Reduced grazing impacts on vegetation communities in southern Siberian taiga
by Temuulen Tsagaan

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Land Resources and Environmental Sciences
Montana State University
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Abstract:
Dukha people, the reindeer herders in northern Mongolia, on the southern edge of the Siberian taiga, are natives of Tuva, a former Soviet Republic. They used to freely migrate across the Russian-Mongolian border, but were no longer allowed to migrate across the border after they were accepted as Mongolian citizens in the 1950s. Since Mongolia's livestock privatization in the 1990s, they now own their herds and have had no more access to social and financial support, which has further reduced the migrating distances. Only a few campsites from where they can easily access urban areas and other income resources have been used. Increased consumption of reindeer meat and hunting pressure has also decreased both the domestic reindeeer and wild ungulate populations. Consequently, this region of the West Taiga has lacked grazing and browsing impact. Ground cover of shrubs has increased while percent cover of graminoids, forbs and lichens has decreased.

To effectively detect changes in the vegetation, two sites that have been grazed for 15 and 28 years and two sites that have not been grazed for 17 and 25 years were * selected. Transects were established starting at the campcenters and extending in the directions of reindeer grazing. Up to four sampling zones (valley bottom, hillside or terrace, forested upper sideslope, and ridgeline) were established within each transect. One large rope hoop (size 13.45 m^2) with a small hoop (size 0.08 m^2) nested inside was placed every 300 paces to document total number of species present, percent ground cover of shrubs, forbs, graminoids, lichens, bare ground and litter, shrub height, percent leaves on shrubs and green biomass. A simplified soil profile was described in each hoop. An apparent trend survey sheet was completed for each hoop.

Valley bottoms, hillsides and ridgelines at grazed sites had less ground cover of shrubs than at ungrazed sites. Ungrazed sites had taller, but less vigorous shrubs with less green biomass compared to grazed sites. Grazed sites also had more plant species than ungrazed sites. Increased percent shrub cover at ungrazed sites reduced percent cover and accessibility of graminoids, forbs and lichens.

Reindeer grazing and browsing need to be more evenly distributed throughout the taiga. Currently grazed sites need to be rested to recover their lichen mats, while ungrazed sites should be utilized to improve plant vigor and better balance the species in the plant communities.

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Abstract

Dukha people, the reindeer herders in northern Mongolia, on the southern edge of the Siberian taiga, are natives of Tuva, a former Soviet Republic. They used to freely migrate across the Russian-Mongolian border, but were no longer allowed to migrate across the border after they were accepted as Mongolian citizens in the 1950s. Since Mongolia's livestock privatization in the 1990s, they now own their herds and have had no more access to social and financial support, which has further reduced the migrating distances. Only a few campsites from where they can easily access urban areas and other income resources have been used. Increased consumption of reindeer meat and hunting pressure has also decreased both the domestic reindeeer and wild ungulate populations. Consequently, this region of the West Taiga has lacked grazing and browsing impact. Ground cover of shrubs has increased while percent cover of graminoids, forbs and lichens has decreased.

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Reindeer grazing and browsing need to be more evenly distributed throughout the taiga. Currently grazed sites need to be rested to recover their lichen mats, while ungrazed sites should be utilized to improve plant vigor and better balance the species in the plant communities.

INTRODUCTION

Mongolia is a landlocked country in north central Asia. It borders Russia (the Siberian Republics of Tuva and Buriatia) on the north, Khazakhstan on the west and China on the south (Figure 1). The northernmost point is at 52°6′ and the southernmost at 41°31′ Northern Latitude (Hilbig, 1995). Mongolia's territory covers 1,565,000 sq. kilometers with a population density of approximately 1 sq. kilometer per capita, which is not evenly distributed. More than one third of the population of 2.3 million live in Ulaanbaatar, the capital city.

Mongolia has 21 provinces, called aimags. The capital, Ulaanbaatar, and other major cities each form their own aimag. Each aimag consists of 12 to 24 smaller administrative units, called soums (Hilbig, 1995). Each soum encompasses a large land area, but each has a central economic and administrative urban center. In addition, there are small sub-units of the soums, called baags.

Ecologically, Mongolia is divided into six basic natural zones, differing in climate, landscape, soil, flora and fauna. They are high mountain, taiga forest, mountain forest steppe, steppe, desert steppe and desert zones (Finch, 1996). Mongolia has a sharply continental climate, with long, cold, dry winters and brief, mild and relatively wet summers. When Arctic air masses dominate in mid-winter, temperatures average –20 to -35°C. In the coldest part of the country, the lowest temperature recorded was -58°C. By contrast, summer temperatures in the Gobi Desert climb as high as 40°C. Annual

precipitation ranges from 600 mm in the northern mountain regions to less than 100 mm in the Gobi (Finch, 1996).

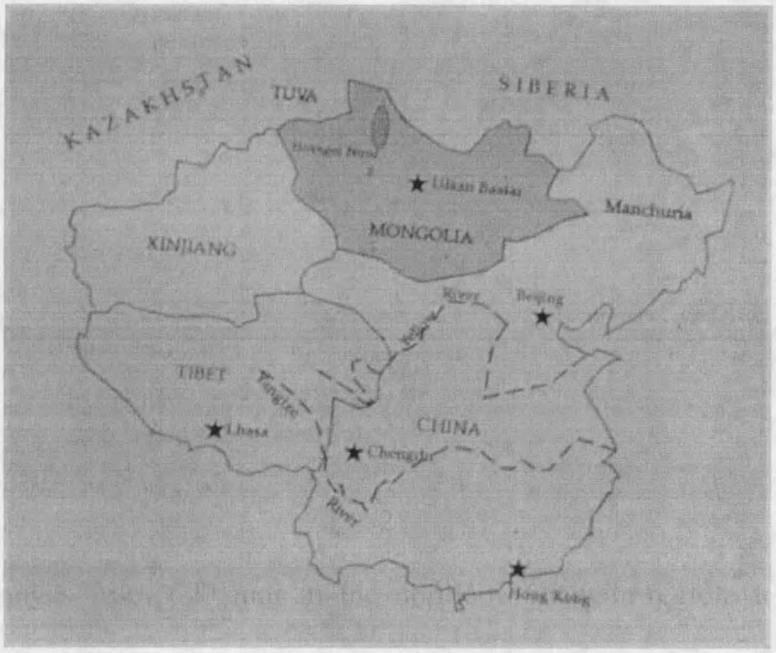


Figure 1. Central Asia

Mongolia's taiga zone, where this study was conducted, includes the southern edge of Siberia's vast taiga forest, the largest continuous forest system on earth. Taiga is a boreal coniferous forest, comprised in Mongolia primarily, of Siberian larch (*Larix sibirica*) (70%), and at higher elevations, Siberian pine (*Pinus sibirica*). The forests are rich in mosses and lichens. The taiga zone occurs only in northern Mongolia and covers about 5% of Mongolia's territory. It experiences more precipitation (300-400 mm annually) and lower temperatures than most of Mongolia, with cold, snowy winters and cool, rainy summers (Finch, 1996).

Mongolia was a socialist country with a centrally planned economy from the 1920s until the early 1990s. In 1990, Mongolia began its conversion to a democratic government and market economy and is still undergoing major political, social and economic change. At the start of the transition, all manufacturing plants and factories were privatized along with all domestic animals. However, all natural resources, including land and land resources, have remained as public property with an exception of homesites. There is no private land ownership, which allows all herders to practice their traditional nomadic herding lifestyle. They herd sheep, goats, camels, horses, cattle and yaks.

In the northern tip of Mongolia, where it reaches furthest into the Siberian taiga, there are approximately 30 households (Wheeler 1999) who herd domestic reindeer (*Rangifer tarandus*). They are called Tsaatan or "reindeer herder" in Mongolian, or Dukha as the people refer to themselves. They live in teepees and are the most nomadic of all herders in Mongolia. Because their nomadic movements are largely determined by the need to pasture the reindeer in specific areas with sufficient lichens and by the availability of wild game to hunt, they have been known to travel great distances, often without concern for the borders of a particular soum or nation (Wheeler, 1999). They are natives of Tuva, a republic of the Russian Federation in south-central Siberia, which borders Mongolia to the north (Figure 1). Tuva "was incorporated into the Soviet Union in 1944, the final addition to the Soviet territory. Prior to that, Tuva was, nominally, an independent state, the Tuva People's Republic (1921-1944). This state, however, was

...controlled by the Soviet Union with the intention of separating the Tuvan territory from Mongolia so that it could be more easily absorbed by the Soviet Union later on, which is exactly what happened in 1944" (Donahoe, 1998). The Tuvans have a long history as nomadic pastoralists. Many scholars have hypothesized that reindeer were first domesticated in this area of southern Siberia, and that this may have been the earliest domestication of livestock anywhere in the world (Donahoe, 1998). Currently, Tuva has a territory of 170,500 sq. kilometers and a population of 308,000.

Until 1911, "Tuva was considered a part of Outer Mongolia. During this time, the Tsaatan had the freedom to migrate within the area which is now divided by the international border of Russia and Mongolia. So, before the various revolutions, the reindeer people were more appropriately citizens of the taiga. In 1926-27, however, the border was more firmly established, marking the beginning of several attempts by the Mongolian Government to relocate the Tsaatan to their "home" in Tuva, where they waited for a season or two and then moved back to northern Mongolia. ...In 1956, after finally realizing that the Tsaatan considered Mongolia their home, the Mongolian Government granted the Tsaatan Mongolian citizenship and gave them citizen passports" (Wheeler, 1999). In northern Mongolia, the reindeer herders historically lived their nomadic lifestyle in Ulaan Uul and Renchinlhumbe Soums of Khuvsgul Aimag. In 1985, the Mongolian parliament resolved to consolidate all Tsaatan and their reindeer both from Ulaan Uul and Renchinlhumbe Soums into one new soum, called Tsagaan Nuur (Wheeler, 1999). Although the 30 reindeer-herding families present a fairly homogeneous group, they are divided into two different groups by location, history and dialect

(Wheeler, 1999). Fourteen of the households live in the East Taiga to the north of Shishkhed River and 16 households live in the West Taiga to the south of this river, but both are within the Tsagaan Nuur Soum. This study covered areas of the West Taiga only.

The reindeer population in Renchinlhumbe and Ulaan-Uul Soums remained at about 1000 in the 1960s and 1970s. However, by the time "Tsagaan Nuur Hunting and Reindeer Breeding State Farm" was established in the following decade to promote hunting and herding for the Tsaatan, the population had declined to 594 owing to inadequate number of herders, low price for reindeer products, and the poor health due to inbreeding. In 1991, due to better veterinary care and herding staff support by the government, the population increased 170%, peaking at around 1030 (Dashdorj, 1992). This population growth continued until 1992 when the herd size reached 1200. During these decades, reindeer were, and still are, used for transportation, milk and meat, but the velvet antler harvest has been the major use since 1978 (Dashdorj, 1996).

During Mongolia's transition into a market economy, the state farm was decollectivized and reindeer were privatized like all other livestock species in the country. With the private ownership of reindeer, everything changed for the Tsaatan. The government subsidies were no longer available for the herders or the herd. The herders now have neither salaries nor other income sources, except for the velvet antlers. The once-a-year velvet antler harvest has not been enough to pay for household expenses. Owing to this reduced income, their food resources have become extremely limited. Consequently, they have been consuming their reindeer. This increased consumption,

coupled with poor veterinary care, has led to a sharp decline in the herd size. The current reindeer population fluctuates around 300 and is in poor health. The closure of the international border has eliminated access to new animals. This has resulted in inbreeding, which is one of the causes of the herd's poor health. Cutting the velvet antlers has also contributed to decreased health by making the animals more susceptible to infections, diseases and parasites (Wheeler, 1999. Personal communication, 1999 and 2000).

