosure is characterized by the Dry Creek Fine Sandy Loam soil. This is a deep soil also, but with low permeability and poor development, reflecting the arid climate of the Big Horn Basin.

Results

Herbage production response was phenomenal during the 5 years from 1962, when the shrub control and grazing treatments were initiated, through 1966. On the mesic Granite Mountain Exclosure *Agropyron smithii, Poa fendleriana,* and *P. secunda* were the dominant understory species. *A. smithii* exhibited a great increase in production under sagebrush control (Fig. 1). A minor increase was associated with cessation of grazing and no shrub control. Production in the grazed-native sites tended to decrease.

The major grasses on the Smilo Exclosure were *A. smithii* and *P. secunda.* Response of *A. smithii* to treatments was proportionally similar at both locations but was much less spectacular under the arid conditions at the Smilo site. The extremely

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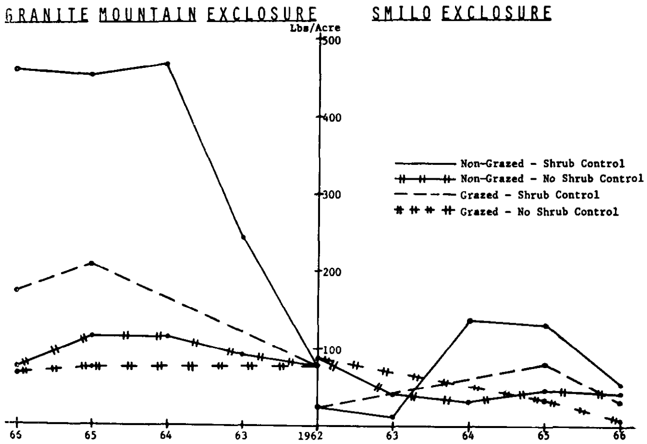

FIG. 1. Herbage production of western wheatgrass as influenced by the sagebrush and grazing control treatments.

arid 1966 moisture conditions were reflected by a sharp production decrease. Greatest production occurred under the shrub control and non-use treatments.

Soil temperature data, combining all depths and seasons of measurement, show a distinct difference due to location, with an annual average temperature of approximately 11 C at the mesic Granite Mountain site and 15 C at the arid Smilo site (Fig. 2). Soil temperatures during the spring increased most rapidly at Smilo and remained high through the summer and well into late fall. Temperature changes at the mesic site were characterized by a relatively slow increase during spring, followed by a rapid decrease in late summer and early fall.

Soil temperature differences due to sagebrush control appear insignificant at all depths, but have followed a consistent pattern at each of the two study sites during the past 5 years (Fig. 3). Under sagebrush (no shrub control), temperatures were almost 1 C warmer than in the shrub control areas. This relationship was reversed at the Granite Mountain site during the *winter* and *summer* periods but at the Smilo site, however, the only apparent reversal occurred during the *early summer* period (Fig. 2).

A greater variation between surface temperatures and subsoil temperatures was exhibited at Granite Mountain than at Smilo (Fig. 3). In the spring, subsurface temperatures at Smilo rose more rapidly than at Granite Mountain. During fall and winter, subsurface temperatures at Smilo fell more slowly and did not become as cold as those at Granite Mountain.

Greatest differences in subsurface temperatures resulting from sagebrush control were noted at the 15-inch depth where soils at both sites tended to be much warmer in the native shrub dominated areas than in those subjected to sagebrush control.

At the 8-inch depth, temperatures were greater under the shrub control treatment at Granite Mountain and almost equal at Smilo. These variations from the normal pattern of higher temperatures under sagebrush must necessarily be associated with grassland moisture-utilization capabilities, associated with changes in soil moisture as influenced by site pecularities.

