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GREEN FESCUE GRASSLANDS:

50 YEARS OF SECONDARY SUCCESSION UNDER SHEEP GRAZING

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REFERENCE ABSTRACT

The 50-year succession of a depleted green fescue (*Festuca viridula*) subalpine grassland in the Wallowa Mountains of northeastern Oregon was greatly influenced by historic soil erosion. The ecologic status[2] of the grassland, grazed by domestic sheep prior to 1938, improved greatly between that time and 1988, with most of the improvement occurring between the 30th and 40th years of observation. Photography was retaken from fixed camera points to illustrate the changes.

Keywords: Grassland management, succession, *Festuca*, grazing, range, subalpine grasslands.

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[2]Ecological Status is the present state of vegetation and soil protection on an ecological site as related to the potential natural community for the site (SRM Glossary of Terms Used in Range Management, 1989.)

RESEARCH SUMMARY

A green fescue (*Festuca viridula* Vas.) subalpine grassland in northeastern Oregon, heavily grazed by sheep for 50 years, was in poor range condition when first studied in 1938. At that time, accelerated erosion was evident and much topsoil (6-10 inches) had been lost. Green fescue had been replaced by needlegrasses (*Stipa* spp.), sedges (*Carex* spp.), and various forbs where erosion had removed all topsoil. On less eroded sites, some topsoil remained in pedestals of sod held together and in place by masses of dead fescue roots. A few pedestals supported small, weakened fescue plants. Others supported needlegrass, sedges, and deep-rooted forbs such as Nuttall's linanthastrum (*Linanthastrum nuttallii* Ewan) and fleeceflower (*Polygonum phytolaccaefolium* Meisn). A large percentage of pedestals, and the eroded surface between them, had no plant growth at all. Photographs illustrate the conditions.

Improvement of both land and sheep management practices after 1938 initiated secondary succession that was observed and photographed again in 1956, 1968, 1978, and 1988. As illustrated by these photographs, there was no evidence of continued accelerating erosion in these years.

After 18 years (1956), green fescue had reestablished where topsoil remained and vegetation vigor, density, cover, and production had greatly increased. This was particularly true for the needlegrass, sedges, and Nuttall's linanthastrum. However, past erosion had strongly regulated the degree of recovery on individual sites, as evidenced by the fact that needlegrass was still conspicuous on eroded surfaces.

After 30 years (1968), vegetation density and overall ground cover had increased. This was most notable in the density of several grasses and sedges on the eroded surfaces. The cover and density components of some forbs had declined. Needlegrass was still the dominant grass, although the density of green fescue had continued to increase on the deepest soils.

After 40 years (1978), green fescue had become the dominant grass. The density of needlegrass, sedges, and most forbs had decreased on the less eroded soils, and green fescue was as prominent as other species on most eroded surfaces.

After 50 years (1988), green fescue continued to be the dominant grass, but in many areas, slender wheatgrass (*Agropyron caninum* Vas.) and timber oatgrass (*Danthonia intermedia* Vas.) had become established on the eroded areas between fescue plants. Forbs were still prominent in many areas where they dominated in 1938.

It was concluded that the vegetation present on many sites in 1988 would prevail in the future due to the amount and intensity of past erosion. However, it was also concluded that where sufficient topsoil remains, the density of green fescue should continue to increase under good management practices. Thus, a continuing upward successional trend is expected unless climatic and/or management activities change.

Elbert Reid was 76 years old in 1988 when he returned to Tenderfoot Basin to revisit and rephotograph his 50-year old plots and photo points. Wade Hall was the Wallowa-Whitman National Forests' Range and Wildlife Staff Officer during two of Reid's revisits to Tenderfoot Basin (1956 and 1968). Wade continued to facilitate Reid's 10-year anniversary revisitations and to accompany him when both were in retirement in 1978 and 1988. At the time of the 1988 revisitation, Wade Hall was 80 years young!

The thorough documentation both have provided enable us to understand the changes which have transpired on rangelands where their investigations were performed. We are the benefactors of a network of monitoring opportunities established through their dedication and commitment to learning the long-term effects of range management practices on the natural vegetation. Their mission to revisit this important place over a 50-year span of time, and to document findings, is truly commendable. Their continuation of this work beyond retirement from Federal service is a testament to their professionalism and sets an example for those of us who follow.

Charles Grier Johnson, Jr.

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INTRODUCTION

A green fescue (*Festuca viridula* Vas.)[3] subalpine grassland in the Wallowa Mountains of northeast Oregon was studied intensively in 1938 (Pickford and Reid 1942). The area had been heavily grazed by sheep for 50 years and was in poor condition. Photographs recorded the deteriorated vegetation and the accelerated soil erosion which was evident in the study plots.

This paper summarizes the changes in vegetation and soil erosion rates that occurred on the site after improved management practices were adopted. These changes comprise 50 years of secondary succession on the grassland and are illustrated by photographs taken at intervals of 18, 30, 40, and 50 years. Changes which occurred in the study area up until 1956 were reported by Strickler (1961); changes which occurred up until 1978 were reported by Reid, Strickler, and Hall (1980). Much of the description of the extant conditions up until 1978 was taken for the Reid, Strickler, and Hall report. The following detailed report of the changes from 1978 to 1988 (and summary of the overall 50 year period) updates these previous observations.

THE STUDY AREA

The 690-acre study area comprises south-facing slopes with elevations between 7,200 and 8,500 feet. The project is located in Tenderfoot Basin near the headwaters of the North Fork of the Imnaha River. The vegetation is typical of much of the subalpine fir zone -- large expanses of grassland interspersed with subalpine fir (*Abies lasiocarpa* (Hook) Nutt.) and whitebark pine (*Pinus albicaulis* Engelm.) trees (Figure 1).

The underlying rock is primarily limestone and basalt, interbedded with some shale and slate (Baldwin 1964, Smith and Allen 1941). The soils are strongly influenced by loess (wind-blown sediment) and vary in depth and texture. On ridgetops and around outcrops, the soils are shallow and very stony. On slopes and in drainage basins, they are two to three feet or more in depth, silty to loamy in texture, and generally weakly structured. They are easily eroded by water and wind without a protective cover of vegetation.

Annual precipitation is between 40 and 50 inches; most occurs as fall rain and winter snow. Snowmelt is usually complete on south-facing slopes by July 1. Summer storms account for 10 to 20 percent of the annual precipitation. Growth of vegetation is rapid, peaking near mid-August, with seed dissemination by green fescue occurring about September 1 (Sampson 1914).

[3]Plant nomenclature follows Hitchcock and Cronquist (1973)

FIGURE 1

1938 - Sheep bunched on one of the main bedgrounds. Such concentrations of sheep hastened depletion of vegetation and erosion of soil through heavy forage utilization and intense trampling. The vegetation was in poor condition, and there were many barren areas. Letterman's needlegrass (*Stipa lettermanii* Vas.) was the dominant plant on the slope in the foreground.

1988 - Fifty years later, after the study area had been managed under prescriptions of reduced and deferred grazing. The area is still used as a bedground. Over the 50 years the condition of the area has improved, but further improvement is possible. Many bare areas have filled in with grass (fescue and needlegrass) and sedge. Green fescue is the dominant plant on the slope in the foreground, and grasses and sedges are spreading downhill into the bare areas.

PROCEDURES

In 1938, soil erosion classes and estimates of plant species cover and composition were determined from plots gridding the study area at 3 ½ chain intervals by using the square-foot density method (Stewart and Hutchings 1936). Photographs were taken on selected sites to illustrate data obtained on the plots. These methods were repeated between 1956 and 1960, thus allowing both quantitative and qualitative discussions of 18-year successional trends (Strickler 1961).

