Long-term responses of dense clubmoss (Selaginella densa Rydb.) to range renovation practices in northern Montana

by John Joseph Dolan

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

Abstract:
Residual effects of various mechanical and manuring treatments on dense clubmoss (Selaginella densa Rydb.) were investigated on an ungrazed mixed prairie site in Northern Montana.

Sixteen plots of native range were treated between 1925 and 1935. In 1965 nine transects were established in each plot to determine basal ground cover. Herbage was harvested from six clip plots per treatment plot in an effort to estimate forage production by species. Protein content of the clipped vegetation was then determined. In addition an estimate of litter production was made.

Resultant data were processed through an IBM 1620 II digital computer. Standard analysis of variance tests preceded Duncan'S multiple range tests used to determine differences in ground cover and herbage yield among treatments. Correlation coefficients were determined to indicate relationships between data from the major categories evaluated.

An inverse relationship between the intensity of mechanical treatment and clubmoss ground cover was discovered. Manure treatments were also shown to reduce clubmoss cover but the effects of treatment intensity were not distinct.

The treatments were shown to affect certain forage species. Litter yields increased with increased treatment intensity and this was associated with increased forage productivity.

Treatment did not affect the protein content of the vegetation.

129

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TABLE OF CONTENTS

	Page
VITA	ii
ACKNOWLEDGMENT	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF APPENDIX TABLES	ix
ABSTRACT	x
INTRODUCTION	1
REVIEW OF LITERATURE	3
Ecology of Dense Clubmoss on the Northern Great Plains	3
General Distribution	3
Site Characteristics	5
Cover	5
Competitive Relationships	6
Ecesis	8
Factors Influencing Local Distribution of Dense Clubmoss	9
Grazing	9
Mechanical Renovation	10
Fertility	11
Water	12
Chemicals	13
DESCRIPTION OF THE AREA	14
Soils	14
Climate	17
Precipitation	17
Temperature	19
Frost-free Period	19
Wind Velocity	20
Evaporation	20
History of Use	20
EARLY RANGE IMPROVEMENT STUDIES AT NORTH MONTANA BRANCH STATION	23
Preliminary Work	23
1925 - 1935 Treatments to Native Sod	23

Page

METHODS 26

Pre-sampling Procedures 26
Plot Relocation 26
Plot Modification 26
Additional Check Plot 28
Sampling Procedures 28
Estimate of Vegetative Cover 28
Transect Location 29
Placement of Transects 29
Collecting Intercept Data 31
Estimate of Herbage Production 33
Clip Plot Location 34
Clipping Procedure 34
Estimate of Litter 39
Vegetation Survey of 21 Areas 40
Data Processing 40
Estimate of Forage Protein Content 42

RESULTS AND DISCUSSION 43

Introduction 43
Response of Clubmoss to Renovation Practices 43
Live Clubmoss 44
Dead Clubmoss 44
All Clubmoss 49
Response of Needle-and-Thread 49
Ground Cover 49
Weight 50
Response of Blue Grama 51
Response of Crested Wheatgrass 51
Ground Cover 51
Weight 56
Response of Western Wheatgrass 56
Response of Annual and Biennial Forbs 57
Response of Other Species 57
Response of Total Vegetation 58
Litter 58
Ground Cover 60
Weight 60
Bare Soil 60
Protein Content of the Vegetation 60

SUMMARY AND CONCLUSIONS 62

Page

APPENDIX 64

LITERATURE CITED 80

LIST OF TABLES

		Page
I.	Average monthly precipitation (North Montana Branch Station)	18
II.	Summary of analysis of variance tests on ground cover	45
III.	Percent ground cover by species	46
IV.	Correlation coefficients showing the relationships between some major categories estimated from 17 treatment plots	50
V.	Summary of analysis of variance tests on herbage yield	52
VI.	Herbage yield in pounds per acre by species	53
VII.	Herbage yield in pounds dry matter per acre	59
VIII.	Crude protein content of grass and non-grass species	61