The influence of the grazing and shrub control treatments upon soil moisture levels presents important variations at the two study sites. The soil moisture recharge data are based on amounts of water in the soil and reflect water accumulation during the spring recharge period, as well as the water lost from the soil by evapo-transpiration

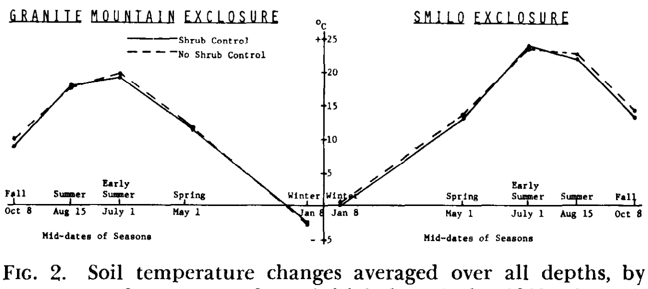

FIG. 2. Soil temperature changes averaged over all depths, by season and treatment from initial data (July, 1963) through December, 1966.

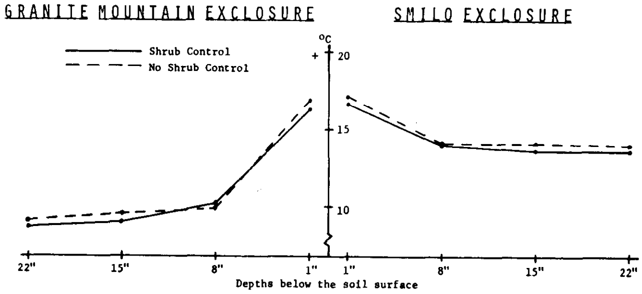

FIG. 3. Soil temperature by depths and treatment from initial data (July, 1963) through December, 1966.

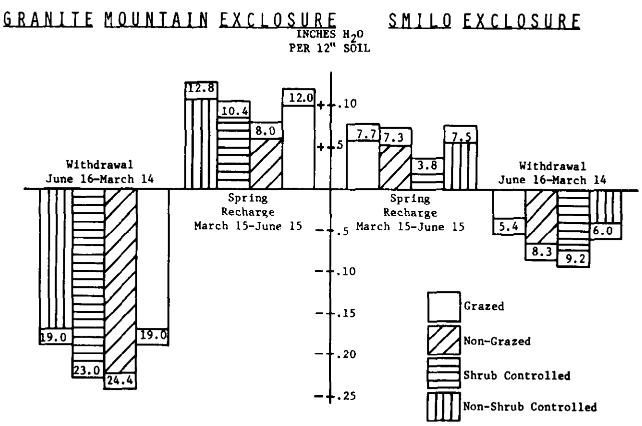

FIG. 4. Soil moisture change over all depths by treatment, from initial data (July, 1963) through December, 1966.

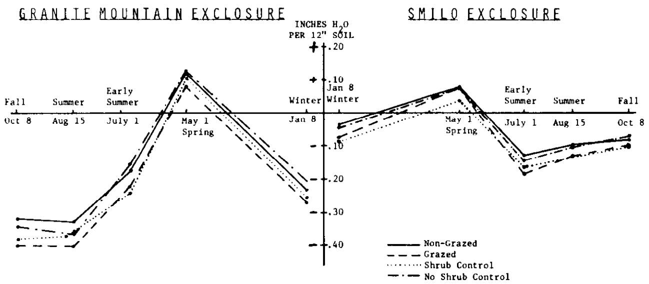

FIG. 5. Soil moisture change averaged over all depths by seasons and treatments from initial data (July, 1963) through December, 1966.

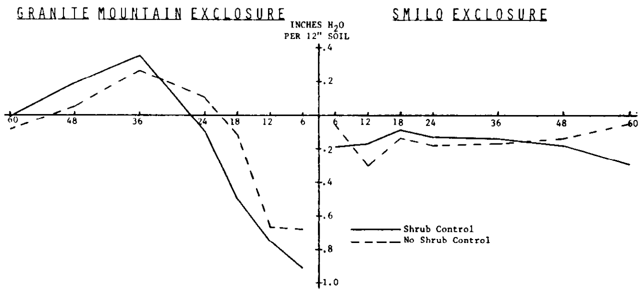

FIG. 7. Early summer moisture change by depths from initial data (July, 1963) through December, 1966.

during the recharge period (Fig. 4). At Granite Mountain, recharge under non-grazing was much less than in the grazed area. At Smilo a very insignificant variation occurred as a result of the grazing treatment.