Photographs were taken from the camera points again in 1968, 1978, and 1988, and changes in plant composition and soil erosion were noted. Resampling the plots in 1968, 1978, and 1988 would have provided continuity of the quantitative aspects of the study, but time was not available for this work. Therefore, the 1968 objectives (repeated in 1978 and 1988) were to: (1) Rephotograph the sites which were reestablished in 1956, 1957, and 1960; (2) estimate, by the square-foot density method, species cover and composition illustrated in the photographs; and (3) make onsite qualitative comparisons of soil and vegetation characteristics with those in the previous photographs and descriptive records. Reid created the original 1938 study and assisted in photographing the sites in 1956, 1968, 1978, and 1988. Hall assisted in the 1956, 1968, 1978, and 1988 revisits of the study area. They were assisted by two plant ecologists: Gerald S. Strickler in 1968 and 1978, and Charles Johnson in 1988. Therefore, reasonable qualitative assessment of the area has been maintained through a cyclic visitation process.

Unfortunately, sheep had grazed the study area two days before the 1968 photographs were taken, leaving only a few sites ungrazed. In addition, heavy snows on the first day of study in both 1968 and 1978 compressed vegetative growth to the surface. In 1968, these conditions prevented cover estimates on most sites and allowed only poor comparisons of vegetation and soil characteristics with earlier or later photographs; only four of the 1968 photographs were used. However, most sites were snow free when the photographs were taken in 1978 and 1988, so normal vegetation growth is shown in these photographs. Where grazing (1968) prevented reliable estimates of cover, relative abundance of species in the photographed area were used to assess the divergence from similar qualitative descriptions recorded in 1956,

The area was ungrazed when the 1988 photographs were taken. However, green fescue flower heads were sparse (except in moist areas along streams) and growth averaged three to five inches; about half its normal stature. This stature was attributed to drought.

A 5 X 7 (negative size in inches) camera was used in the 1938 photography, whereas a 4 X 5 camera was used in subsequent years. Enlarging 4 X 5 negatives to match the original field of review resulted in slight differences in the area covered. Wet soils in the 1968 and 1978 photographs have tones that are similar to the vegetation, making it difficult to compare the extent of barren soil with that in earlier photographs. Therefore, we determined the extent of the bare soils from color positive images taken at the same time as the black and white photographs. Figures 1-12 illustrate the variations in trend. All photographs and records were made in August when the grasses had matured.

USE BY SHEEP BEFORE 1938

The openness and productivity of green fescue grasslands make them prime summer range for domestic sheep (*Ovis aries*). In the Wallowa Mountains, sheep began grazing the grasslands in the early 1880's and their populations rapidly increased thereafter (Wentworth 1948).

Early use of the study area is not well documented, but some records indicate Tenderfoot Basin was badly overgrazed and deteriorated by 1900. For example, a July 15, 1903 photograph taken in the adjacent Aneroid Basin shows a wide expanse of green fescue grassland with no visible herbage growth. The photographer noted: "Grass almost destroyed by early grazing. Snow hardly gone, but sheep have run over hills through mud."[4]

In 1938, the 2,256 acres of the upper Tenderfoot Basin Allotment had an estimated grazing capacity of 0.44 sheep month (SM) per acre (Pickford and Reid 1942). This estimate closely approximated the actual use of the study area in 1938 when sheep removed 44 percent of the green fescue herbage, which was slightly below the 50 percent considered proper use at the time. This grazing capacity, however, was apparently a great reduction from the historic productivity. In 1916, 4,800 head of sheep were reported to have grazed the allotment -- including the study area -- for three months. This represented a stocking equal to 6.4 SM/acre, about 15 times more capacity than the area could support in 1938.

At the inception of the study, the reduction in capacity was also compared with that of an adjacent, uneroded, lightly grazed late seral green fescue grassland in Lick Creek Basin near Nebo Lookout. Its estimated capacity was 5.35 SM/acre or 12 times more than the deteriorated range in Tenderfoot Basin (Pickford and Reid 1942).

USE BY SHEEP - 1938 TO 1988

Use of the allotment and study areas from 1938 to 1945 by sheep was the same as in 1938 (0.44 SM/acre). No sheep grazed the area between 1945 and 1948. Grazing was reduced in 1949, and was usually deferred until late August or early September in the study area. Except for the years 1953 and 1972, when there was no use at all, the upper Tenderfoot Basin averaged 0.17 SM/acre from 1949 through 1978. These records indicate use of the study area by sheep for the 30-year period was 60 percent less than the 1938 estimated capacity, and only 3 percent of the capacity of a late seral vegetation community.

During the decade 1979 to 1988, grazing use was more irregular, although it continued to be restricted to late August and early September. No records of the number of sheep grazed or length of grazing are available for 1979, 1980, 1981, 1984, or 1985. The area remained ungrazed during 1983, 1986, and 1988. Stocking was 1.32 SM/acre in 1982 and 0.87 SM/acre in 1987. Utilization of green fescue (in years of use) varied from 5% to 38% with the use being a little heavier on bedgrounds. So, with the possible exception of 1982, grazing was not heavy during the 1980's.

[4]Photograph files, Range and Wildlife Habitat Laboratory, Pacific Northwest Forest and Range Experiment Station, La Grande Oregon.

SOIL AND VEGETATION IN 1938

Measurements taken in 1938 showed that large amounts of topsoil had been lost through erosion and that the remaining vegetation was in poor condition (Pickford and Reid 1942). The degree of soil erosion varied by site, depending on soil depth, slope, amount of trailing by the sheep, type of grazing, and proximity to the bedgrounds. In turn, the degree of erosion at each site influenced the type of vegetation present.

One site was considered to be in late seral condition (Figure 2). Green fescue accounted for 80 to 90 percent of the vegetation there and erosion was minimal. The root mass was concentrated in a dense sod, 6 to 10 inches in depth.

Severe erosion had cut the fescue sod in other sites, leaving only remnant soil pedestals or miniature mass-like hummocks. Much of the fescue was dead, but the sod remnants were held firmly in place by the persistent dead root masses (Figure 3). Open stands of Letterman's needlegrass (*Stipa lettermanii* Vas.), a minor secondary species in climax vegetation, were conspicuous under these erosive conditions (Figure 4).

FIGURE 2

1938 -- A subalpine grassland community in good condition (late seral stage). Vigorous green fescue was the dominant species; only occasionally were other grasses and forbs present.

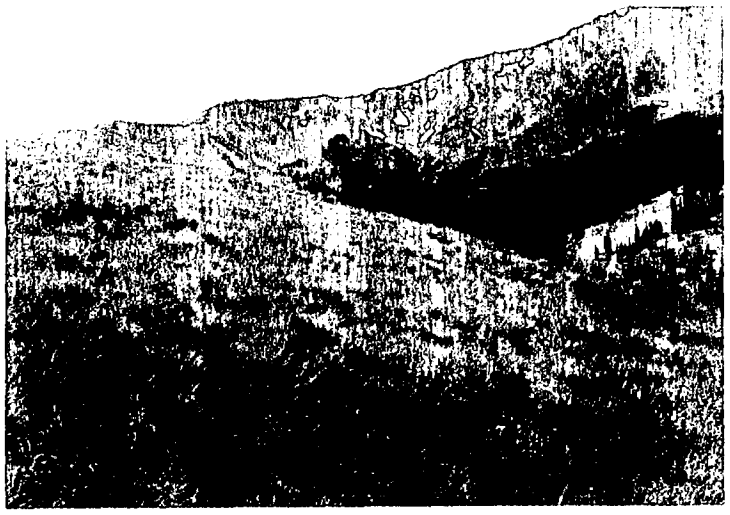
1944 -- Condition of the community had deteriorated because of its heavy use as a sheep bedground for two consecutive seasons. The density and cover of green fescue had decreased and those of needlegrass, common yarrow, and fleabane had increased since 1938. Accelerated soil erosion, however, had not occurred.