LIST OF FIGURES

		Page
1.	Close-up view of dense clubmoss	4
2.	Dense, shallow root system of dense clubmoss	4
3.	Sixteen treated plots looking west	15
4.	Relict area looking northeast from check plot 18	15
5.	Soil map of the treatment plots and relict area, North Montana Branch Station	16
6.	Diagram of chronological treatment schedule	25
7.	Vegetational aspect	27
8.	Diagram of transect locations	30
9.	Reading and recording a transect	32
10.	Diagram of clip plot locations	35
11.	Two clipping crews and field office	36
12.	Details of the clipping operation in native vegetation	36
13.	Sample page from herbage yield record book	37
14.	Recording sack numbers at the field office	38
15.	Consolidating six clip plot bags into one bag representing a treatment plot	38
16.	Collecting litter in an area invaded by crested wheatgrass	40
17.	Sample page from litter record book	41

LIST OF APPENDIX TABLES

Page

I. Yearly precipitation distribution at North Montana Branch Station since 1916 65

II. Average monthly wind velocity (N. M. B. S.) 66

III. Average monthly evaporation (N. M. B. S.) 66

IV. Transect locations 67

V. Transect coding key 73

VI. Intercept type code 74

VII. Clip plot coding key 75

VIII. Presence of species in 21 areas 76

ABSTRACT

Residual effects of various mechanical and manuring treatments on dense clubmoss (Selaginella densa Rydb.) were investigated on an ungrazed mixed prairie site in Northern Montana.

Sixteen plots of native range were treated between 1925 and 1935. In 1965 nine transects were established in each plot to determine basal ground cover. Herbage was harvested from six clip plots per treatment plot in an effort to estimate forage production by species. Protein content of the clipped vegetation was then determined. In addition an estimate of litter production was made.

Resultant data were processed through an IBM 1620 II digital computer. Standard analysis of variance tests preceded Duncan's multiple range tests used to determine differences in ground cover and herbage yield among treatments. Correlation coefficients were determined to indicate relationships between data from the major categories evaluated.

An inverse relationship between the intensity of mechanical treatment and clubmoss ground cover was discovered. Manure treatments were also shown to reduce clubmoss cover but the effects of treatment intensity were not distinct.

The treatments were shown to affect certain forage species. Litter yields increased with increased treatment intensity and this was associated with increased forage productivity.

Treatment did not affect the protein content of the vegetation.

INTRODUCTION

The presence of dense clubmoss (Selaginella densa Rydb.)[1/] has long been recognized on northern mixed prairie ranges. In some areas the species has accounted for more than 80 percent of the ground cover, yet until recently investigators had not studied it intensively. Some ignored it. Others either assumed that its effect on other vegetation was negligible or theorized that it played a vital role as a soil stabilizer in the severe environment of the Northern Great Plains.

Under certain environmental conditions clubmoss probably serves as an efficient soil stabilizer. Although little is known of its water utilization characteristics, clubmoss may sometimes prevent runoff, which may ultimately benefit the range. On the other hand, there are areas where clubmoss appears to compete with other vegetation while not performing a vital function in production of forage nor in long-term stability of the range.

Recent mechanical range renovation treatments at the North Montana Branch Station near Havre have increased the productivity of preferred forage species. This effect has been partially explained by the removal of clubmoss competition for water and an increase in available nitrogen resulting from the decomposition of uprooted clubmoss. No immediate deterioration of the soil resource has resulted from removal of clubmoss on this relatively level rangeland.

Concurrent experiments of range fertilization at the same location indicated that the basal area of clubmoss decreases with increased fertil-

1/ Hereafter referred to as clubmoss in the body of the paper.

ity. In this same experiment forage productivity increased.

Several questions arise in the areas of ecology and economy as a result of these range experiments. Will the total range resource be jeopardized by clubmoss removal? How long may the range be expected to maintain increased productivity? Will the clubmoss on such treated range return to its former abundance?

A unique opportunity to probe into these questions existed at the experiment station at Havre. Six miles north of the present range renovation experiments a series of mechanical and manure treatments were applied to similar range between 1925 and 1935. This area has remained essentially undisturbed since that time. An evaluation of these 30 to 40 year old treatments was made during the summer of 1965. This paper is a report of that evaluation.

REVIEW OF LITERATURE

Ecology of Dense Clubmoss on the Northern Great Plains

General Distribution

Late in the nineteenth century Underwood (1898) stated that clubmoss (*S. rupestris* (L.) Spring.) was distributed from New England to British Columbia and grew to an elevation of 7,000 feet. He considered western specimens growing at high elevation different from those of the east only to the extent that they were characteristically more compact. He theorized that this trait assisted in water conservation in the arid western environment.