Under the shrub control treatment at Smilo much *less* moisture was stored in the soil than in the *non*-sprayed sagebrush area. A similar pattern occurred at Granite Mountain but the variation was minor. These soil moisture recharge data certainly show the varying influence of differences in soil permeability and moisture loss due to plant use under the two study treatments.

Withdrawal of soil moisture was similar at the two study sites. Less moisture was taken from the soil under the grazed and non-sprayed treatments than in the areas which were non-grazed and shrub controlled.

Seasonal moisture levels, (Fig. 5) combining all depths and years, portray greater rates and amounts of soil moisture withdrawal and recharge variation at the mesic Granite Mountain site as compared to the arid Smilo site. Differences between treatments again appear insignificant.

During the spring period from mid-March to mid-June, soil moisture levels by depth, given in inches in depth below the soil surface, show the influence of high soil permeability at Granite Mountain (Fig. 6). Under *shrub control* high moisture content occurred below 24 inches in the zone from which sagebrush normally utilized great amounts of water. Low moisture levels occurred above 24 inches in the grass root zone. At Smilo the very low moisture under shrub control below the 12-inch depth apparently resulted from utilization of most of the available moisture at the upper level by grasses. The very high moisture content of the surface to 6-inch depth reflects again the relative impermeability of soils at this site.

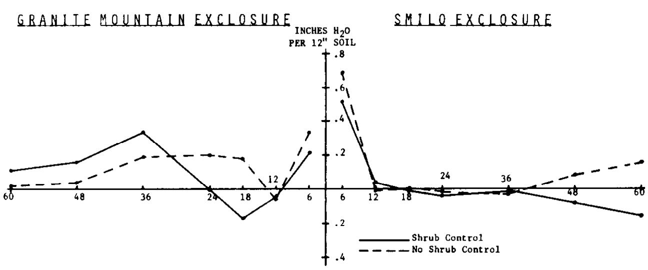

FIG. 6. Spring moisture change by depths from initial data (July, 1963) through December, 1966

By early summer (Fig. 7) the pattern of soil moisture changes to a configuration which is similar through the summer, fall, and winter seasons. These data exemplify the influence of differing climates and soils on moisture relationships and the strong interaction at both locations, with time and treatments.

At Granite Mountain, grasses utilized almost all available moisture in the upper two ft of soil, but that which was not utilized moved downward to accumulate in the 36 to 60-inch zone from which sagebrush depends for its major water supply.

At Smilo, water losses due to runoff, even on level areas, combine with low infiltration to explain some of the contradictory findings of other workers. At the 6-inch level under shrub control, we see the same pattern as that exhibited through the 24-inch depth at Granite Mountain, and a similar pattern from 12 through 36 inches at Smilo, as compared to the 24 through 60 inches depth at Granite Mountain.

Discussion

Non-grazing and sagebrush control treatments result in similar vegetative responses. Greatest response to cessation of livestock utilization occurs on rangeland in poor condition relative to climax composition. Response to sagebrush control is analagous except on sites where condition has deteriorated to such an extent that insufficient native vegetation remains for reestablishment of formerly abundant species. In actuality this condition may occur, as well, in situations of continued intensive grazing pressure.

In association with the herbage production data (Fig. 1), basal area of understory species following the shrub control treatment increased more than two-fold during the 5 years of study. During the first 2 years, greatest increase was exhibited by *Poa secunda*, a short-leaved, early-maturing species. Basal area of *Agropyron smithii* increased more slowly as did other decreaser species which provide much more ground cover and production per unit of basal area than *P. secunda*. Thus the decreased soil temperature associated with sagebrush control must be related to light and heat interception by herbaceous vegetation. This concept has been examined by Geigey (1957) but few would extrapolate his work to the rather sparse and diminutive vegetation of the northern cold deserts.