FIGURE 2 (Continued)

1956 -- Green fescue constituted 58 percent, fleabane 22 percent, needlegrass and yarrow 6 percent each, and sedge 3 percent of the plant composition. The plant cover was much improved over that of 1944.

1968 -- Vegetation cover and composition appeared much as it did in 1938, having recovered from the deteriorated condition of 1944.

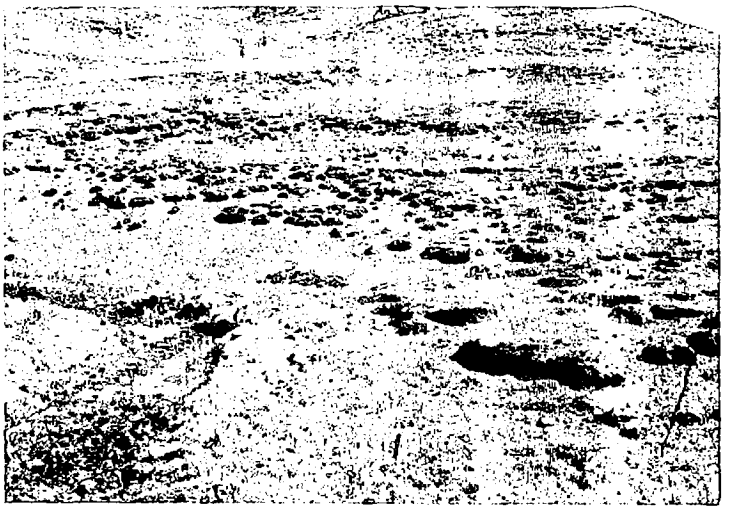
FIGURE 2 (Continued)



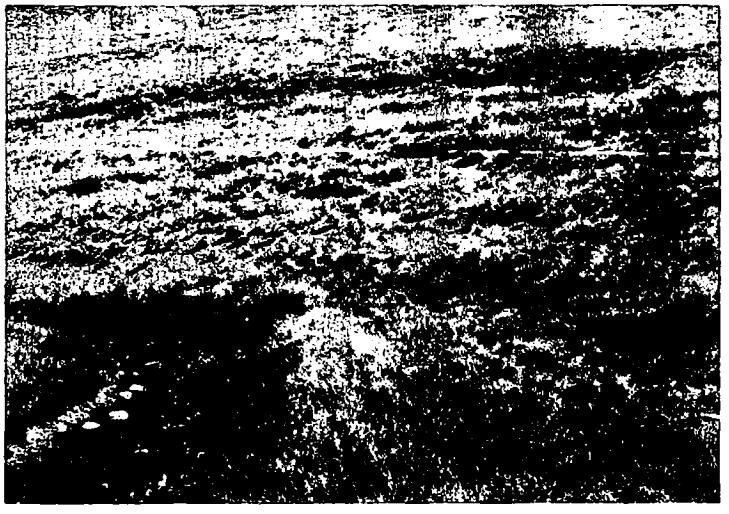
1978 -- Green fescue constituted 90 percent of the vegetation cover. Secondary species comprised yarrow, ovalhead sedge, penstemon, and needlegrass. Vegetation was again in good condition, approximating the climax community.

1988 -- After 50 years, the general appearance was much the same as it was in 1938. However, probably due to the recent drought, the green fescue composed only 45% of the cover (estimated at 75%) and forbs and sedges had greatly increased (largely yarrow and aster). Bare soil was exposed between the grass clumps.

FIGURE 3



1938 -- An eroded slope near permanent water where much of the original topsoil was lost. Dead roots of green fescue held 80 percent of the foreground pedestals in place; live fescue and needlegrass occupied the remaining pedestals. Needlegrass was the dominant plant on the eroded surface between pedestals. Sedges occurred along the stream.



1956 -- Cover had greatly increased; most was needlegrass that had increased on the eroded surface; although with some thickening of the plants on the pedestals. Density and cover of green fescue had also increased. Note that most of the soil pedestals were still in place.

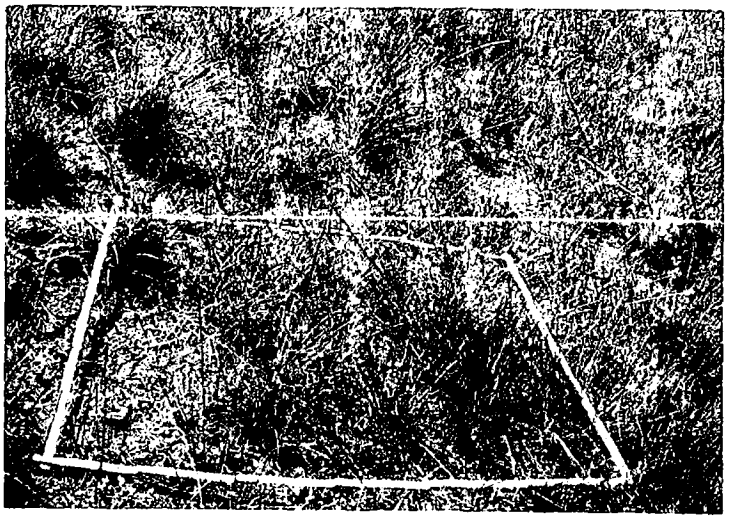
FIGURE 3 (Continued)

1978 -- Vegetation cover on the slope continued to increase, both on and between the pedestals. A majority of the cover was green fescue, needlegrass, and sedges, with minor amounts of other grasses and forbs. Soil pedestals were still present, but the slope had lost some of its stairstep appearance. Green fescue had largely replaced the needlegrass as the dominant species and most of this replacement took place between 1968 and 1978. Sedges and penstemon were the main species along the stream.

1988 -- Vegetation after 50 years was much the same as it was in 1978, with green fescue dominant on the drier sites and occupying the plant stools. Sedges and penstemon still dominated along the stream. The bare area is caused by traffic on the Tenderfoot Trail where it fords the stream. After 50 years, the site was well vegetated with late seral species dominating as the main components.

FIGURE 4

1938 -- A closeup of the condition on the slope shown in Figure 3: The masses of dead green fescue roots hold the topsoil in place; remnant fescue plants of low vigor are widely scattered.



1956 -- 18 years later, there had been a major increase in needlegrass, making it the dominant species. Green fescue plants had increased greatly in vigor, but little in density. Litter had increased, and the soil pedestals, though still present, were not as prominent as they were in 1938.

FIGURE 4 (Continued)

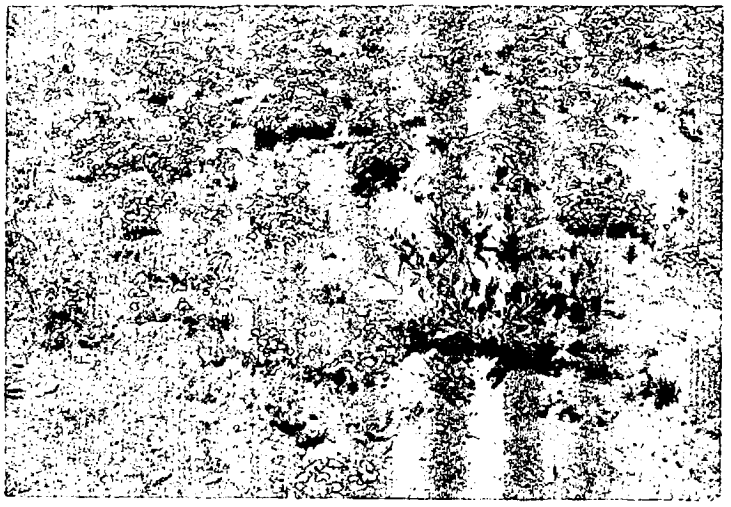
1988 -- The soil pedestals were still present, but were well vegetated -- primarily with green fescue, the species considered to represent the climax situation. Needlegrass, sedge, and penstemon were secondary species. Vegetative cover was estimated at 80 percent, consisting of 60 percent grass, 38 percent sedge, and 2 percent forbs. The downhill sides of the pedestals were again steep, as opposed to their condition in earlier years when they were less steep and smoother.