At the turn of the century Rydberg (1900) examined clubmoss specimens from seven Montana locations. Specimens from the Little Rocky Mountains, an isolated mountain group 60 miles southeast of Havre, were included. He separated *S. densa* (Figure 1) from *S. rupestris* mainly by the "striking difference in habitat" and noted that it appeared more "moss-like" than its eastern ally. Rydberg described *S. densa* as growing on exposed hillsides, among gravel or rocks throughout the Rocky Mountain region and eastward to the Black Hills of western Nebraska. Later Rydberg (1932) again used habitat to differentiate among three species of *Selaginella*. He separated *S. densa* Rydb. from *S. selaginoides* (L.) Link. and *S. rupestris* (L.) Spring. by stating that its range was restricted to hills and mountains.

These early reports of clubmoss on the Northern Great Plains were made by taxonomists. Their papers were characteristically concerned with distinguishing species, and largely neglected the ecological aspects of the plant community.

The first recorded observation of clubmoss near the North Montana

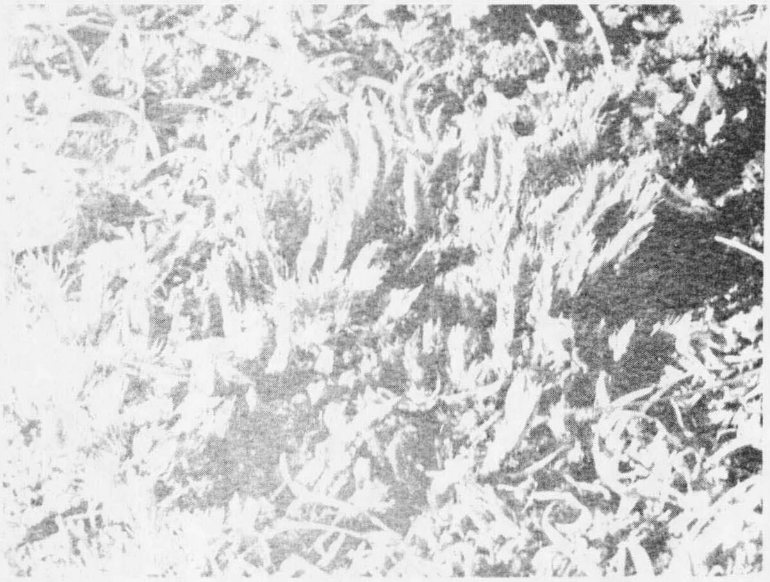

Figure 1. Close-up view of dense clubmoss. Natural size.

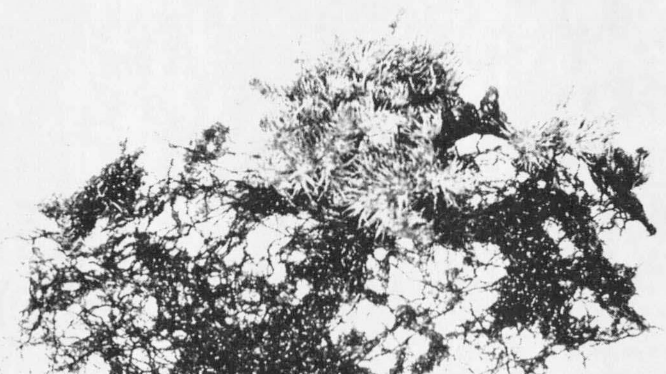

Figure 2. Dense, shallow root system of dense clubmoss.

Branch Station was made four miles northeast of the study site by H. L. Shantz in 1916 (Phillips, 1963).

Site Characteristics

Two ecological features of S. densa var. densa were noted by Tryon (1955). Its habitat was characteristically dry and open and the species did not thrive in the presence of other plants. Tryon indicated that clubmoss was abundant in areas of moderate rainfall and in locally dry habitats in moist areas. He found it on barren soil and on rocky, gravelly or cliff areas where other vegetation was not abundant.