As the herd size declines, the population of active reindeer herders is also decreasing. When a household consumes all of their reindeer, their only income resource besides relatively small and sporadic income from selling and trading handicrafts and from occasional outright gifts, they have to move down to lower elevations to herd other animals or to urban towns to find jobs. Harsh climate and poorly drained, rugged topography in the taiga do not allow herders to have other species of domestic animals, such as cattle or sheep. Preferred reindeer rangelands are often in the remote, high mountains that are at least a day or two horseback ride from any urban centers. The only means of arriving at these camps is by horseback or on foot, rigorous by both means. These factors provide limited options of livelihood for the herders. The number of households is decreasing every year. If this situation remains the same, the reindeer-herding culture of the Tsaatan, the world's southern most nomadic reindeer herders, will likely disappear. This extinction would be a loss to the diversity of world culture. There are some Mongolian and international organizations, such as the Mongolian Reindeer

Fund and the Red Cross, which are working to save this unique culture by bringing in new reindeer herds from Tuva to refresh the genetic pool.

Reindeer herders have, historically, been hunters and gatherers (Wheeler, 1999). The Siberian taiga ecosystem sustains wildlife populations of roe deer (*Capreolus pygargus*), moose (*Alces alces*), musk deer (*Moschus moschiferus*), caribou[1] (*Rangifer tarandus*), ibex (*Capra sibirica*), brown bear (*Ursus arctos*), wolf (*Canis lupus*), sable (*Martes zibellina*), Eurasian river otter (*Lutra lutra*), and others (Dashdondov, 1990). However, to reduce reindeer consumption, the reindeer people have heavily hunted the wild animals in this region. As a result, most of the wild ungulates have left this area and migrated to Russia (Personal interviews, 1998, 1999, 2000). Now few wild animals or game species are found in this region (personal interviews and observation, Appendix A).

Due to decreased populations of domestic reindeer and wild ungulates, a majority of this vast mountain range has lacked grazing and browsing[2] utilization for at least the past decade. The remaining few herders have been using a few preferred campsites more often and for longer periods of time. These campsites are relatively close to urban towns, providing opportunity for trade and income from tourism. While these few areas are being heavily grazed and browsed, the rest of the region has been rested.

[1] Caribou are wild, whereas reindeer refers to domestic animals, even though they are the same species.
[2] Grazing refers to graminoids and forbs, while browsing refers to shrubs.

Problem Statement

According to some reindeer herders, most mountain valleys and campsites were previously dominated by grasses and forbs (personal interviews, 1998-2000). However, they now are largely covered with shrubs, which has caused problems: 1) some of the old campsites are now not utilized because the camping space is covered with shrubs, which makes them even less desirable, and 2) some of the other desirable forage species, such as lichens and forbs, have been replaced by shrubs.

Literature Review

Mongolia's vegetation includes more than 3000 species of vascular plants, 927 lichens, 437 mosses, 875 fungi and numerous algae (Finch, 1996). Common tree species in the taiga zone of Mongolia include *Larix sibirica, Pinus sibirica, Picea ovobata* and *Pinus sylvestris*, although *Larix sibirica* dominates. Dominant shrub species are *Juniperus pseudosabina, Betula platyphylla, Betula rotundifolia, Betula berberis, Salix glauca* and *Salix divaricata* with understories of *Vaccinium vitis-idaea, Rhododendron ledebouri, Pedicularis flava, Ranunculus altaicus, Potentilla gelida, Bergenia crassifolia, Pyrola rotundifolia* and *Cladonia rangiferena* (Finch, 1996).

Caribou/reindeer consume lichens throughout the year, although this forage loses its importance in summer, when dwarf birch represents the key summer food (Crete and Doucet, 1998). Willows and various forbs also are prominent in reindeer diets in the spring and early summer (personal interviews, 1999).

Many studies have simulated browsing on deciduous shrubs. Crete and Doucet (1998) studied the effects of heavy browsing by caribou on deciduous shrubs. They surveyed and compared five heavily browsed and two lightly browsed birch stands. The leaf/wood ratio and the percent dry weight of leaves were higher in lightly browsed than in heavily browsed stands. Leaf biomass was twice as high in lightly browsed versus heavily browsed areas.

Manseau et al. (1996) also studied effects of summer grazing by caribou during the grazing season on vegetation composition and productivity. In stands of dwarf birch repeatedly used by caribou, leaf biomass and ground cover were significantly lower than in unused sites. Leaf biomass in used sites was 20.5 g/m^2 compared to 57.2 g/m^2 in unused sites. They concluded that heavy browsing reduced annual forage productivity by more than 50%.

Leaf stripping and bud ablation in summer negatively affect most deciduous shrubs (Crete and Doucet, 1998). Ouellet et al. (1994) showed that *Salix* also represents an important component of caribou summer diets and is negatively affected by clipping. Intense ungulate herbivory can lead to willow decline in which suppressed willows produce one-third to one-fourth the aboveground biomass than taller willows (Singer et al., 1994). Heavy browsing impacted seed production, because catkins are produced only on shoots that were not browsed the previous year (Singer et al., 1994). Moreover, Kay and Chadde (1997) measured seed production inside and outside willow exclosures and found that protected willows produced, on average, 306,000 seeds per sq.meter, while

plants outside produced none (Kay, 1997). Given the browsing impact on biomass and seed production, willows are expected to decrease in abundance as the caribou population increases.

Archer and Tieszen (1980) and Chapin (1980) analyzed the impact of browsing and grazing on some plant species in Alaska. Both of these studies concluded that plants grazed and browsed by caribou in Alaska had increased nutrient concentrations. Stark et al. (2000) studied reindeer grazing effects in Finnish Lapland and found that net nitrogen of plants was increased by grazing.

Ouellet et al. (1994) also simulated grazing and browsing of vegetation available to caribou in the Arctic. Their study showed that grazing generally reduced plant net production. However, it positively modified chemical composition of shrubs and sedges and enhanced forage quality. They found that willows and sedges had lower levels of cellulose and lignin and higher concentrations of nitrogen, potassium and phosphorus than control plants. Enhancement of forage quality by browsing and grazing may favor herbivores that reselect these plants later in the summer (Ouellet et al., 1994).

Plant quality is likely to have a major effect on the diet of caribou (Ouellet et al., 1994). A winter diet high in lichens puts caribou in a negative phosphorus balance. It may also create a negative nitrogen balance in these animals. Caribou have to replenish phosphorus and nitrogen during the growing season. Therefore, preference and digestibility of caribou summer foods are positively correlated with nitrogen and phosphorus levels and negatively with fiber content (Chapin et al., 1986).

If plants respond to grazing and browsing by compensatory growth or by positive changes in nutrient levels, caribou may adopt a strategy of returning to plants that have been browsed previously (Ouellet et al., 1994). This is consistent with Singer et al.'s (1994) conclusion that heavily browsed willows produced lower amounts of chemical defense compounds, resulting in a higher preference by ungulates. This may suggest that previously used sites can be preferred over rested areas.

Although rest may improve plant vigor, it decreases forage palatability, intake, digestibiliy and digestion rate due to increased ADF (acid detergent fiber residue) and NDF (neutral detergent fiber residue) (Launchbaugh et al., 1978). Chapin et al. (1986) examined seasonal patterns of carbohydrate, lipid, cellulose, hemicellulose and lignin in deciduous shrubs, tussock graminoids, mosses and lichens. They found that cellulose content of deciduous shrub leaves and stems increased with age. They also had less ADF and NDF early in the season. This is possibly why wild ungulates migrate from low elevations to higher elevations as the growing season progresses (Albon and Langvatn, 1992). Migrating animals prolong their access to preferred high protein and low fiber species by travelling to higher elevations or latitudes, where the same plant species are in their earlier phenological stages due to later snow melt. This may mean that moving the camp more often during the growing season would benefit the herd.

Chapin (1986) studied nutrient allocation in tundra growth forms, deciduous shrubs, graminoids, and herbivory impact on these nutrients. He suggested that tundra plants invest a large proportion of their total nutrient capital in leaves. His results showed

that deciduous shrubs, willows and birch, have high nutrient concentrations in their leaves following snowmelt and can rapidly translocate nutrients into new growth. They are most vulnerable to herbivores at this time.

Graminoids, in contrast, possess large below ground nutrient reserves and are able to rapidly produce new shoots in response to repeated defoliation (Chapin, 1986). Graminoids in the tundra have their tillers in the lichen and moss layer, so that they do not require apical meristem regrowth after defoliation (Chapin et al., 1986, Bell and Bliss, 1980). This makes them tolerant of grazing throughout the growing season, unless defoliation is so severe and/or too frequent that it removes the tillers or the lichen layer is overgrazed.

Heavy grazing by reindeer reduces the lichen mat (Ouellet et al., 1994). Manseau et al. (1996) showed that annual productivity of lichens at heavily grazed sites was only 6% of that of ungrazed sites. The lichen mat was also absent in grazed sites. Ground that was previously lichen-covered was either bare or covered with fragments of dead lichens, mosses or early successional lichens.

Grazers in tundra plant communities maintain relatively high plant species diversity and prevent any of the plant species from gaining a high dominance (Virtanen, 2000). However, because individual plants are not completely consumed when grazed, differences among species in their response to herbivory in terms of survivorship, growth, reproduction and competitive ability can be a critical determinant of community changes (Augustine and McNaughton, 1998). Encroachment of shrub species is expected to decrease ground cover of lichens due to their low shade tolerance (Topham, 1974).

Foraging selectivity can be another important driver of community change in all systems (Augustine and McNaughton, 1998). Preferred species have to cope with a much more competitive environment and recover more slowly, when surrounding plants are not grazed (Caldwell, 1984). Changes in tundra species composition due to intensive herbivory by caribou appear to be the result of differential tolerances to tissue loss among species. Therefore, slow growing lichens decline dramatically with caribou grazing (Augustine and McNaughton, 1998).

Proposed Hypothesis

The objectives of this study are to: 1) characterize current plant communities, species diversity, and plant vigor at different campsites, 2) identify differences in vegetation cover associated with varying grazing regimes, and 3) characterize the effects of nongrazing on plant communities. This will provide information for local herders, local and regional governments and other institutions, such as non-governmental organizations interested in the management of this area, to determine if lower ungulate numbers and potentially fewer predators are causing changes in the vegetation composition and vigor. The information can be used in determining policies for hunting and reindeer management including potential increases in numbers. It can also provide a basis for recommendations regarding herd sizes, length of grazing and rest periods, spatial and temporal distribution of grazing and optimal campsite locations.

This study proposes a hypothesis that the reduced number of wild ungulates and reindeer has resulted in: 1) increased percent cover of deciduous shrubs due to reduced

browsing impact 2) decreased presence and percent cover of other functional vegetation groups, some of which include desirable forage species such as lichen, and 3) decreased species diversity and plant vigor.

METHODS AND MATERIALS

Study Design

To determine the effects of grazing on vegetation communities, four summer campsites were selected for study. Campsites of the same seasonal (summer) use were chosen because reindeer forage habits vary from season to season. Two of the campsites, Urtun Khyarkh and Joshim, were selected to represent "grazed" campsites. They have been used for the past 15 and 28 years, respectively (personal interviews, 1999-2000). The other two, Terturag and Dood Saalig, were chosen to represent "ungrazed" campsites. They have not been used for the past 17 and 25 years, respectively, with the exception of 1996, 1999 and 2000 regarding Dood Saalig (personal interviews, 1999-2000).

All four campsites are located 17-30 km from each other on tributaries of the Tenggis Gol (river) which eventually flows into the Enisey River (Figure 2). Joshim is west of the Tenggis Gol in the Ikh Agaya Mountain Range whose summits are at 2400-2800 meters elevation. The other three campsites, Terturag, Urtun Khyarkh and Dood Saalig, are in the Saalig Mountain Range east of the Tenggis Gol. The average elevation of the Saalig Range summits is approximately 2500 meters (Tsogt, 1992). All four campsites are located in glaciated valleys below mountains that rise above the tree line. Campsite elevations range between 1835 and 1895 meters. All four valleys share

common landscape characteristics such as the presence of glacial deposits, side valley alluvial fans and stream terraces and floodplains.