The sod had been cut on the slopes where sheep trailing had been intensive, giving them a stairstep appearance. Although a few pedestals supported low-vigor fescue, most had been invaded by needlegrasses, sedges, and perennial forbs, such as Nuttall's linanthastrum, cinquefoils (*Potentilla* spp.), western groundsel (*Senecio integerrimus* Nutt.), common yarrow (*Achillea lanulosa* [Nutt.] Piper), and Rydberg's penstemon (*Penstemon rydbergii* A. Nels.). Perennial forbs dominated in some areas (Figures 5 and 6) and needlegrass in others (Figure 7).

Erosion had progressed farther near bedgrounds and on intensively trailed areas. In such places, only a few sod pedestals were occupied by forbs or needlegrass. Fescue usually capped the pedestals where grazing had not been heavy, and the eroded surfaces were either barren or occupied by needlegrasses.

Perennial forbs commonly occupied areas where all topsoil had been eroded away. Where the remaining soil was deep or moist, the sites were usually occupied by penstemon, groundsel, fleabane (*Erigeron* sp.), and Nuttall's linanthastrum in combination with needlegrasses and sedges (principally ovalhead sedge (*Carex macloviana* Cham.) (Figure 8). Buckwheats, particularly Wyeth's buckwheat (*Eriogonum heracleoides* Nutt.) and golden buckwheat (*Eriogonum flavum* Nutt.), were the dominant forbs on drier sites, especially those with shallow soils (Figure 9).

FIGURE 5



1938 -- A slope where grass sod was severely cut by sheep trailing. Ninety percent of the green fescue root masses contained within 7-inch topsoil pedestals were dead. The pedestals were becoming occupied by secondary species, primarily by Nuttall's linanthastrum, sedges, and needlegrasses. Groundsmoke (*Gayophytum* spp.) and fleeceflower were becoming established between the pedestals.

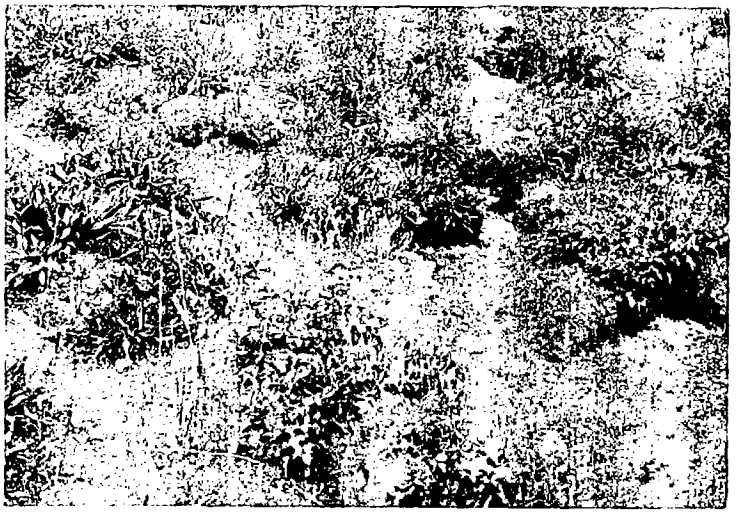
1956 -- Green fescue cover had increased from 0.5 percent to 13 percent. Nuttall's linanthastrum cover had almost doubled (7 to 12 percent), but the needlegrass and sedge cover showed only a slight increase. The pedestalled root masses had become somewhat rounded, but the eroded surface configuration remained about the same.

FIGURE 5 (Continued)

1978 -- Density of green fescue had increased greatly and constituted half the vegetation cover. Linanthastrum made up about 25 percent of the cover and Rydberg's penstemon constituted 10 percent. Common yarrow and buckwheats had also increased, but needlegrasses and sedges had greatly decreased. Note the fleeceflower plant in the 1938 photograph was still present 40 years later.

1988 -- The vegetation and soil conditions were much the same as in 1978, except that the vegetation was very dry due to a period of exceptionally dry years. Green fescue was short and dry, yet prominent in the vegetation. The linanthastrum, which had been the prominent forb since 1938, had flowered and the flowers had dried. Rydberg's penstemon appeared to have increased in abundance since 1978. The fleeceflower plant in the lower right of the photographs was still present after 50 years, but was of low stature.

FIGURE 6



1938 -- A moist slope, with topsoil held in place by dead fescue root masses, was occupied by Rydberg's penstemon, sticky cinquefoil (*Potentilla glandulosa* Lindl.), Wyeth's buckwheat and stickseed (*Hackelia* sp.). A few plants of needlegrass and fleeceflower were present on the eroded soil between pedestals.

1956 -- The perennial forbs were still predominant, but green fescue and needlegrass had greatly increased. Sedges were encroaching on the pedestals. Penstemon made up 33 percent of the cover, needlegrass 15 percent, and green fescue 38 percent. Bare soils between pedestals were still conspicuous.

FIGURE 6 (Continued)

1978 -- By 1968 (no photograph), grasses had increased and most perennial forbs had decreased. Many individual forb plants identified in 1938 were still present, and the density of fleeceflower had greatly increased. In 1978, green fescue had largely replaced needlegrass as the dominant plant. Fleeceflower had become the most abundant forb, gland cinquefoil was common, and other forbs were still present. Pedestals, though rounded off, could still be identified. The plants growing on them had moved or were moving onto the spaces between pedestals.

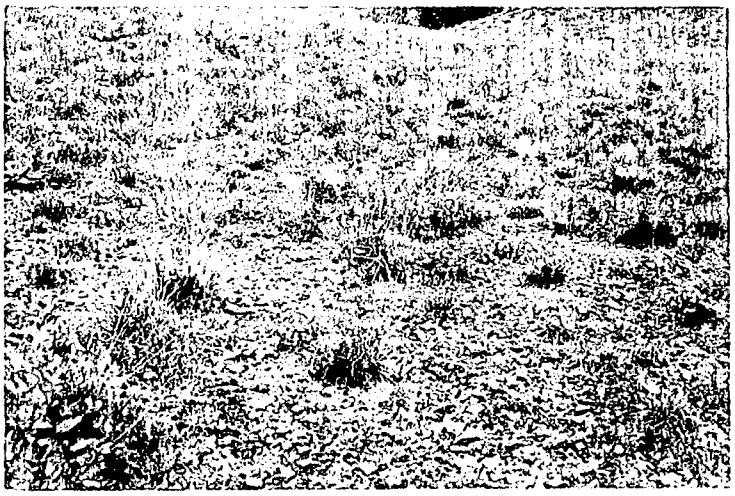
1988 -- The vegetation and soil conditions were similar to those in 1978 -- with vegetation consisting of 65% grasses and 35% forbs. Green fescue was the dominant grass and also the dominant species. Some sedges and slender wheatgrass (*Agropyron caninum*) were present, though the wheatgrass had not been recognized on the area previously. Forbs, in order of abundance, were: Fleeceflower, lupines (*Lupinus* spp.), sticky cinquefoil, and yarrow. The condition of the pedestals appeared to be similar to that observed in 1938.