Robertson's 1947 work in Nevada indicated that soil moisture increased under sagebrush control but Hutchinson (1956) found the opposite. Both men were probably correct in conceptual application to the sites on which their work was conducted. The present study shows two kinds of conditions. On the mesic study site at the Granite Mountain exclosure, soil moisture levels were much lower under sagebrush control and non-use than in the sagebrush and grazed areas, but little variation was noted on the arid study site at the Smilo exclosure.

At the Smilo exclosure, the more arid climate, associated with impermeable soils, resulted in greater restriction to vegetative potential, although species composition was similar to that at Granite Mountain. Increased herbage production and basal area innately require greater amounts of water, and sagebrush removal liberates soil moisture; but the key to the problem can be found in the Oklahoma work of Prill (1965) in which he found grasses able to utilize more of the soil moisture than sagebrush. It is generally recognized that sagebrush is a wasteful and rapid user of available moisture but grasses are apparently able to withdraw more from the soil, over a longer period of time, than the shrubs.

Soil moisture differences between the two study areas are thus a result of climatic variation, soil differences, and variation in rate of vegetative rehabilitation. At the mesic grassland site understory vegetation was able to increase sufficiently following sagebrush removal to utilize more of the soil moisture than pre-existing vegetation. At the arid cold desert shrub site, rigid climatic characteristics did not allow sufficient revegetation for effective utilization of the released soil moisture following sagebrush control.

Conclusions

Herbage production increased on both the arid and mesic sites following sagebrush and grazing control. The greatest increase occurred on the mesic site.

Average annual soil temperature combined for all depths was 11 C at the mesic site and 15 C at the arid site. Soil temperatures increased rapidly in the spring at the arid site and remained high through the summer. At the mesic site they increased more slowly in the spring and decreased earlier and more rapidly in the fall than at the arid site.

Average annual soil temperatures at both sites, combined for all depths, were almost 1 C warmer in the shrub-dominated areas than in the non-shrub grassland areas. On a seasonal basis this relationship was reversed on the mesic site during the winter and summer periods, but on the arid site the only reversal occurred during the early summer period.

The greatest differences in subsurface temperatures occurred at the 15-inch depth where temperatures were much warmer in the native shrub dominated areas than those subjected to sagebrush control. At the 8-inch depth however, temperatures were greater under the shrub control treatment at the mesic site and almost equal at the arid site.

Soil moisture recharge during the spring period at the mesic site was much greater under the non-use treatment than in the grazed area. At the arid site an insignificant variation occurred as a result of the grazing treatment. At the mesic site little variation in soil moisture recharge resulted from the shrub control treatment. At the arid site, however, soil moisture recharge was much less in the shrub controlled grassland area than in the non-controlled shrub area.

Soil moisture withdrawal was similar at both the arid and mesic sites. Less moisture was taken from the soil under the grazed treatment and the non-controlled shrub treatment than in the areas which were non-grazed and shrub controlled.

Variation of seasonal moisture levels combined for all depths and years showed a much greater variation at the mesic site than at the arid site. During the spring period from mid-March to mid-June soil moisture levels by depth were greatest from 24 to 60 inches below the soil surface at the mesic site. Greatest values occurred in the shrub-controlled grassland area. Low moisture levels occurred above 24 inches in the grass root zone. At the arid site, high moisture levels during the spring occurred only down to the 12-inch depth. At greater depths, moisture was low, apparently resulting from utilization of most of the available moisture at the upper levels by grasses.

At the mesic site, grasses utilized almost all available moisture in the upper two feet of soil but that which was not utilized moved downward to accumulate in the 36 to 60-inch zone from which sagebrush depends for its major water supply. At the arid site the same pattern was exhibited through the 6-inch level as that exhibited through the 24-inch depth at the mesic site and a similar pattern at the arid site from the 12 through 36-inch depth as that at the 24 through 60-inch depth at the mesic site.

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