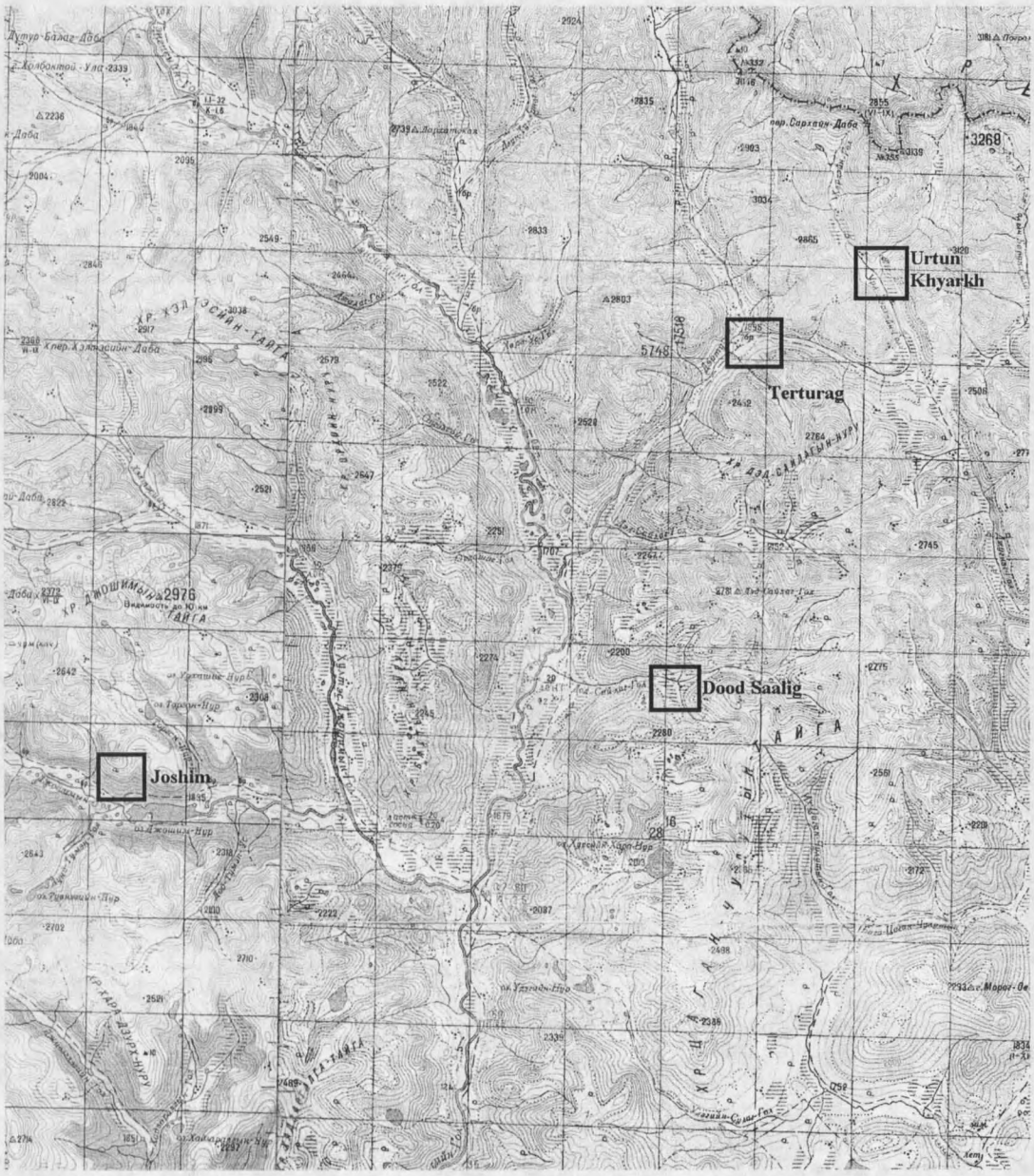


Figure 2. Tenggis River Drainage and Study Sites.

Due to their close proximity and similar elevation and latitude, all four valleys have a similar climate. The average annual precipitation in these mountain ranges is 400-500 mm and average growing season lasts for 95 days (Tsogt, 1992). Temperatures range from –49 C° to 35 C° (Tsogt, 1992).

Sampling Methods

Transects were established starting at the center of each campsite and extended in the directions of reindeer grazing. Directions of reindeer grazing at the ungrazed sites were defined through interviews and studying landscape characteristics. If campsites were located at a convergence of two rivers, transects followed only the river(s) or branch(es) that the reindeer grazed along. Therefore, the number of transects at each campsite also varied with reindeer grazing pattern. The length of each transect depended upon how far the herd went. Certain landscape characteristics such as the valley length and major river and stream locations also affected the transect lengths. All transects were 1-2 km long.

Given that the plant community types varied with landscape position, up to four sampling zones (valley bottom, hillside or terraces, forested upper sideslopes and ridgeline) were established within each transect. Only one transect had 1 zone due to its valley bottom location between 2 streams, whereas all other transects had 3-4 zones. Due to the linear valley bottom topography, each zone ran parallel to the valley bottom stream and was usually as long as its parent transect.

One large rope hoop (13.45 m^2) was placed every 300 paces within each zone of each transect to document vegetation characteristics of the shrub canopy. A small hoop ($0.08m^2$) was thrown over one's shoulder within each large hoop, and used to measure lower strata vegetation and standing green biomass. Each zone had 3-6 hoops depending on its length. In addition to the transect measurements, five hoops were distributed within two campsite centers to document vegetation characteristics. These hoops were arranged more or less evenly along axes representing the length and width of campsites as indicated by discarded teepee poles, fireplaces, and remnant grassland vegetation. These campsite measurements were a new addition to the study design and, therefore, used at the last two campsites only.

Data categories for the large hoop were total number of species present, percent ground cover of different functional vegetation groups, bare ground and litter, shrub height, percent leaves on shrubs and a simplified soil profile description. Total number of species included all strata present in the hoop: trees, shrubs and understory. Percent ground cover was visually estimated and grouped into functional groups: shrubs, graminoids, forbs, lichens, other species and litter. A typical shrub height, selected by visual estimation within the hoop, was measured. A typical branch was selected and then percent of the branch covered with leaves was visually estimated in order to indicate shrub vigor. Percent bare ground was the percentage covered by rocks and bare ground. Similar vegetation data was collected from the small hoops including number of species, percent ground cover, shrub height, percent leaves on shrubs and percent bare ground. In

addition, live grasses and forbs were clipped and shrub leaves stripped by hand (to mimic browsing) for a measure of wet weight of green biomass. In addition, a rangeland health checklist (Mosley, 1997) and utilization and apparent trend score card (Taylor and Lacey, 1996) was completed for each large hoop.

Although the four sites shared similar landscape characteristics, another confounding variable was soils. Differences in vegetation between grazed and ungrazed sites may have been due to soil differences. Therefore, to determine if the vegetation differences were due to grazing impact only, soils at the four sites were also studied and compared. A soil profile was described in each large hoop with measurements of horizon thickness and depth to bedrock, water and/or permafrost, if present. Soil textural class, moist color, percent clay and percent coarse fragments were determined. All horizons present in the profile were named and their depths identified. Depth of each excavation was dependent upon the depth to bedrock, water or permafrost and varied between 15-80 cm. A sample of each horizon in the profile was textured by hand and percent coarse fragments and percent clay estimated. Moist color of each horizon was identified (Munsell, 1975).

Statistical Analysis

A two-way Analysis of Variance was conducted (SAS 1998) to analyze the vegetation data. Grazing and nongrazing treatments, all transects, and sites were treated as fixed variables (independent) and hoops as random variables (dependent). Each of the dependent variables measured within the hoops, such as number of species and percent

cover, were separately analyzed and averaged at the hoop level within the same vegetative zones to compare them at the treatment level. Thus, for instance, data from all hoops in the valley bottom of all four sites were analyzed separately from other hoops in other zones and were averaged and compared at the treatment level. This enabled a separate analysis of each vegetation zone from all four sites. A significance level of $p \leq 0.05$ was used in the analysis.

"Summary of vegetation patterns" section in the "Results and Discussion" chapter also includes some graphs and figures that are not based on the SAS-produced statistical analysis, but on the means only and/or observed overall trend in the raw data (Figures 19, 20, 21, 22, 23 and 24).

Site Description

Urtun Khyarkh

Urtun Khyarkh campsite is a grazed campsite to the north of Dood Saalig camp. It has been utilized every summer for the past 15 years. It is located at the confluence of Urtun Khyarkh River and Nariin Stream (Figure 3). The two streams flow southwest through high mountains. However, where the two meet, the valley becomes broader and flatter. This valley stretches downstream approximately 6 km. The hillsides are covered with Siberian larch (*Larix sibirica*) forests and higher colluvial fans had no vegetation cover. The Khuvsgul Lake Atlas (1989) shows that this area is in a mountain tundra zone on soils of glayee tundra, glayee mountain-valley and tundra-podzol types.

Reindeer trails and herds were observed along both rivers above their confluence. They also followed the main river downstream below the confluence. Since the camp was located at the confluence, it served as a starting point for three transects that stretched out along the rivers: two upstream transects and one downstream transect. All three transects had three vegetation zones due to topography and vegetative characteristics: valley bottom, hillside, and forested upper sideslope (Figure 4).

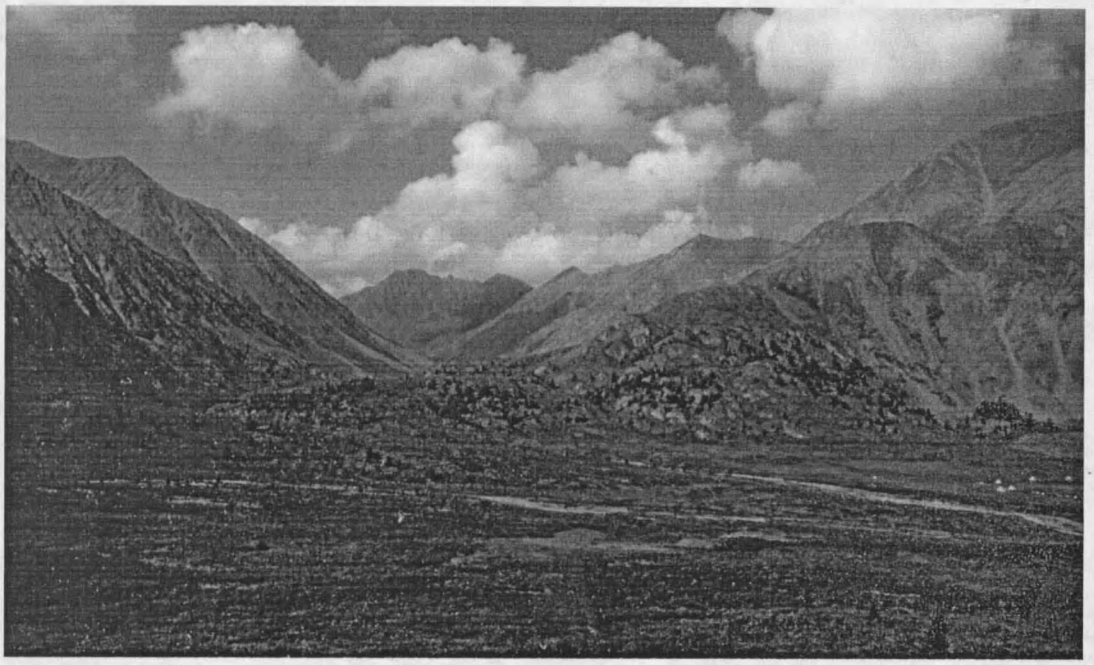


Figure 3. The Confluence of the Urtun Khyarkh River and Nariin Stream

Transect 1 stretched downstream along the river into the main valley. It had three hoops in valley bottom, four on the hillsides and two on the forested upper sideslopes. Transect 2 was established along the Urtun Khyarkh River. It had four hoops in valley bottom along the river, three on the hillside and two on the forested upper sideslope.