FIGURE 7

1938 -- Years of trailing on this site had resulted in the erosion of most of the topsoil and the elimination of green fescue. A few remnant soil pedestals (on the right and upper left) indicate the severity of the erosion. Needlegrass and a single fleeceflower plant had become established on the erosion pavement, and few plants of Nuttall's linanthastrum were established on pedestals.

1956 -- Green fescue, spike trisetum (*Trisetum spicatum* (L.) Richt.), and additional fleeceflower plants had become established. Needlegrass was still the principal species.

FIGURE 7 (Continued)

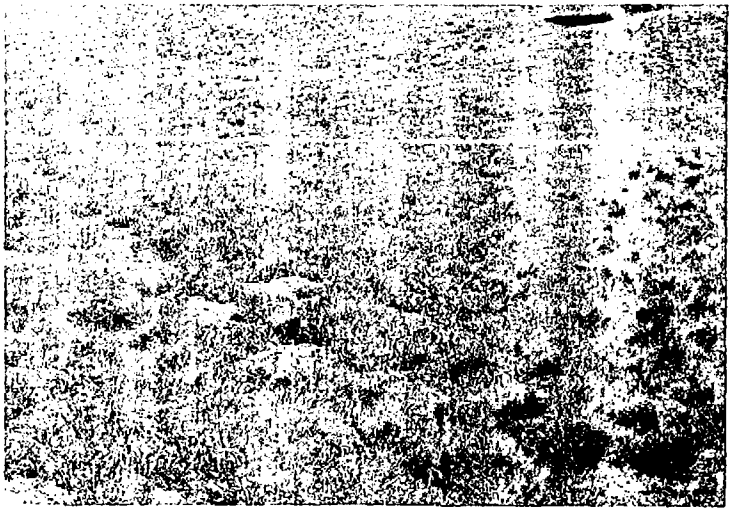


1978 -- Green fescue, sedge, needlegrass, and linanthastrum (in order of abundance) were the predominant species. Other perennial forbs that were becoming established in 1968 included common yarrow, pussytoes (*Antennaria* spp.), Rydberg's penstemon, buckwheats, and fleabane. The fleeceflower plant, present in 1938, was still present, along with several new plants of the species. The remnant pedestals were still intact.

1988 -- Vegetation had increased since 1978, principally in the forb component of the community. The lone fleeceflower plant present in 1938 was still present in 1988, giving some indication of the longevity of the species. Grasses and grasslike plants were sedge, fescue, and needlegrass in the foreground; and mainly fescue in the background. Forbs were fleeceflower, yarrow, linanthastrum, fleabane, and penstemon. The total plant cover was 30%; it consisted of 60% grass and grasslike plants and 40% forbs. The vegetation on the site was still improving.

FIGURE 8

1938 -- A swale site where most of the topsoil had eroded away. The depth and moisture of the remaining soil created favorable conditions for the establishment of moderate to dense patches of Rydberg's penstemon (center), Nuttall's linanthastrum (upper center and right slope), and needlegrass. Sedges, buckwheats, and prickly sandwort (*Arenaria aculeata* Foir.) were less prominent. Note the barren slope in the background.



1956 -- After 19 years under reduced grazing, green fescue had become reestablished on the site. Needlegrass, spike trisetum, and sedge dominated the species composition. The populations of penstemon, buckwheat, and linanthastrum had decreased, but total cover had increased. The barren slope in the background had mostly filled in with ovalhead sedge, needlegrass, spike trisetum, and bottlebrush squirreltail (*Sitanion hystrix* Nutt.).

FIGURE 8 (Continued)

1978 -- After 40 years, green fescue dominated the dense stand of vegetation in the middle and foreground. Penstemon and linanthastrum were still the main forbs, although they were not as abundant as they were in 1956 and 1968. Needlegrass and bottlebrush squirreltail were the principal species on the slope in the background. In the foreground, about 10 percent of the area between plants was covered with litter. About 10 percent of the more eroded slope in the background was covered with litter.

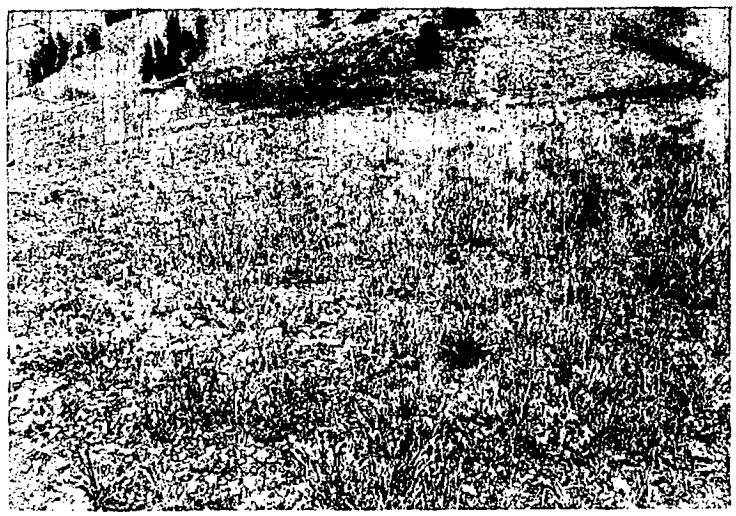
1988 -- After 50 years, the swale site was dominated by grassland vegetation. Green fescue was the dominant grass, but some timber oatgrass and slender wheatgrass had become established since 1978. Forbs, principally Rydberg's penstemon, were still prominent, but they were much reduced from previous populations. The formerly bare slope in the background was well vegetated, but still capable of supporting an increased density of the grasses.

FIGURE 9

1938 -- A bench site where a shallow topsoil was lost through erosion, but was partially replaced by a light soil deposition (on the right). Golden buckwheat, silverleaf phacelia (*Phacelia hastata* Dougl.), ballhead gilia (*Gilia congesta* Hook.), and pussypaws (*Spraguea umbellata* Torr.) are prominent on the eroded site. Needlegrasses, sedges, and fleabanes dominate the deposited soil. The large grass plants in the foreground are bottlebrush squirreltail.

1956 -- There was little change in plant composition or cover. Golden and Wyeth's buckwheats were the dominant species. Ballhead gilia and pussypaws were still conspicuous. The coverage by sedges, fleabanes, and bottlebrush squirreltail had decreased. Needlegrass seedlings and Rydberg's penstemon were established on the eroded soil.

FIGURE 9 (Continued)



1978 -- Wyeth's buckwheat was the dominant species, accounting for 50 percent of the vegetation cover. Grasses had greatly increased and included mountain brome (*Bromus carinatus*), oniongrass (*Melica* sp.), slender wheatgrass (*Agropyron caninum Vas.*), needlegrasses, and green fescue. Fescue accounted for 3 percent of the cover, though it had not been recorded in earlier years.

1988 -- After 50 years, the site had 10 percent plant cover, 50 percent of which consisted of forbs. Grasses and sedges were primarily represented by needlegrasses, mountain brome, green fescue, and Hood's sedge (*C. hoodii* Boott). Fescue was present but sparse. Oniongrass, abundant in 1978, was not encountered. Forbs were primarily Wyeth's buckwheat and yarrow. The major change since 1978 was a shift to a higher percentage of grasses and a slight increase in plant cover.