Coupland (1950) found clubmoss most commonly on medium-textured soils, less commonly on sandy soils and rarely on clay in the Canadian mixed prairie. Sturm (1954) suggested that the species was associated with poor sites and thin soils in northern Montana. In Wyoming's Big Horn Mountains Beetle (1956) found clubmoss associated with dry, shallow soils of granitic origin. The species occurred most frequently on sandy loam soils in northeastern Montana according to Majorowicz (1963).

Areas on which clubmoss occurred in the Palouse Prairie region of southwestern Montana were found to be in higher range condition than areas on which it did not occur (Van Dyne and Vogel, 1966). However, the soils on which the species was found were shallower and contained more rock and gravel but less sand than soils on which the species did not occur.

Cover

Clarke et al. (1942) reported a heavy cover of clubmoss on the prairie in southern Canada. Although clubmoss cover commonly ranged from 10 to 25 percent, a cover of up to 50 percent was not unusual. These researchers stated that the clubmoss cover prevented wind and water erosion and trampling damage. In addition they reported that sheep grazed the species during the spring, an occurrence generally thought to be uncommon. Coupland (1950) observed that clubmoss occurred with a frequency of 74 to 98 percent in his study of the Canadian mixed prairie and provided 6 to 25 percent ground cover on medium textured soils.

Heady (1952) reported that on a Montana mixed prairie "relict" area clubmoss provided 28.5 percent ground cover. Seed plants occupied 3.4 percent ground cover. Investigations by Sturm (1954), using a point quadrat method, indicated a clubmoss cover of 12.4 percent in the same relict area.

Competitive Relationships

The earliest available evidence suggesting that clubmoss presented some competition to other plant species was noted on a site at the North Montana Branch Station which had a history of heavy grazing for about 30 years. The 1925 annual station report (North Montana Branch Station, 1925) stated that as a result of cultural treatments to "native sod" in which the cover of a "species resembling liverworts"[2/] had been disturbed, western wheatgrass (*Agropyron smithii*)[3/] tended to increase and an opportunity was thereby presented for increased growth of all forage species.

Although clubmoss probably was present on that site as a natural part of the plant community before restricted herds of domestic livestock became an influencing factor, the degree to which it occurred is not known. It was present in 1925 to such an extent that it provoked comment at a

2/ Later changed to *Selaginella* in an undated, uninitialed correction.
3/ Botanical names according to Booth, 1950, and Booth and Wright, 1962.

time and place when only the most apparent aspects of vegetation received recognition.

In his analysis of Canadian mixed prairie vegetation Coupland (1950) did not include clubmoss because its ecological relationships were not understood and its influence on the habitat and other vegetation considered small. Further work in the same region led Clarke and Tisdale (1945) to state that although clubmoss was abundant over much of the area it exerted little influence in the plant association because of its low water and nutrient requirements. Clarke et al. (1947) observed that clubmoss as well as Sandberg bluegrass (Poa secunda) and Hood's phlox (Phlox hoodii) increased as a result of the 1929-1936 drought. Blue grama (Bouteloua gracilis), needle-and-thread (Stipa comata) and western wheatgrass decreased.

Majorowicz (1963) suggested that clubmoss competed for moisture by intercepting water from low intensity storms, thus subjecting it to rapid evaporation.

Tryon (1955) credited the shallow but extensive root network of clubmoss (Figure 2) with the ability to utilize rapidly small quantities of water. This matted root system was also described by Wagner (1966). He traced it to a maximum depth of about 3 inches and noted its probable water interception capability. Wagner further noted that this characteristic, which is apparently an asset during part of the year, would conversely limit the growing season of clubmoss to those periods when moisture is available at very shallow depths.

Tryon (1955) observed that although clubmoss is not particularly adapted for water storage or prevention of water loss it has a unique ability to revive after severe desiccation. A herbarium specimen of S. densa var. densa replanted by Tryon grew after six months in the herbarium. He attributed this ability to "unusual physical and chemical properties of the cell contents."

Similar verification of the ability of clubmoss to survive long periods of drought was made by Webster and Steeves (1964). After 33 months in a laboratory without water some clubmoss plants were revived. These experimenters concluded that this ability was related to "some physiological mechanism" in the cells. They suggested that the vital parts of the cell were in some way protected although the specific process could not yet be explained. Wagner (1966) observed changes in top growth 10 minutes after watering a dormant sod of clubmoss. Two hours after watering the plants began to turn green.