Transect 3 was established on the southern bank of the Nariin Stream with three hoops in each zone.

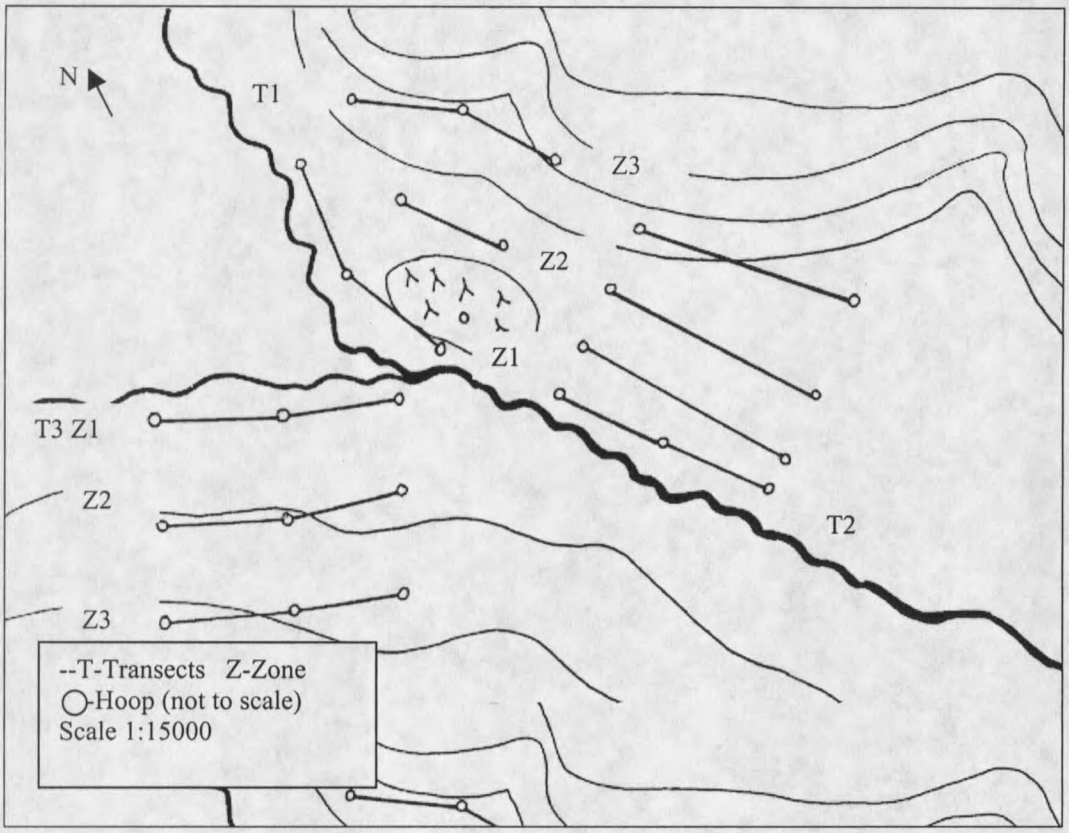


Figure 4. The Urtun Khyarkh site transects

Joshim

Joshim is a currently used campsite which has been grazed for approximately the past 30 years. This area is one of the Tsaatans' preferred campsites due to its dependable fishing for supplemental food. The Tsaatan camp here in the late summer every year

starting from early to middle August until they move to the autumn campsites in September or early October.

Figure 5. Joshim valley

Joshim is one of the major rivers that flow into the Tenggis Gol from the west. It meanders through the Joshim Valley and at one point becomes a lake, also called Joshim. The campsite is located approximately 3 km upstream from the lake. The Joshim Valley is another glaciated mountain valley with an active flood plain in the bottom, with wet soils overlying permafrost. Wet, poorly drained soils preclude the Tsaatan establishing a campsite on the river bank. The size of the river also prohibits the reindeer from crossing

it. South of the river is a steep north facing mountain slope. However, the north side of the river has a well-drained terrace-like landform, possibly glacial till or landslide debris, above the flood plain and makes a suitable campsite. This landform merges into a Siberian larch forest at the mountain foot slope, which rises up to a high rocky ridge crest that is almost devoid of vegetation.

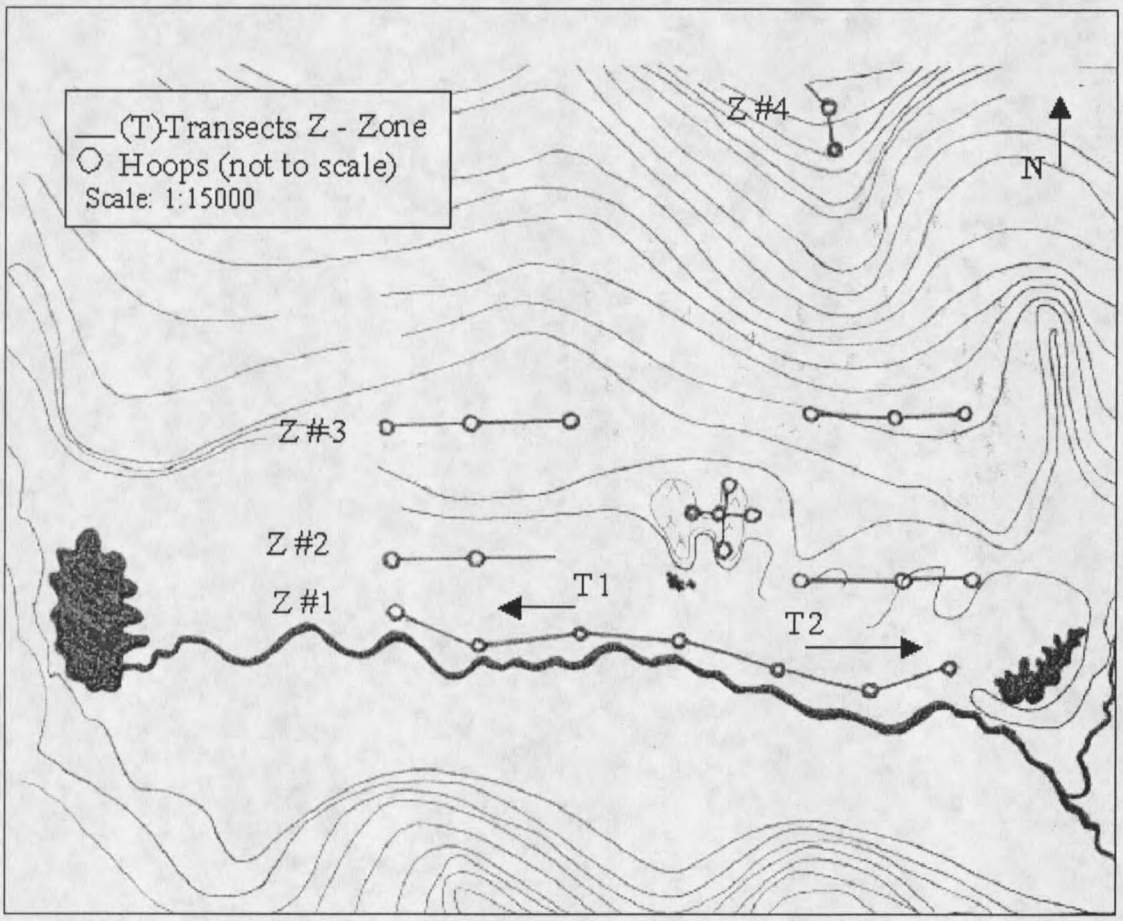


Figure 6. The Joshim site transects

Two transects were established on the north side of the river (Figure 6). The first transect was oriented upstream and the second one followed the river downstream. Transect 1 had three vegetation zones: valley bottom, hillside/terrace and forested upper sideslope, whereas Transect 2 had four zones with the addition of the ridge crest. In addition, five hoops and soil pits were measured inside the campsite.

Dood Saalig

This campsite is named after the Dood Saalig Gol and represents an ungrazed site. Prior to 1999, Dood Saalig was not used for 17 years. However, it was being used in 1996 and during my study visits in 1999 and 2000.

Figure 7. The Dood Saalig Valley

The Dood Saalig Gol flows west to the Tenggis Gol. It originates in two glaciated mountain valleys, both 2-3 km long, which converge to form one major valley. The campsite was located on the stream bank in the middle of this main valley. Khuvsgul Lake Atlas (1989) indicates that this valley is in a southern-Siberian-type landscape with sparse pine trees and shrubs on mountain-valley glayee-tundra soils. This campsite is located in the *Pinus sibirica, Duschekia fruticosa, Rhododendron parvifolium* and *Rosa acicularis* zone of the boreal forest Khuvsgul Lake Atlas, 1989).

Mountain slopes formed in igneous rocks (Khuvsgul Lake Atlas, 1989) are covered with colluvium and residuum, including talus and frost rubble. At the foot of the mountain slopes are alluvial fans spreading into the valleys. The valleys are filled with stream alluvium, including several terraces and flood plain levels, which are now vegetated. Portions of the valley bottoms have frost polygons and rock rubble fields (boulder fields), some of which are covered with ice (Figure 7).

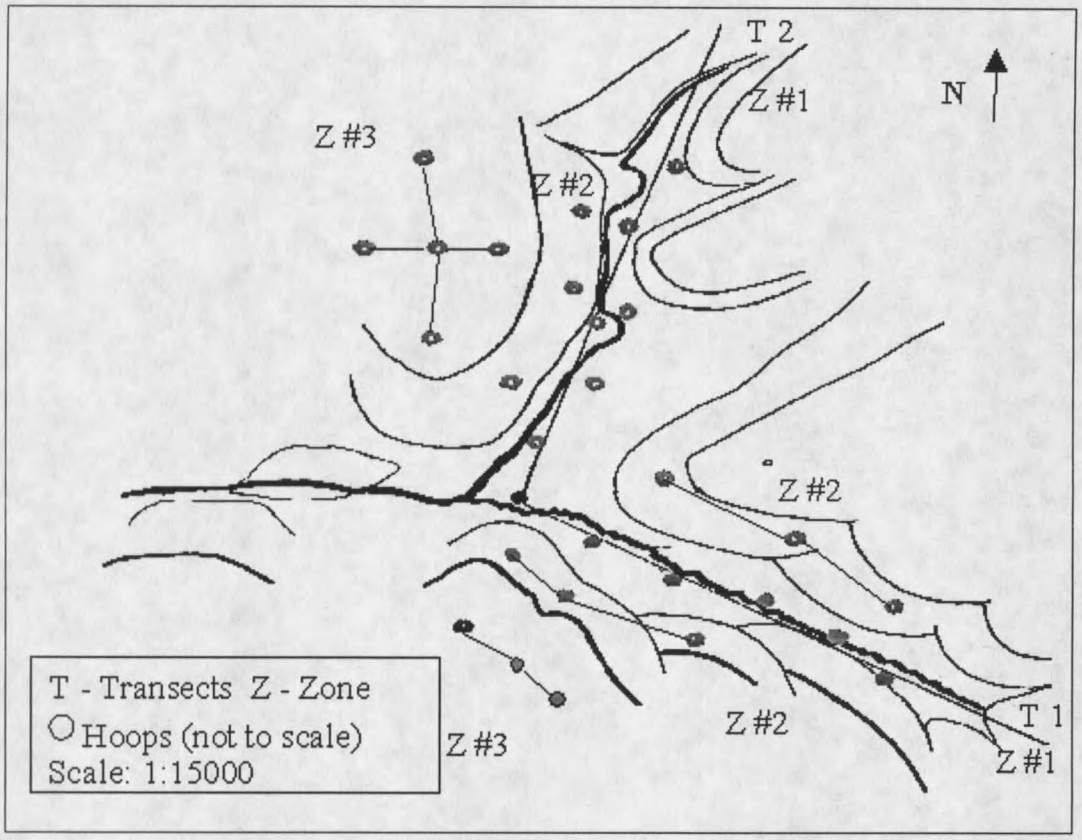


Figure 8. Dood Saalig site transects.