RESULTS

THE FIRST EIGHTEEN YEARS: 1938 - 1956

Even with continued sheep use on the site, no further loss of soil was observed in 1956. Most soil pedestals present in 1938 were still intact (Figure 3) and generally supported a vigorous growth of perennial plants. Soil sloughing from the pedestals had remained on the eroded surface and was stabilized by encroaching plants. The old erosion channels, the extensive pavements on old bedgrounds, and the stock trails were healing as plants invaded the area. Density, cover, and production had increased in the needlegrasses, green fescue, linanthastrum, and sedges.

The greatest factors in preventing a substantial improvement in vegetation by 1956 were loss of topsoil and the encroachment and increase of secondary species prior to 1938. These factors appear to have regulated the rates of plant establishment and the consequent alterations in density, cover, and production of plants, especially green fescue. It was concluded that plant density was approaching its potential on the eroded sites and that many secondary and associated species would maintain their prominence in future years (Strickler 1961).

EIGHTEEN TO THIRTY YEARS: 1956 - 1968

The major changes in the vegetation during the 12-year period from 1956 to 1968 was an increase in density and cover of grasses (particularly needlegrass and green fescue) and a decrease in perennial forbs.

The general aspects were those of a grass-forb mixture, or a grass sward in areas where topsoil remained in pedestals. Grasses and sedges had thickened on erosion pavements where they had occurred only as a sparse stand in 1956, thus reducing the extent of the bare areas. The principal increasing species were needlegrasses, ovalhead sedge, mountain brome (*Bromus carinatus* Hook, and Arn), bottle brush squirreltail (*Sitanion hystrix* (Nutt.) J. G. Small), and oniongrass (*Melica bulbosa* Geyer ex Porter and Coult.). Slender wheatgrass occurred as occasional plants.

As in 1956, the erosion of the soil appeared to have ceased accelerating. A few soil pedestals, recognizable from the earlier photographs, had toppled, and some had sloughed downslope.

THIRTY TO FORTY YEARS: 1968 - 1978

Between the thirtieth and fortieth years, there was a general reduction in the density of needlegrasses, sedges, and perennial forbs, a large increase in green fescue, and a continued increase in total plant cover. Needlegrasses had become a secondary constituent of the vegetation in some areas where it had previously dominated, and had become very sparse or was no longer found on other sites. Green fescue had become the dominant grass. Grasses and sedges had continued to invade bare areas and green fescue was as much an invader as the needlegrasses and sedges.

Perennial forbs were still prominent in the vegetation. Forb composition was generally much the same in 1978 as it was in 1938, but forb density and cover was less. Fleeceflower continued to increase in some areas in spite of the fact that the plant is quite palatable to sheep.

Accelerated erosion of the soil was not apparent in 1978. Many soil pedestals observed in 1938 were still in evidence, and they were similar in shape and size to their forms in 1968, though most were more rounded, and being well vegetated, were not as conspicuous as in 1968. The slopes still had a stairstep appearance, but the steps were less abrupt and plants covered much of the intervening space.

FORTY TO FIFTY YEARS: 1978 - 1988

A lack of moisture seemed to be the dominant factor affecting growth of the vegetation in Tenderfoot Basin in 1988. The Basin is in a remote portion of the Eagle Cap Wilderness Area where no measurements have been taken to indicate how much moisture had been received. Indicators of dry conditions (and the resulting poor growth) were:

1. Very short growth of the vegetation. Green fescue over much of the area averaged 3 to 5 inches in leaf height and only flowered on sites of favorable moisture. Forbs, such as Nuttall's linanthastrum had flowered, but the flowers had dried without maturing. Fleeceflower, usually up to 3 feet tall, was very short (often a foot or less in height).

2. Soils were unusually dry for loamy soils at high elevations.

3. Many small streams that had been observed to flow all summer long in the past were dry in 1988.

Even under the dry conditions, the vegetation cover was as dense as it had been in 1978. The relative abundance of major species had changed little if any since 1978. Also, there had been some upward successional changes in the vegetation, though they were less obvious than the major changes that occurred between 1968 and 1978. The principal changes observed were the establishment of slender wheatgrass, junegrass (*Koelaria cristata* (L.) Pers.) and timber oatgrass (*Danthonia intermedia* Vas.) where they had not occurred before. These plants occupied bare areas between older grass clumps.

One interesting change was the establishment, in some abundance, of juvenile Nuttall's linanthastrum plants between the fescue plants on a large area in upper Tenderfoot Basin. This area had obviously been used as a bedground during the 1968 - 1978 period and in 1978 the area had been largely bare between the fescue plants. Therefore, Nuttall's linanthastrum appears to perform as an important pioneer in early seral stands.

Soil surfaces in 1988 appeared much the same as they did in 1978, especially with respect to the stairstep appearance of the slopes and plant stools. The dry gully through the meadow (Figure 10) near Twin Springs had widened somewhat with some new sloughing of the banks. New grass had become established in the bottom of the gully and on its lower slopes. A few small barren areas had developed during the ten year period near trail crossings of live streams in the Twin Springs area. Development of these spots represented some range deterioration due to use, most probably the trailing of sheep and/or horses.

ECOLOGICAL CHANGES IN FIFTY YEARS ON SELECTED SITES

Green fescue formed dense stands on uneroded soils in 1938. The same situation existed 50 years later. Thus, Clement's (1916) and Pickford and Reid's (1942) concepts seemed verified: namely, that a subalpine grassland climax can be one in which the climax grass species occurs in almost a pure stand. Furthermore, any severe use by sheep would reduce palatable climax species and allow secondary species to increase, as was observed in 1944 on one site (Figure 2). Essentially uneroded, this site required at least 20 years to recover to approximately the original climax composition. The abundance of secondary species on the same site in the dry year (1988), when they constituted 55 percent of the cover is interpreted as a temporary retrogression induced by drought.

In 1938, there were several sites where soil was held in place by roots of dead fescue plants and where plant stools were occupied in varying degrees by secondary plants. The species occupying these stools and the amount of cover they generated seemed to depend on site characteristics.

Figure 3 illustrates a badly eroded site being invaded by needlegrasses in 1938. The most prominent characteristic is the abundance of plant stools held together by roots of dead or low vigor fescue plants. Figure 4 illustrates a closeup view of these conditions. By 1956 (18 years later), needlegrass had become the dominant increasing species, while the original fescue plants had become the dominant species overall. A number of sedge and needlegrass seedlings were becoming established between the soil pedestals. The pedestals themselves had become well vegetated, primarily by green fescue. There was no obvious soil erosion in 1988. Vegetative cover was estimated at 80 percent, consisting of 60 percent grasses, 38 percent sedges, and 2 percent forbs.

A different situation is represented by Figure 5. This is apparently a drier site located on a southwest exposure which had been severely trailed by sheep, so much so that it demonstrated a stairstep appearance. In 1938, most of the green fescue plants had been killed, but the dead roots remained in spite of the trailing. The pedestals had become occupied by secondary species, primarily: Nuttall's linanthastrum, sedges, and needlegrasses. Groundsmoke (*Gayophytum* sp.) and fleeceflower were becoming established between the pedestals.

Eighteen years later, after sheep management had been changed, green fescue had increased manyfold. Also, the linanthastrum had nearly doubled, but the needlegrass and sedge had made only slight increases. By 1968 (picture is not shown because it had been grazed at the time of photographing), green fescue was less prominent due to its having been closely grazed. Needlegrasses and sedges appeared about the same as they did in 1956 and, Rydberg's penstemon, along with buckhwheats, had become well established. By 1978, green fescue had increased greatly and constituted half the vegetative cover. Conversely, linanthastrum made up only about 25 percent of the cover, with penstemon occupying 10 percent of the site. Common yarrow and buckwheat had both increased.