Ecesis

Little is known of the ecesis of clubmoss. Fragmentation is a possible means of dispersal. Young sporophytes have been reported only occasionally (Lyon, 1901; Tryon, 1955). Webster and Steeves (1964) have observed sporophytes of clubmoss in all stages of development in a mixed prairie habitat in central Saskatchewan. This suggests that the introduction of clubmoss into a new area could perhaps take place more rapidly than would be expected by the slow vegetative spreading process. Wagner (1966) observed that in a moist greenhouse environment maximum lateral top growth of clubmoss was slightly more than 1 inch per year. Under range conditions maximum lateral top growth was less than 1/2 inch per year.

Factors Influencing Local Distribution of Dense Clubmoss

The literature concerning the response of clubmoss to stimuli is limited. Effects of various influences upon clubmoss have been noted in most cases only incidentally from investigations primarily concerned with vegetation other than clubmoss.

Grazing

Coupland (1950) observed that clubmoss increased on Canadian mixed prairie if protected from grazing. A decrease was noted following grazing. This he attributed to the trampling of grazing animals. Coupland[4/] offered another possible explanation for this response of clubmoss. After a period of grazing the surface soil is drier than if protected by ungrazed vegetation. Thus, a larger proportion of the clubmoss might be dormant during a dry period and recorded as dead during summer studies.

In 1960 Smoliak compared the effects of two grazing systems on the vegetation of southeastern Alberta. After a period of nine years clubmoss ground cover had decreased on continuously grazed pasture. The species had increased under a system of deferred-rotation grazing. Vogel (1960) indicated that clubmoss did not increase with grazing in southwestern Montana but may have increased following protection from grazing. In southwestern Montana Van Dyne and Vogel (1966) and Vogel and Van Dyne (1966) found that clubmoss decreased more on grazed range than on protected areas. Clubmoss cover was observed to decrease under intensive grazing.

Hubbard (1951) observed a highly significant increase of clubmoss in

4/ Coupland, R. T. 1966. Personal correspondence.

southeastern Alberta under a system of continuous grazing as well as under rotational grazing. The study was made during the dry years 1931 through 1937, therefore the lack of water may have confounded the results. Sturm (1954) also reported an increase in clubmoss resulting from grazing on both year-long and spring-grazed ranges in northern Montana.

On the mixed prairie ranges of southeastern Alberta, Smoliak (1965b) noted changes in the basal area of clubmoss as grazing practices varied. A highly significant increase in basal area of live clubmoss resulted from light grazing. Smoliak[5/] indicated that this increase of clubmoss can be expected primarily in an area subjected to light grazing after long-term protection. A highly significant decrease was observed after 14 years deferment. Smoliak suggested that the change in clubmoss cover was related to speciation changes which resulted from grazing intensity. As an area was grazed the aspect changed from *Stipa-Bouteloua* to *Bouteloua-Stipa*. Deferment after a history of grazing caused taller mid-grasses such as needle-and-thread to increase to the detriment of short grasses. The resulting decrease in clubmoss was attributed to greater shading by the taller species and a heavier mulch accumulation.

Mechanical Renovation

Visual estimates of the effects of mechanical treatments on clubmoss were cited in the annual reports of the North Montana Branch Station during the treatment period (North Montana Branch Station, 1916-1937). Severe mechanical treatments destroyed some clubmoss and blue grama sod. Western

5/ Smoliak, S. 1966. Personal correspondence.

wheatgrass was stimulated by the mechanical renovation.

Reduced clubmoss cover resulting from range pitting and a sod-scalping process used in Montana range interseeding studies was reported by Ryerson et al. (1962a) and Ryerson et al. (1962b).

Fertility

Estimates of the effects of manure applications on clubmoss were also reported by the North Montana Branch Station during the treatment period (North Montana Branch Station, 1916-1937). Although a quantitative estimate of pretreatment clubmoss cover was not reported, its presence was mentioned repeatedly. At the end of the first growing season following the first treatment in 1925 total vegetative growth was reportedly stimulated on manured plots. A decrease in clubmoss was visible on manured plots at the end of the second growing season. It was stated that the manure treatments subordinated clubmoss to more vigorous stands of native grasses. Manuring was said to have improved yields of native hay more than any of the mechanical treatments.