Three zones were established: valley bottom, hillside and mountain ridge crest and labeled as Zone 1, 2 and 3, respectively (Figure 8).

Starting at a horse-tying pole in the middle of the campsite, transects 1 and 2 radiated upstream into each tributary valley (Figure 8). Transect 1, along the eastern tributary, had five hoops along the stream in Zone 1, six hillside hoops in Zone 2 on both sides of the stream, and three mountain ridge crest hoops in Zone 3. Transect 2, which followed the other valley to the northeast, had six hoops in Zone 1, three in Zone 2 and four along the ridgeline in Zone 3.

Terturag

This ungrazed campsite is located at the confluence of Urtun Khyarkh and Terturag Rivers and has not been used by the Tsaatan since 1975 (Figure 9).

The campsite lies to the west of the confluence on a side tributary alluvial fan which cuts through a glacial till at the foot of a north facing mountain slope that is at 2400 meters in elevation. The river flows along a steep eroding terrace scarp on the west side of the valley. This leaves an expansive alluvial valley bottom east of the river, including three small spring fed streams that flow into the main river, the active floodplain level and a well vegetated, higher, less active level of alluvial floodplain. Above that is a glacial till terrace, with dwarf birch and sparse larch trees, and then the mountain slope mantled with colluvium and residium.

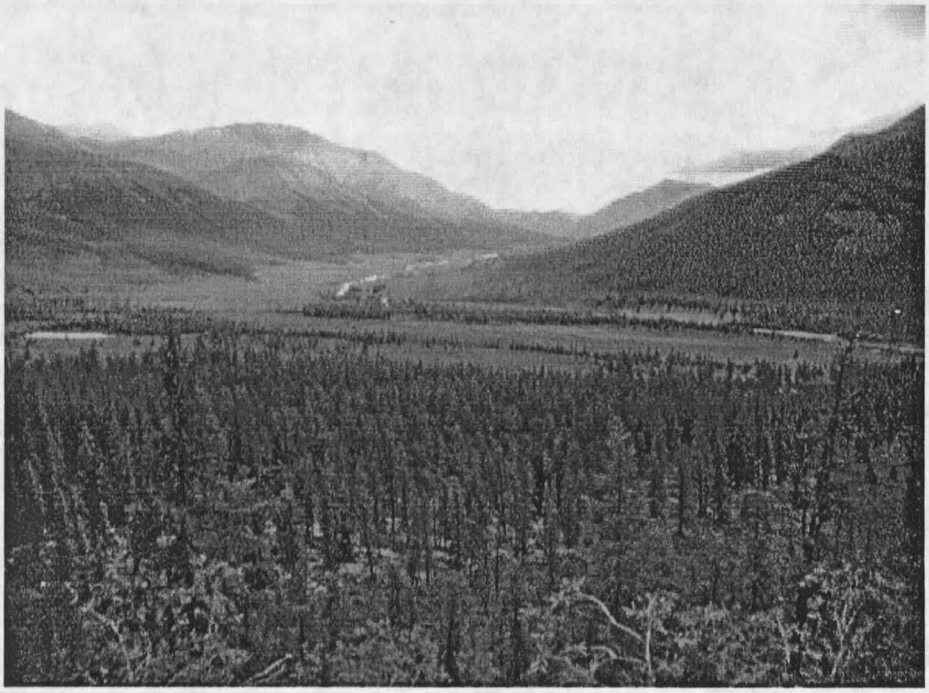


Figure 9. The Terturag site.

The Khuvsgul Lake Atlas (1989) indicates that this valley is in the *Pinus sibirica* and *Larix sibirica* zone with common species including *Hylocomium proliferum, Aulocomnium palustre, Pleurozium schreberi, Rhytidium rugosum, Ptillium crista-castrensis, Climacium dendroides, Mnium affine, Festuca altaica, Bromopsis sibirica* and *Pulsatilla patens.*

The campsite and most of the easily available forage was east of the river. No measurements were taken west of the river. Transect 1 ran along the valley floor with 3 hoops in Zone 1, and no data was collected in any other zones (Figure 10).

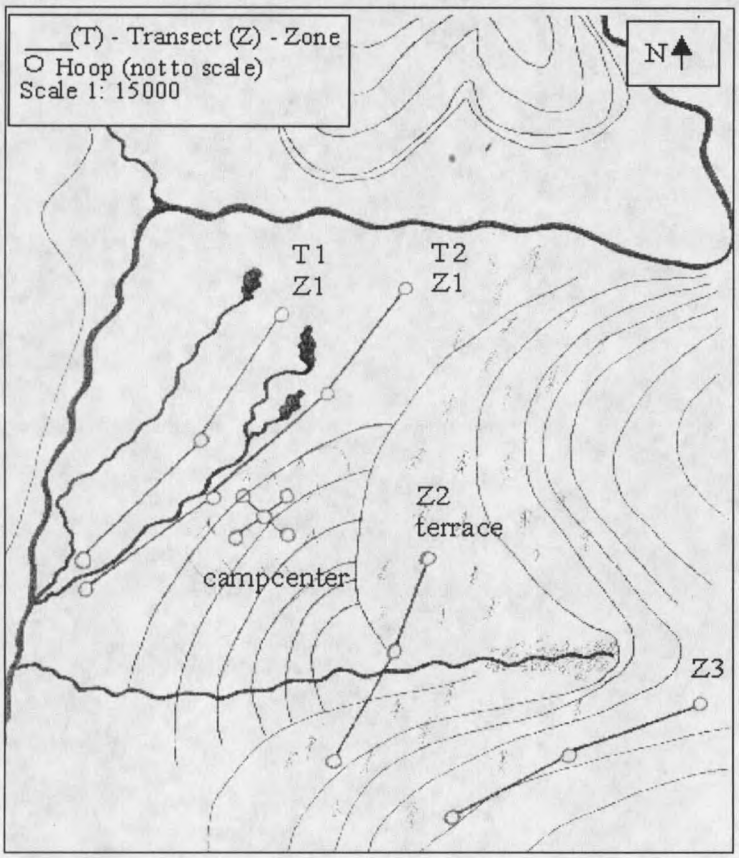


Figure 10. The Terturag site transects.

Transect 2 had four hoops in the valley bottom along a spring creek fed stream, along with three hoops on the hillside and three hoops on the forested upper sideslopes (Figure 10).

RESULTS AND DISCUSSION

This chapter includes both vegetation and soils data. The vegetation portion is divided into 5 parts: 1) overall description of vegetation at all sites, 2) comparison of vegetation characteristics at grazed and ungrazed sites, 3) a summary of vegetation patterns, 4) a rangeland health assessment, and 5) a description of landscape and vegetation.

Vegetation

Vegetation Characteristics

All four campsites were located in glaciated valleys with similar landscape features. Figure 11 shows typical landscape and vegetation characteristics in these valleys Table 1 shows dominant plant species in each zone of all sites. Valley bottoms were often dominated by shrubs, willows and birch, which also made up a large portion of the vegetative cover at the higher terraces or hillsides, with more graminoids and forbs (Table 1). Forested upper sideslopes supported larch trees in addition to the shrubs, graminoids and forbs, whereas ridgetop was always along the ridgelines above the tree line and, therefore, dominated by lichens and *Dryas oxyodonta* (Table 1) (Appendix A for species list).

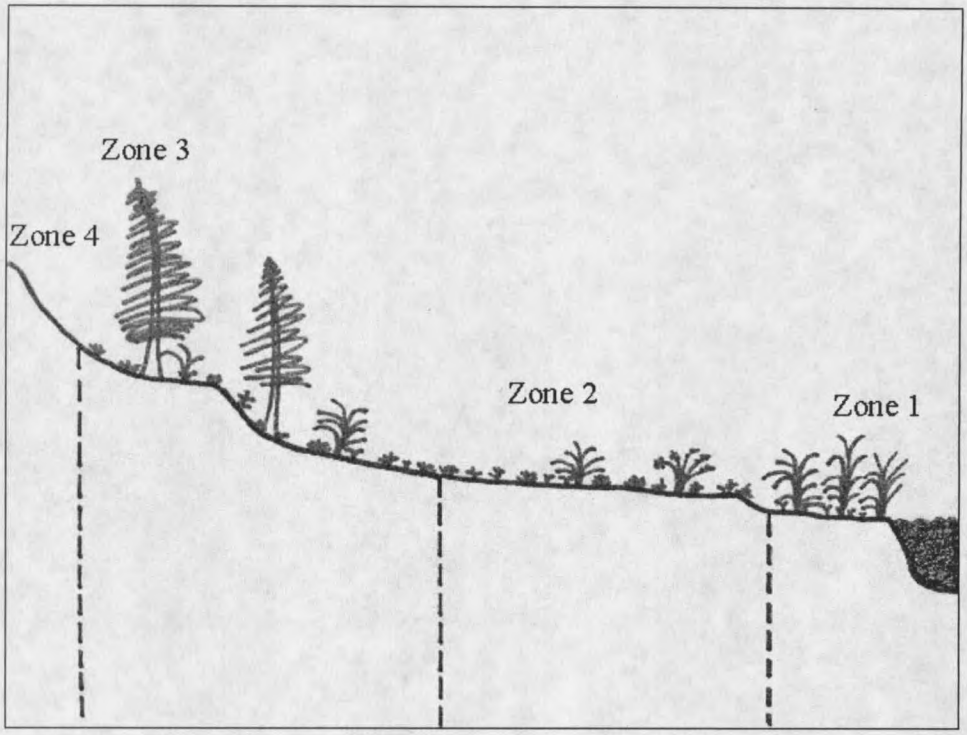


Figure 11. Typical landscape and vegetation.

Table 1. Dominant species in all zones at all sites.

	Valley bottom				Hillside				Upper sideslopes				Ridge top			
Species/Sites	DS[3]	UK	TT	J	DS	UK	TT	J	DS	UK	TT	J	DS	UK	TT	J
Larix sibirica									x	x	x	x				
Juniperus pseudosabina									x	x	x	x				
Betula roduntifolia	x	x	x	x	x	x		x			x					
Betula berberis	x															
Betula fusca								x				x				
Salix divaricata	x	x	x													
Salix glauca	x	x			x											
Salix caesia									x		x	x	x			
Salix spp.			x	x				x								
Potentilla fruticosa	x	x														
Rhododendron parvifolium					x											
Rhododendron adamsti						x		x	x		x					
Rhododendron aurium											x					
Spirea spp.			x							x	x	x				
Vaccinium vitis-ideae									x	x	x	x				
Vaccinium uligonosum											x					
Astaragalus spp.		x														
Cladonia rangiferena			x						x	x	x	x	x			x
Dryas oxyodonta													x			x
Inpetioum nigrium									x		x		x			
Poaceae spp.	x		x			x		x				x	x			
Carex spp.	x		x	x				x			x	x				
Ledum palustre								x	x	x		x				
Aconitum chenxanovskii			x													

[3] DS-Dood Saalig UK-Urtun Khyarkh TT-Terturag J-Joshim

Comparison of Vegetation Characteristics at Grazed and Ungrazed sites

Table 2 shows average values for each variable measured within the large hoops and Table 3 those within the small hoops. These variables are grouped by each zone across all four sites, including the camp centers and compared between the grazed versus ungrazed treatments. Data from large hoops and small hoops were analyzed separately. Analysis of all four zones will be discussed separately with each zone divided into large hoop and small hoop data analysis.