In 1988 (after 50 years), green fescue was short and dry, yet prominent in the vegetation. Linanthastrum had flowered and the flowers had prematurely dried. Penstemon seemed to have increased in abundance. One fleeceflower plant, present in 1938, was still present in 1988; but it was very short due to the dry conditions that year. The area still retained its previously marked stairstep appearance. Overall, the vegetation and soil had greatly improved since 1938, but the site would still have to undergo further changes before it reaches a desirable ecologic status.

An eroded but moist site with good amounts of topsoil remaining in the form of pedestals held together by fescue roots is illustrated by Figure 6. In 1938, the area was mainly occupied by

forbs (i.e., penstemon, sticky cinquefoil, fleeceflower, stickseed, and buckwheats); although some needlegrasses, sedges, and other grasses were present. In 1956, forbs were still predominant. Cinquefoil and penstemon had decreased, but new plants of the same species had occurred on the stabilized soil between pedestals. Needlegrasses and sedges had increased, and green fescue had become established on the topsoil remnants. By 1968 (no photograph), grass constituents had increased and most perennial forbs had decreased, although many individual plants identified in 1938 were still present. Density of fleeceflower had greatly increased. By 1978, green fescue had made a marked increase and replaced the needlegrass and sedges. This marked the greatest change between the thirtieth and fortieth years noted on the site. By 1988, the vegetation comprised of 65 percent grasses and 35 percent forbs. Green fescue was the most abundant plant. The old sod on which most of the vegetation grew appeared to be essentially unchanged from its condition in 1938.

Years of sheep trailing over the small pass, shown in Figure 7, resulted in the loss of most of the topsoil and the formation of a rocky erosion pavement. The site is located on the Tenderfoot Basin Trail. The vegetation in 1938 consisted largely of needlegrasses. A single plant of fleeceflower had become established on the pavement, and a few plants of linanthastrum were established on the pedestals. By 1956, green fescue, spike trisetum, and sedge had become established, but needlegrass was still the principal species. By 1968, buckwheat, pussytoes, linanthastrum, needlegrass, yarrow, and bottlebrush squirreltail were thickening and/or becoming established. In 1978, the vegetation was still increasing. The primary grasses and grasslike species were fescue, sedges, and needlegrass, in descending order of abundance. The forb population was made up of linanthastrum, pussytoes, fleeceflower, and one or two plants of fleabane, penstemon, cinquefoil, and yarrow. In 1988, there appeared to be more vegetation on the area than in 1978, but the species were similar to those observed in 1978. Furthermore, in 1988 the cover reached the 30 percent level, and consisted of 60 percent grasses and sedges and 40 percent forbs. The erosion pavement and the plant stools were similar to those noted in 1938.

Figure 8 represents a swale site that had been eroded, but which also received some soil deposition from adjacent slopes. Growing conditions appeared good. Over the 50 years, the vegetation changed from a dominance of perennial forbs, primarily Rydberg's penstemon and Nuttall's linanthastrum, to a grass vegetation dominated by green fescue in 1988. Timber oatgrass and wheatgrass were observed in 1988 but were not observed in 1978. Thus, plant succession is apparently still proceeding.

A situation where, after the initial grazing, little topsoil remained, residual soil was shallow and rocky, and the site was well drained is illustrated by Figure 9. The area had been severely used for a long time, probably as a bedground. In 1938, it was dominated by perennial forbs, largely buckwheats. Grasses, most of which consisted of needlegrass and bottlebrush squirreltail, were sparse. Eighteen years later, the buckwheats were still dominant, and while some other species had decreased, needlegrass and penstemon exhibited an increase. By 1968, the buckwheats were still dominant, but needlegrass had become more prominent and was the principal grass. After 40 years, the grasses had greatly increased and included a number of species; these were: Mountain brome, oniongrass, wheatgrass, needlegrass, and green fescue. Green fescue, which accounted for 3 percent of the plant cover, was not recorded in earlier years on the site. After 50 years, the site was still sparse (10 percent cover) with about 50 percent forbs and 50 percent grasses. A greater variety of both grasses and forbs were present, but Wyeth's buckwheat was still the most abundant forb.

SOIL EROSION

Little general accelerated soil erosion was observed to have occurred over the 50 year period. Figure 10 shows changes in a gully situated in a small meadow. The vegetation of the meadow was a tough sod of sedges, needlegrasses, Rydberg's penstemon and other species. The gully was adjacent to a trail in a meadow that appeared to have received heavy grazing.

FIGURE 10

1938 -- Past accelerated erosion is indicated by the small, steep-sided gully cutting through a tough sod of sedge. Sedges and needlegrasses (dark lines) are conspicuous. Small colonies of Rydberg's penstemon occur in the sod.

1956 -- A lack of appreciable widening or deepening of the gully over the intervening 18 years attests to substantial decreases in the amount and velocity of runoff water. Continuation of a lowered water table has resulted in: The sedges becoming less prominent, Rydberg's penstemon spreading considerably, and green fescue (bunches), spike trisetum, and Wyeth's buckwheat becoming more prominent in the composition.

FIGURE 10 (Continued)

1988 -- After 50 years, the gully was still widening, causing overhanging sod mats to break off occasionally. The bottom of the gully had flattened and gravel had accumulated. Some grasses and forbs had become established at the bottom and on the sides. Species established in this manner were slender wheatgrass, needlegrass, Rydberg's penstemon, alpine timothy (*Phleum alpinum* Rydb.), sticky cinquefoil, and sedge.

In the first 18 years, the gully deepened and widened and the sod growing on its sides occurred as sharply overhanging mats. By 1968, the gully had widened considerably, but the sod continued to overhang, and there was some bank undercutting. By 1988, vegetation was being established on the gully bottom and sides but the gully had still not stabilized. Sod along the bank was still being undercut, and which would inevitably lead to more bank sloughing.

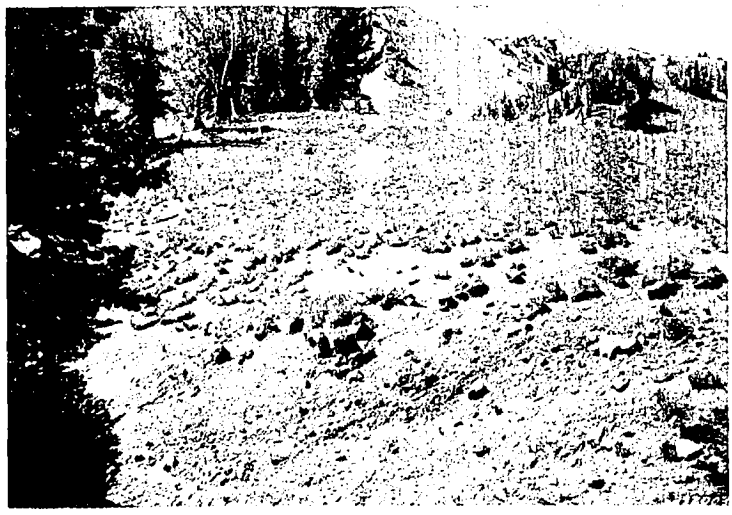
Sheet erosion was not readily apparent on the plots, especially where there were abundant green fescue roots, dead or alive, holding the soil. Such areas readily established the growth of new plants. Also, in such areas bare patches between grass clumps became well covered with litter. The places most prone to sheet erosion were those where sheep had been heavily trailed.