Heady (1952) re-evaluated these treatment plots in 1947. A needle-and-thread aspect had replaced the blue grama-western wheatgrass aspect described in the early annual station reports. Although hay yields generally corresponded with those obtained from the same plots during the treatment period Heady felt that the speciation differences which existed in 1947 could not be attributed to treatments. The effects of more than four manure applications were apparent in 1947 by significant differences in culm heights of needle-and-thread. Although no specific attempt was made to evaluate the effects of the treatments on clubmoss, Heady reported the existence of at least some clubmoss on all 16 plots.

A highly significant reduction in basal clubmoss cover resulted from each of four treatments applied to Canadian mixed prairie range (Smoliak, 1965a). The treatments consisted of 30 tons of barnyard manure per acre; 30 tons wheat-straw per acre; an inorganic fertilizer of 300# N, 150# P_2O_5, 300# K_2O per acre; and 30 tons of wheat-straw plus the mixture of inorganic fertilizer. The reduction of clubmoss was partially attributed to increased nutrients available to forage species from treatments of manure and fertilizer. However, a more dramatic decrease of clubmoss was apparent from treatments containing organic matter. A mulch effect was evidently responsible for this severe reduction.

At the end of three years of range fertilization trials in northern Montana Ryerson et al. (1962b) reported that clubmoss ground cover had been reduced as a result of fertilization. Fertilization and mechanical procedures used concurrently were more effective in destroying clubmoss than either process alone (Ryerson et al., 1962a; Ryerson et al., 1962b).

In a range fertilization study in the Palouse Prairie vegetation of southwestern Montana Ryerson and Taylor (1963) found that the response of clubmoss to applications of nitrogen and phosphorus was more erratic than its response to similar treatments at the northern Montana study. Clubmoss ground cover in fertilized plots was found to be heavier than that in the check plots.

Water

Availability of water probably influences clubmoss distribution but similar responses of the species have not always been reported. Such factors as quantity, time and duration of applications probably affect the response.

An increase in clubmoss cover was observed by Clarke *et al.* (1947) in Canadian prairie vegetation after seven years of drought.

Six water spreading projects in southeastern Alberta were designed to better utilize spring runoff (Hubbard and Smoliak, 1953). The results of five of the projects disclosed that a decrease in the basal cover of clubmoss resulted from the increased availability of water. Klages and Ryerson (1965) reported an increase of clubmoss cover corresponding to applications of up to 12 inches of additional water to range in western Montana.

Chemicals

Preliminary investigations of the effectiveness of chemicals for the control of clubmoss on Montana range land have been initiated by Wagner (1966). Several chemicals have either killed all vegetation or have killed clubmoss and reduced the yield of other species. Two preparations, "AMS" and "Atrazine", appear to be effective in controlling clubmoss and may actually stimulate other vegetation. These studies are only one year old, so few conclusions can be drawn at this time. The studies are being continued.

DESCRIPTION OF THE AREA

The North Montana Branch Station, six miles southwest of Havre, is situated in the mixed prairie region of North America. This vegetational association is the most extensive of those forming the continent's grasslands. It extends from northern Alberta and Saskatchewan to the Staked Plains of Texas in the south, and from central North Dakota westward to eastern Utah (Coupland, 1961; Weaver and Albertson, 1956; Weaver and Clements, 1938).

The plots of native sod which received mechanical and manure treatments between 1925 and 1935 are located along the north side of a mixed prairie relict area which has remained relatively undisturbed since 1915 (Figures 3 and 4). This area lies in Section 32 of Township 32N, Range 15E at an elevation of about 2700 feet above sea level. The plots slope evenly and gently to the west.

Soils

At least two ice sheets have previously covered the northern Montana plains. Two distinct types of glacial till give evidence of this.

The treatment plots are located on soil classified as "Joplin clay loam, 2 to 4 percent slope" (U.S.D.A., S.C.S., 1960). A small portion of six plots overlap an area of "Joplin clay loam, 5 to 10 percent rolling" and "Devon loam, 0 to 2 percent slope" (Figure 5).

The Joplin soil series consists of an intergradation of Chestnut and Brown soils which have developed from glacial till or superglacial deposits. A high silt and fine sand content is characteristic of these parent materials. This has resulted in fine-textured soils of high moisture holding capacity. The undisturbed grassland has a grayish brown loam surface