Table 2. Means of measurements[4] made within the large hoops and P-values from all zones at grazed and ungrazed sites

Campcenter	Grazed	Ungrazed	P-values
# of species	11 (±4.1)	7(±1.1)	0.09
% graminoids	22.4 (±26.7)	24(±16.3)	0.91
% forbs	8.6 (±6.8)	4.2(±3.9)	0.25
% shrubs	24 (±19.8)	58(±26.5)	0.05
% lichens	2(±2.7)	12(±13)	0.13
% other species	0(±0)	0(±0)	
Shrub height (cm)	44.6(±23.5)	57(±23.8)	0.43
% leaves on shrubs	65(±20)	29(±16.3)	0.01
% bare ground	14(±15.5)	0(±0)	0.07
% litter	30(±17.6)	22.5(±21.7)	0.58
Zone 1			
# of species	7.6(±3.1)	5.8(±2.9)	0.001
% graminoids	37.9(±25)	21.2(±31)	0.12
% forbs	4.2(±3)	2.4(±3.6)	0.20
% shrubs	37.9(±24.3)	72.7(±28.2)	0.17
% lichens	0(±0)	2.9(±6.2)	0.17
% other species	13.7(±22)	0(±0)	0.001
Shrub height (cm)	41.2(±13.6)	83(±46)	0.01
% leaves on shrubs	42(±27.9)	23(±19.5)	0.01
% bare ground	5.4(±6.3)	0(±3.6)	0.003
% litter	20(±25)	30(±23.1)	0.46

[4] Each value is the least squares mean of all values across the transects of that zone occurring at all sites. Data for each zone are subsequently presented in figures. Blank space indicates missing data.

Table 2 continued...

Zone 2			
# of species	7(±3.5)	6.3(±1.7)	0.38
% graminoids	27(±14.9)	23(±21.6)	0.38
% forbs	32(±21.4)	1(±3.8)	<.00
% shrubs	49.6(±20.7)	54(±17.5)	0.71
% lichens	3(±3.8)	15(±13.1)	0.01
% other species	12.3(±14.1)	8.9(±20)	0.77
Shrub height (cm)	51.1(±25.8)	56.6(±69)	0.66
% leaves on shrubs	51.2(±17.7)	35.7(±25.6)	0.029
% bare ground	6.6(±17.3)	6.6(±15.7)	0.93
% litter	8(±5.2)	8(±2.6)	1
Zone 3			
# of species	10.5(±3.8)	6.1(±2.4)	0.005
% graminoids	16.6(±7.7)	1.8(±4)	0.001
% forbs	19.1(±12)	0.1(±0.4)	0.000
% shrubs	44.1(±20.5)	24.4(±11.2)	0.09
% lichens	5(±5.9)	36.3(±31)	0.01
% other species	21(±20.4)	13.5(±15.8)	0.02
Shrub height (cm)	58.3(±4.9)	51.6(±58.5)	0.77
% leaves on shrubs	55(±17.2)	27(±11.5)	0.63
% bare ground	7.5(±3.7)	27(±36.6)	0.14
% litter	4.1(±8)		
Zone 4			
# of species	11.6(±5)	5.7(±1.2)	0.06
% graminoids	18.3(±18.9)	14.2(±20.5)	0.7
% forbs	46.6(±11.5)	18.7(±22.5)	0.11
% shrubs	1(±1.7)	17.5(±17)	0.16
% lichens	11(±16.5)	16.2(±7.5)	0.59
% other species	4(±5.2)	11.5(±8.3)	0.23
Shrub height (cm)	6.6(±11.5)	30(±10.6)	0.22
% leaves on shrubs	22.5(±51.9)	57.5(±10.6)	0.53
% bare ground	5(±8.6)	25(±15.8)	0.10
% litter	4(±1.7)		

Table 3. Means of measurements[5] made within the small hoops and P-values from all zones at grazed and ungrazed sites

Campcenter	Grazed	Ungrazed	P-value
# of species	5.2 (±1.6)	5.2(±3.3)	1
% graminoids	26(±30.2)	15(±11.1)	0.46
% forbs	12(±11.5)	14(±16.5)	0.81
% shrubs	2(±4.4)	27(±42.6)	0.22
% lichens	2.4(±3.3)	10(±14.1)	0.27
% other species	15(±30.8)	18(±30.3)	0.88
Shrub height (cm)	8(±17.8)	23(±33)	0.39
% leaves on shrubs	10(±22.3)	15(±30.8)	0.77
% bare ground	8(±15.2)	0(±0)	0.27
% litter	36.6(±32.6)	16(±13.8)	0.23
Biomass weight (g)	11.8(±9.3)	14.2(±29.5)	0.69
Zone 1			
# of species	4.6(±2.4)	2.8(±1.5)	0.03
% graminoids	31.4(±33.8)	22.5(±35.8)	0.53
% forbs	4.1(±12.2)	2.4(±7.9)	0.20
% shrubs	35.8(±31.3)	70(±33.3)	0.01
% lichens	0(±0.4)	2.8(±10.3)	0.55
% other species	7.2(±9.7)	0(±0)	0.00
Shrub height (cm)	17.8(±11.8)	47.7(±47.3)	0.15
% leaves on shrubs	52.5(±28.9)	20.6(±22.7)	0.02
% bare ground	10(±13.8)	0(±0)	0.01
% litter	15(±22.5)	34(±26.2)	0.20
Biomass weight (g)	20(±17.6)	35(±31.7)	0.31
Zone 2			
# of species	4.3(±1.4)	3.6(±1.5)	0.32
% graminoids	17.9(±15.1)	20.2(±21)	0.88
% forbs	6.9(±5.7)	2.9(±12.8)	0.50
% shrubs	41.7(±31.7)	34(±26.1)	0.53
% lichens	4(±7.3)	15.8(±21.1)	0.19
% other species	9(±7.8)	17(±21.1)	0.24
Shrub height (cm)	18(±35)	20.3(±18.9)	0.99
% leaves on shrubs	13(±18.2)	46(±47.2)	0.15
% bare ground	10(±7.5)	2.5(±16)	0.49
% litter	27(±19.5)	10(±8.6)	0.23
Biomass weight (g)	13.5(±7.5)	28(±38.2)	0.16

[5] Each value is the least squares means of all values across the transects of that zone occurring at all sites. Data for each zone are subsequently presented in figures. Blank space indicates missing data.

Table 3 continued…

Zone 3			
# of species	5.2(±2.7)	3(±1.5)	0.06
% graminoids	14(±14.8)	3.4(±2.7)	0.24
% forbs	10(±12)	0(±0)	0.22
% shrubs	41(±27.7)	5(±15)	0.7
% lichens	6.8(±7.9)	41.5(±40.1)	0.11
% other species	26(±21.3)	0.5(±0.5)	0.11
Shrub height (cm)	35(±14.1)	6(±11.5)	0.02
% leaves on shrubs	60.8(±19)	6(±11.5)	0.00
% bare ground	7.5(±26.9)	40(±53.1)	0.27
% litter	15(±12.5)	3(±2.6)	0.59
Biomass weight (g)	13(±8.8)	93(±63.2)	0.00
Zone 4			
# of species	4.6(±1.5)	6(±3.4)	0.57
% graminoids	12(±20.8)	25(±7)	0.73
% forbs	56.6(±20.8)	0(±0)	0.03
% shrubs	0(±0)	25(±7)	0.00
% lichens	12(±19.6)	25(±17.3)	0.27
% other species	0(±0)	2.5(±3.5)	
Shrub height (cm)	0(±0)		
% leaves on shrubs	0(±0)		
% bare ground	9.6(±4.7)	22.5(±10.6)	0.14
% litter	5.3(±7.5)		
Biomass weight (g)	24(±22.5)	88.5(±55.8)	0.15

Camp center

Large hoops

Vegetation at one grazed and one ungrazed camp center was compared (Tables 2 and 3). The grazed campsites had a significantly greater number of species and less percent shrub cover. Percent of shrub branches with green biomass was significantly less in ungrazed sites than in grazed sites. This agrees with the overall trend of decadent shrubs at the ungrazed sites, which had very sparse green biomass on them (personal observation 1999 and 2000). Moreover, percent bare ground at grazed camp centers was

greater than at ungrazed sites. This could be due to trampling and higher concentration of both animal and human impact within the camp center (personal observation, 1999 and 2000). However, percent cover of graminoids, forbs, lichens, other species and litter were not significantly different under the two treatments (Figure 12).

Small hoops

Number of species within small hoops also differed between the grazed and ungrazed campsite centers (Table 3). All other variables, percent cover of shrubs, graminoids, forbs, lichens, other species, bare ground and litter as well as shrub height, percent leaves were not different, possibly, due to high variability.

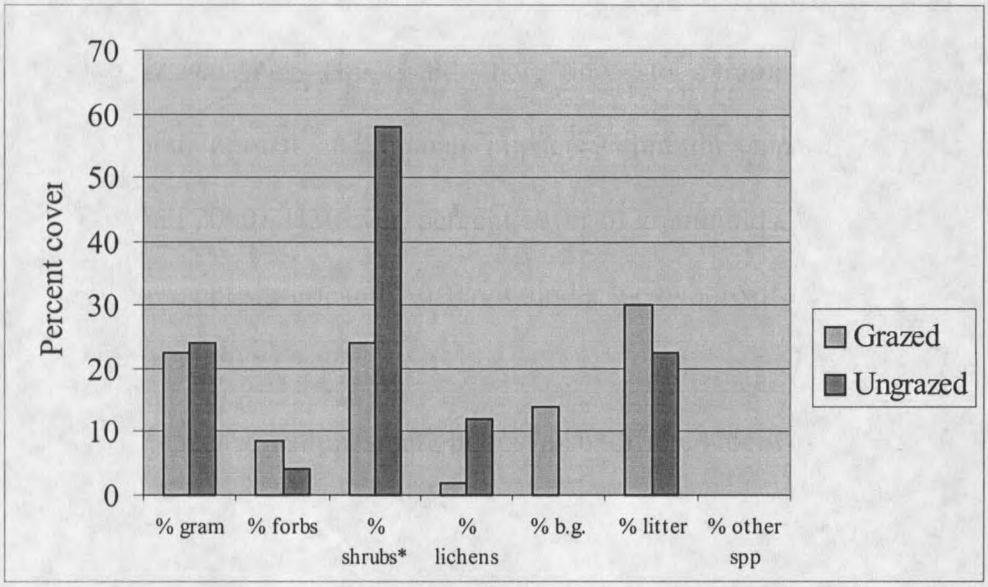


Figure 12. Vegetative cover of camp centers at grazed and ungrazed sites[6].

<u>Zone 1 - Valley bottom</u>

Large hoops

Number of species and percent shrub cover in this zone differed between the grazed and ungrazed sites (Figure 13). Grazed sites had greater number of species and less percent shrub cover than ungrazed sites.

Percent cover of other species and bare ground were also less at ungrazed sites than at grazed sites. Given this research method, canopy cover (percent ground cover) could not exceed 100 percent. Therefore, all variables have direct impact on each other. High percent cover of shrubs at the ungrazed sites must have caused reduced percent cover of other species. Other variables including percent cover of graminoids, forbs, lichens and litter were not different (Figure 13).