Another type of soil erosion can occur which causes the formation of soil pedestals; this type of erosion is principally the result of trailing on slopes. Figure 11 illustrates this sort of rangeland deterioration. By 1938, the site had experienced serious erosion which resulted in the formation of green fescue-capped pedestals. Over the ensuing years, needlegrass, sedge, and Parry's rush (*Juncus parryii*) became established on the eroded areas, while green fescue remained or became established on most pedestals. Some pedestals were stabilized and held in place, but others were eventually undercut, causing them to break from the slope and roll down hill with the soil still being held together by root masses. Many of the pedestals were still present after 50 years. In that time, the soil had become well stabilized by the vegetation that had established itself on the eroding areas. Therefore, these observations indicate that the history of specific areas should be known before pedestals are used as indicators of current use or trends in range condition.

Figure 12 illustrates another site along the Tenderfoot Basin Trail where both sheep and horse travel resulted in cutting the sod and the forming of plant pedestals. In this case, the slope was fairly gentle. Although many pedestals were present in 1938, lighter use over the 50-year period allowed all the pedestals containing perennial plants to remained standing. So, by the end of the period the old sod was well covered with vegetation (primarily green fescue) and the erosion surfaces between pedestals became quite well covered with sedge sod. Nine trees (subalpine fir) had become established by 1988 where none existed in 1938. It is of interest to note the down log in the 1938 photograph. It was partially decayed in 1938, and four feet of it still remained in 1988, indicating the slowness of decay at these high elevations (about 8,000 feet).

This site demonstrated an upward trend in ecologic status between 1938 and 1988, but still had ample capability for further ecological development. This conclusion can be reached for most of the sites studied.

FIGURE 11



1938 -- An area that had been seriously eroded by sheep trailing. The deep and densely interwoven root masses of green fescue held straight-sided blocks of topsoil intact, resulting in a pedestalled or hummocked appearance. A number of these pedestals had separated from the soil and were being moved down hill when the photograph was taken.

1956 -- The heavy erosion pavement shown in 1938 has been invaded by needlegrasses. Most of the remnant soil pedestals supporting live green fescue plants in 1938 were still present in 1956. However, many of those without live plants in 1938 were no longer present.

FIGURE 11 (Continued)

1988 -- Some soil pedestals shown in 1938 were still present. Others had broken loose from the soil and rolled downhill. Green fescue plants had increased since 1978, and many trees were established.

FIGURE 12

1938 -- A site along the Tenderfoot Basin Trail that had been heavily trailed by sheep and horses. The green fescue sod had been cut and eroded, resulting in numerous pedestals which supported green fescue plants.

1956 -- After changing management, needlegrass, sedges, and green fescue had become well established on the eroded soils with an erosion pavement. Plant vigor had increased, and erosion was not as prominent as had been observed previously.

FIGURE 12 (Continued)

1988 -- The area had the same general appearance as it did in 1978, even though 1988 was a dry year. The erosion surfaces were filled with vegetation, mainly sedges, and the clumps of old sod were prominent and well covered with green fescue. The area was still being used for trailing, but it had healed over with vegetation. Subalpine fir trees were becoming well established (nine trees in 1988 remained where there were none in 1938), and only four feet remained left of the down log shown in the foreground of the 1938 picture.

SUMMARY AND CONCLUSIONS

It is difficult to make general statements as to the plant succession that occurred over the entire study area and time period because the sites varied with changes in slope, aspect, extent of erosion, amount of topsoil, moisture conditions, previous grazing, and other factors. However, the following general successional changes appear to have occurred:

1. Green fescue was the dominant plant species on those sites in good ecologic condition (late seral stage). Fescue increased or became established on all areas during the 50 years of observation. The rate and amount of establishment (or increase) depended on the amount of topsoil remaining on each site. On sites with good soil retention, the fescue became the dominant plant. On badly eroded sites with little topsoil left, fescue was present only as sparsely scattered plants after 50 years.

2. Needlegrasses are well adapted to poorer range conditions (early seral stages) and as such, quickly became abundant when grazing was reduced. They became established under virtually all soil conditions except the most seriously eroded sites, and on all sites they were largely replaced by green fescue between the thirtieth and fortieth year of observation. Western needlegrass (*Stipa occidentalis*) seemed to require better growing conditions than Letterman's needlegrass (*S. lettermanii*).

3. Sedges vary by species as to their place in plant succession. Raynolds sedge (*C. raynoldsii* Dewey) and elk sedge (*C. geyeri* Boott.) appeared to occur late in the succession, while Hood's sedge (*C. hoodii* Boott.) and ovalhead sedge (*C. macloviana* Cham.) tended to occur in the mid seral stage, often closely associated with the needlegrasses.

4. Forbs also vary by species as to their place in succession. Many were readily established as pioneers where bare soil was available. Once established, some did not compete well with the fescue and were therefore ephemeral on those sites. Others were long-lived and competed much better. Fleeceflower, for example, persisted throughout the 50 years, and while buckwheat and linanthastrum plants were too numerous to follow individuals, stands persisted throughout the study.

5. Good seed production was observed in all measurement years except the dry year of 1988, indicating that annual seed production was not usually a limiting factor.

A conclusion that can be made for most of the sites studied is that they had improved a great deal in ecological status between 1938 and 1988, but that there is considerable opportunity for further ecological development with good management practices. In the future, many sites may develop only sparse stands of green fescue because of past soil erosion. However, the density of secondary grasses and forbs should be sufficient to provide the cover necessary to prevent accelerated soil erosion.

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PLANT NAMES

Aster	*Aster* sp. L
Brome, mountain	*Bromus carinatus* Hook. and Arn.
Cinquefoil, sticky	*Potentilla glandulosa* Lindl.
Buckwheat, golden	*Eriogonum flavum* Nutt.
Buckwheat, Wyeth's	*Eriogonum heracleoides* Nutt.
Fescue, green	*Festuca viridula* Vas.
Fleabanes	*Erigeron* spp. L.
Fleeceflower	*Polygonum phytolaccaefolium* Meisn.
Fir, subalpine	*Abies lasiocarpa* (Hook.) Nutt.
Gilia, ballhead	*Gilia congesta* Hook.
Groundsel, western	*Senecio integerrimus* Nutt.
Junegrass	*Koelaria cristata* (L.) Pers.
Linanthastrum, Nuttall's	*Linanthastrum nuttalli* Ewan
Needlegrass, western	*Stipa occidentalis* Thurb.
Needlegrass, Letterman's	*Stipa lettermanii* Vas.
Oatgrass, timber	*Danthonia intermedia* Vas.
Oniongrass	*Melica bulbosa* Geyer ex Proter and Coult.
Penstemon, Rydberg's	*Penstemon rydbergii* A. Nels.
Phacelia, silverleaf	*Phacelia hastata* Dougl.
Pine, whitebark	*Pinus albicaulis* (Hook.) Nutt.
Pussypaws	*Spraguea umbellata* Torr.
Pussytoes	*Antennaria* spp. Gaertn.
Sedge, elk	*Carex geyeri* Boott.
Sedge, Hood's	*Carex hoodii* Boott.
Sedge, ovalhead	*Carex macloviana* Cham.
Sedge, Raynolds	*Carex raynoldsii* Dewey
Squirreltail, bottlebrush	*Sitanion hystrix* (Nutt.) J. G. Sm.
Wheatgrass, slender	*Agropyron caninum* ssp. majus (Vas.)
Yarrow, common	*Achillea lanulosa* (Nutt.) Piper
Trisetum, spike	*Trisetum spicatum (L.) Richt.*
Groundsmokes	*Gayophytum* spp. Juss.
Lupines	*Lupinus* spp. L.
Sandwort, prickly	*Arenaria aculeata* Wats.
Timothy, alpine	*Phleum alpinum* Rydb.
Rush, Parry's	*Juncus parryii* Engelm.

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