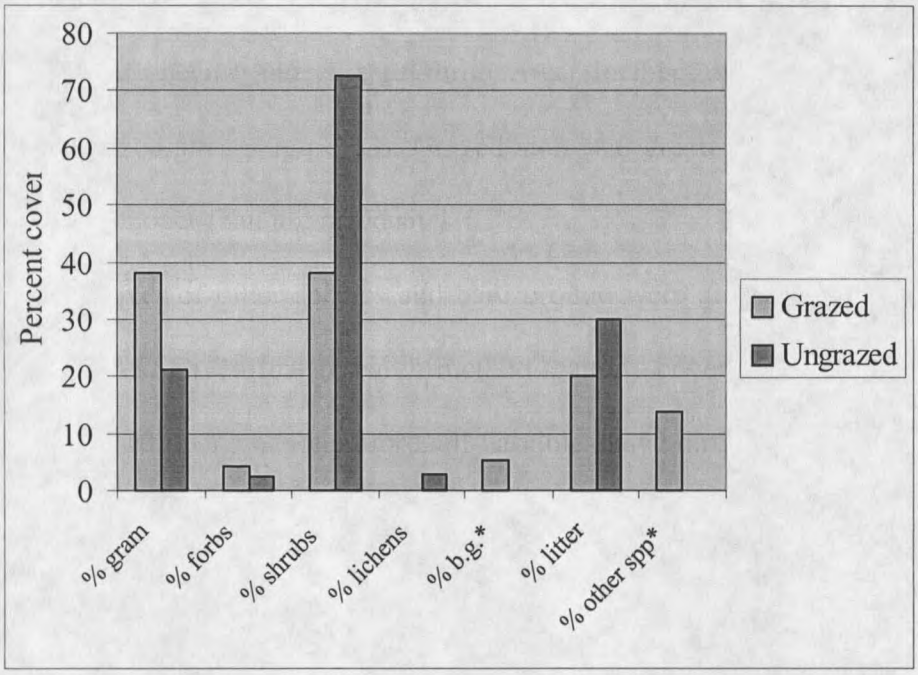


Figure 13. Valley bottom vegetation cover at grazed and ungrazed sites.

[6] * in the graphs indicate significant differences.

Average shrub heights at grazed and ungrazed sites did not differ significantly, but their means were 41 cm at grazed sites and 83 cm at ungrazed, which seemed considerably different. Percent of branches with leaf cover was used to indicate shrub vigor. Mean percent leaves was significantly different under the two treatments (Table 2). Percent leaves at grazed sites was greater than that of ungrazed sites, even though a large portion of the shrubs were browsed at grazed sites during the sampling season, especially in valley bottom, where the herd was heavily concentrated (personal observation, 1999 and 2000). This shows that the shrubs at ungrazed sites with long gray branches and very little green biomass on them were much less vigorous than at grazed sites.

Small hoops

Number of species and percent cover of shrubs within the small hoops were significantly different between grazed and ungrazed sites (Table 3). Average number of species at grazed versus ungrazed sites was 4.6 and 2.8 with a mean shrub cover of 35 and 70 percent, respectively. This agreed with the expected lower shrub cover at grazed sites due to browsing impact (Ouellet et al. 1994; Manseau et al. 1996). Although not statistically significant, grazed sites also had much less average green biomass (25g compared to 35g) than ungrazed sites, which agreed with Crete et al.s (1998) and Manseau et al.s (1996) study showing that leaf biomass was reduced by caribou grazing. In addition, percent cover of other species was different, with means of 7 and 0 at grazed and ungrazed sites, although percent cover of graminoids, forbs, lichens and litter did not differ (Table 3). Percent bare ground at grazed sites was greater with its mean of 10

compared to 0 at ungrazed sites, which again could be due to heavier use by animals (Manseau et al., 1996) as well as flooding events, since this zone is in the riparian area (Figures 4, 6, 8 and 10).

Zone 2 -Hillsides

Large hoops

In contrast to the increased number of species and decreased percent shrub cover associated with grazed sites of valley bottom and the campcenters, hillside number of species, shrub cover and height did not differ (Table 2). However, percent leaves was greater at grazed sites versus ungrazed. Meanwhile, percent cover of forbs was greater at grazed sites than at ungrazed sites, with means of 32 and 1.6 percent, respectively (Table 2). This may imply that preferred species on the hillsides are different than those in valley bottoms. Species preference could vary due to topographic positions (Archer and Smeins, 1991). Species tolerance to grazing can also differ across the landscape due to topographic locations (Archer and Smeins, 1991). Average graminoid cover was 27 and 23 percent at grazed and ungrazed sites and did not differ.

Percent lichen cover in this zone was one variable that was lower at grazed sites with a mean of 3 percent versus 15.3 percent at ungrazed sites. Since Zone 2 was established on terraces which received less grazing and browsing that the floodplains, it provided a better habitat for lichens. Grazing can seriously impact lichen mats and reduce their cover (Manseau et al., 1998). Percent cover of litter, other species and bare ground did not differ between grazed and ungrazed sites (Figure 14).

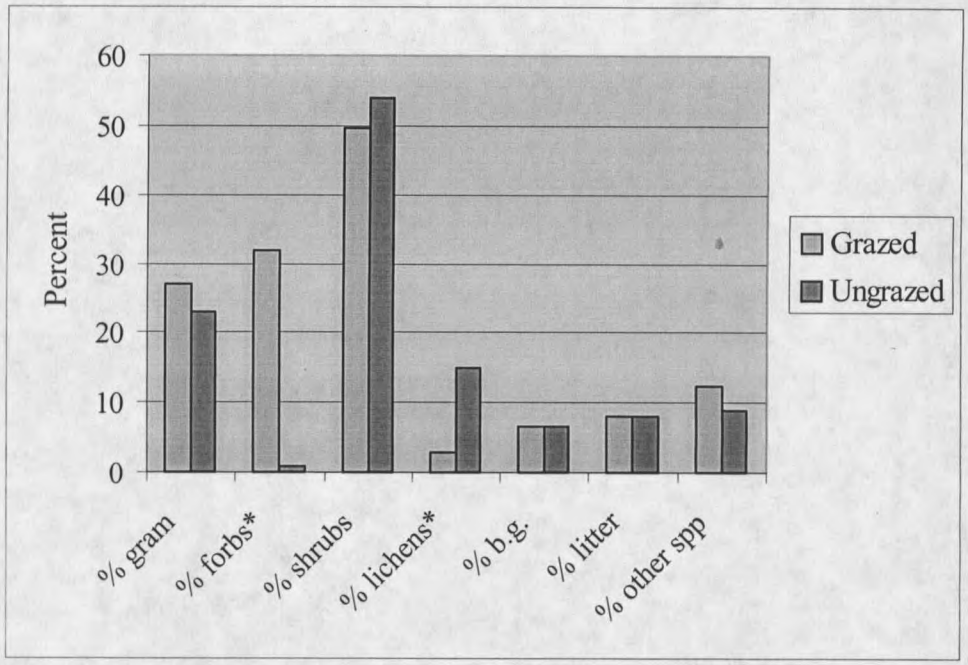


Figure 14. Hillside vegetation cover at grazed and ungrazed sites.

Small hoops

No variable within the small hoops differed significantly between grazed and ungrazed sites, although some of them had fairly contrasting means (Table 3). Mean number of species and percent cover of graminoids and shrubs were similar at grazed and ungrazed sites. Nonetheless, average percent cover of forbs was 7 and 3, whereas lichen covered 4 and 16 percent at grazed and ungrazed sites, respectively. Average percent cover of other species in ungrazed and grazed sites were 9 and 18, respectively, but showed no statistical significance. Although the mean shrub heights were very similar at grazed and ungrazed sites (18 and 20 cm, respectively), percent leaves were again

substantially different. Grazed sites had 13 percent of shrub branches covered with leaves, on average, whereas ungrazed sites had 47 percent leaves on shrubs. This could have contributed to the difference in the total green biomass weights, although not significant at the confidence level of 95 percent. Average green biomass weight at grazed sites was 13 g and 28 g at ungrazed sites.

Zone 3 – Forested upper sideslopes

Large hoops

Number of species in Zone 3 at grazed sites (average 10.5) was greater than 6 at ungrazed sites (Table 2).

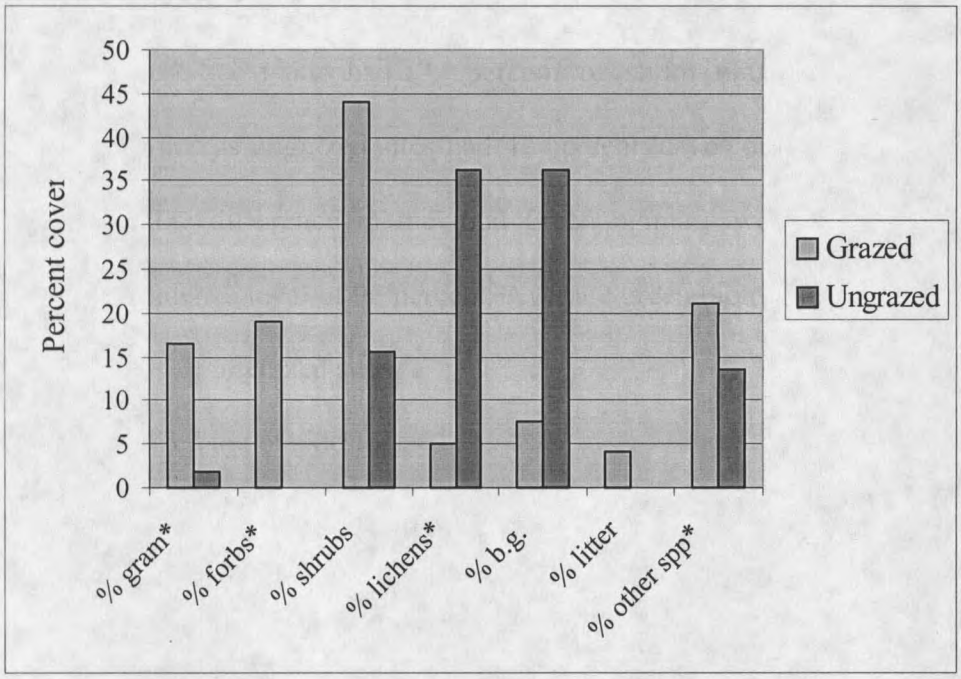


Figure 15. Upper sideslope vegetation cover at grazed and ungrazed sites.

Interestingly, quite a few of the variables are greater at grazed sites than at ungrazed sites (Figure 15). Percent cover of graminoids differed significantly, which was not the case in any of the other zones, with 17 at grazed sites and 1 percent at the ungrazed. Forbs, with a mean of 19 at the grazed sites, also covered a significantly greater percent of area than at the ungrazed sites. This increased cover of forbs resulted in reduced shrub cover in other zones, but did not in this zone. Percent shrub cover was still high at grazed sites. Indeed, shrubs covered a greater percentage than at ungrazed sites, which is the opposite of that observed in other valley bottoms and on hillsides. This could mean that at higher elevations, the preferred species are different and shrubs are not browsed as often as they are at lower elevations (Archer and Smeins, 1991). This is supported by the fact that the lichen covered 5 percent at grazed sites and 36 at ungrazed sites, which was significantly different. Lichens occur more commonly at higher elevations (Topham, 1974) and are one of the preferred reindeer forages (Manseau et al., 1996, Tsogt, 1992). Since elevations and landscape positions were similar in Zone 3 at these sites (personal observation, 1999 and 2000), grazing impact could be the main reason for differing lichen covers. Other studies have also shown that lichen covers at grazed sites are much less than at sites that are not used (Manseau, 1998).

Percent cover of other species was greater at grazed sites. Mean height of shrubs and average percent leaves were not significantly different. Average percent leaves were 55 and 50 at grazed and ungrazed sites, respectively. Percent bare ground at ungrazed sites was much greater with a mean of 27 percent compared to 7.5 at grazed sites, but this difference was not significant. This difference may be the result of differing surface cover

of rocks. Much of the lichen cover and other plant species were from previous years and had no new growth in them at ungrazed sites. This may have contributed to the greater percent cover of litter (Table 4).

Small hoops

Small hoop data in Zone 3, forested upper sideslopes, showed fairly similar results to those from the large hoops (Table 3). Average number of species in grazed sites was 5, which was again greater compared to 3 at ungrazed sites. Percent shrub cover at grazed sites was also greater with its mean of 45 percent compared to 5 at ungrazed sites. There were no significant differences in percent cover of graminoids and forbs, even though their means were considerably different. Yet, green vegetation biomass weight at ungrazed sites was significantly greater. The mean weight was 93 g, whereas the biomass at grazed sites weighed only 13 g, which could have been due to the great difference in lichen covers (Table 2) (Table 4). The mean percent lichen cover was 6 at grazed and 42 at ungrazed sites. This, again, agrees with Manseau et al.s (1996) conclusions regarding reindeer impact on lichens.

Zone 4 –Ridge top

Large hoops

Zone 4 was established at ridgelines and often represented alpine vegetation (Figure 15). Number of species in this zone also differed significantly and was greater at grazed sites. Forbs and graminoids had considerably different cover under the two treatments, but were not significantly different. Furthermore, percent shrub cover did not differ statistically between the two sites, although the means were 1 percent at grazed

sites and 17.5 at ungrazed sites. Percent cover of lichens and other species also showed the same trend. Means that are apparently different in this zone may have been statistically insignificant due to greater errors and fewer degrees of freedom, since only Joshim and Dood Saalig sites had a transect which included Zone 4. This resulted in a small number of hoops, which affords the statistical model less degrees of freedom than for other zones.

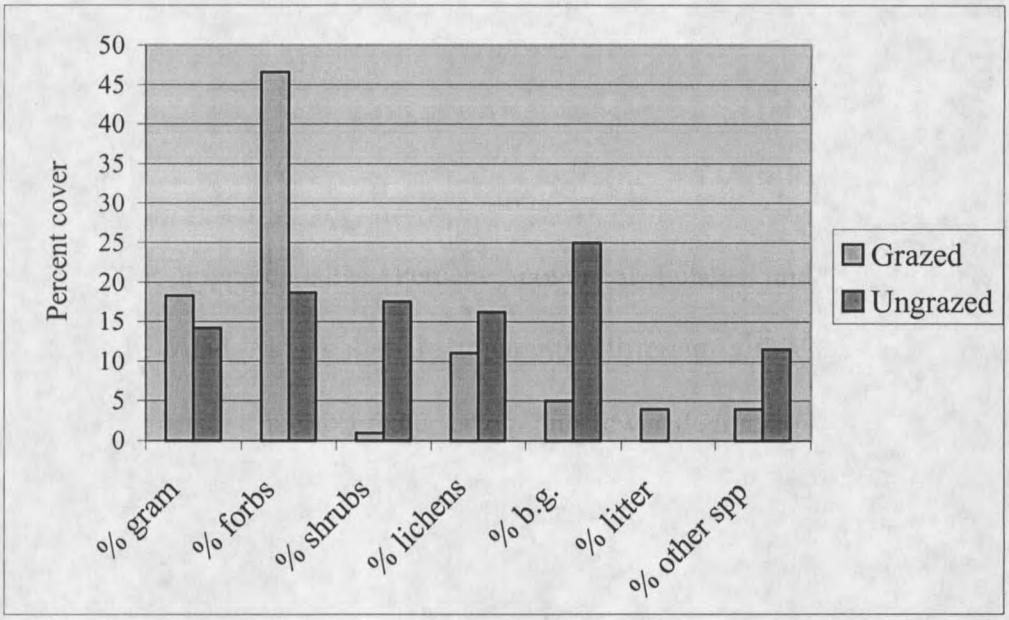


Figure 16. Zone 4 vegetation at grazed and ungrazed sites.

The other cover data that was different, but not significantly, in Zone 4 was that of percent bare ground. Ungrazed sites again had 25 percent bare ground, a much greater value than at grazed sites. This might have been the case due to differing percent cover of rocks at these two sites. Shrub height and percent leaves are two more variables in this zone that did not prove statistically significant, but whose means differed substantially.

The lower height and percent leaves at the grazed site were consistent with what was to be expected (Doucet, 1998; Manseau et al., 1996) since the reindeer forage quite commonly at higher elevations (Tsaatan, personal communication, 1999 and 2000).

Small hoops

Data from small hoops did not show much difference between grazed and ungrazed sites. Number of species, percent cover of graminoids, other species and bare ground were not different (Table 3). However, percent cover of forbs and shrubs did differ. Ungrazed sites again had much greater percentage covered with shrubs than the grazed sites. Forbs at the grazed site covered 56 percent of the area and 0 percent at the ungrazed. SAS statistical software could not produce results for comparison of average shrub heights and percent leaves within the small hoops. Lastly, the mean biomass weights at the two sites did not differ statistically, although the means were 24 g and 88.5 g at grazed and ungrazed sites.

Summary of vegetation patterns

Provided with the above discussion of vegetation comparison within the zones, the average number of species was significantly greater in all zones of grazed sites except in Zone 2 (Figure 17).

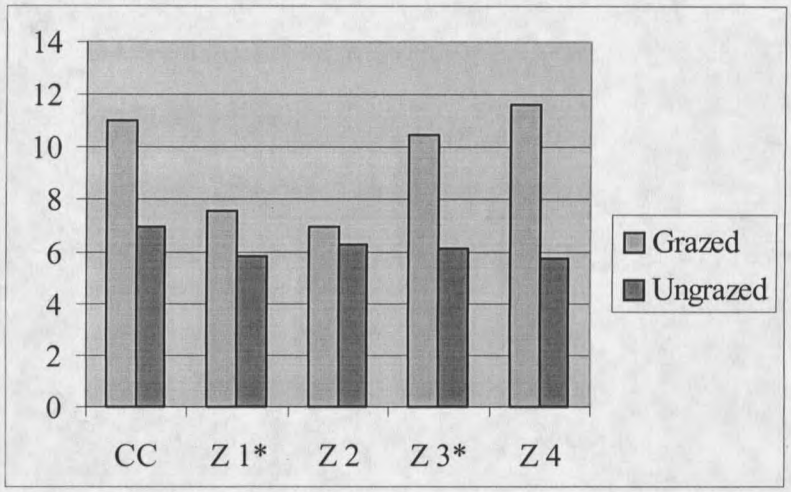


Figure 17. Number of species in all zones at grazed sites and ungrazed sites.

Percent shrub cover showed the same overall trend and was greater at ungrazed sites where the browsing impact was less (Manseau et al., 1998) (Figure 18). Percent shrub cover did not differ between grazed and ungrazed sites in Zone 2. What's more, Zone 3 at grazed sites had greater shrub percent cover than ungrazed sites, which was the opposite of what was expected (Manseau et al., 1998). This may mean that browsing impact is greatest in valley bottoms and gradually decreases towards higher elevations (Archer and Smeins, 1991).

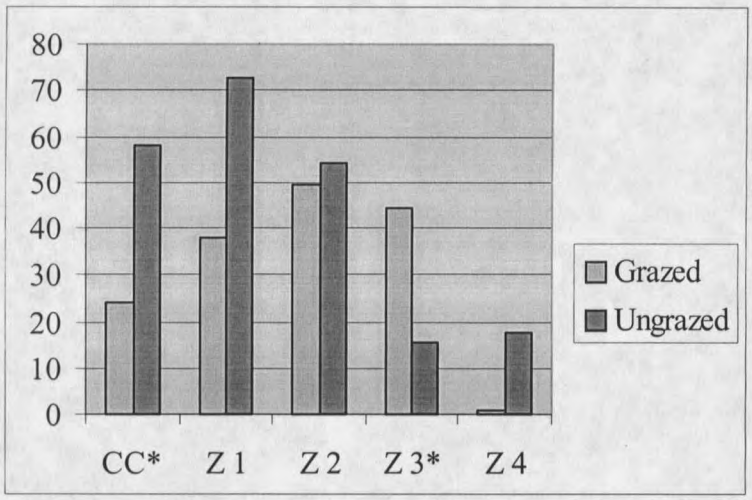


Figure 18. Percent cover of shrubs in all zones at grazed and ungrazed sites.

Grazed sites had a greater number of species, but smaller percent shrub cover, while ungrazed sites had smaller number of species with greater percent shrub cover. In an attempt to identify if a relationship existed between percent shrub cover and number of species, average percent shrub cover from all transects in valley bottom at all four sites was plotted against the mean number of species from those transects (Figure 19). However, Figure 19 shows that there is no strong correlation between the two.

Similarly, percent shrub cover was plotted against percent cover of other functional groups: graminoids, forbs, lichens and other species (Figure 20). Although increased shrub cover did not reduce the number of species, it decreased percent cover of graminoids, forbs and lichens (Table 4). As Figure 20 shows, graminoids, forbs and lichens occur only when the shrub cover is less than 20 percent.

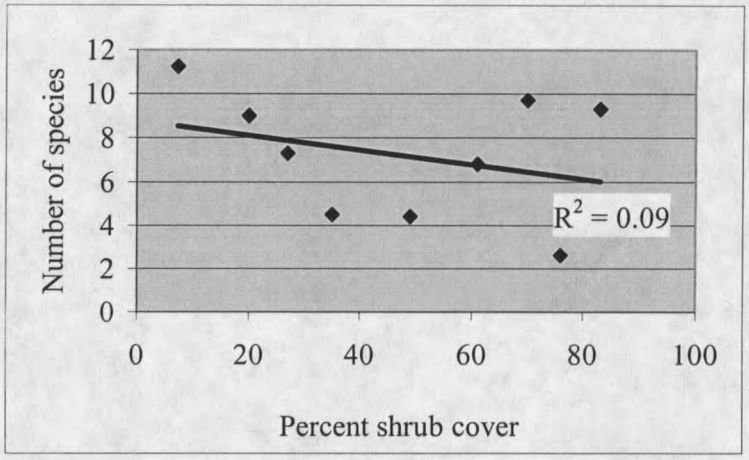


Figure 19. Number of species vs percent shrub cover

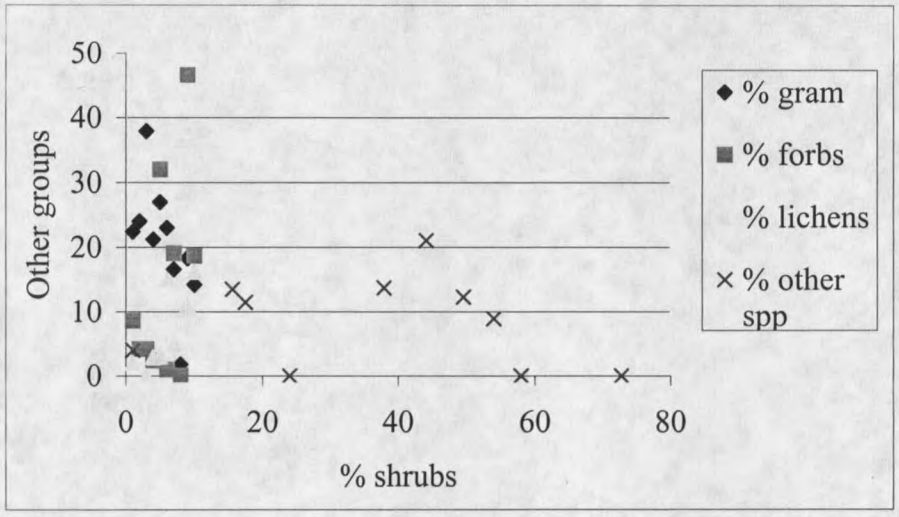


Figure 20. Percent cover of shrubs vs other functional groups

Moreover, the total percent cover of graminoids, forbs and lichens decreases as percent cover of shrubs increases (Figure 22) (Table 4).

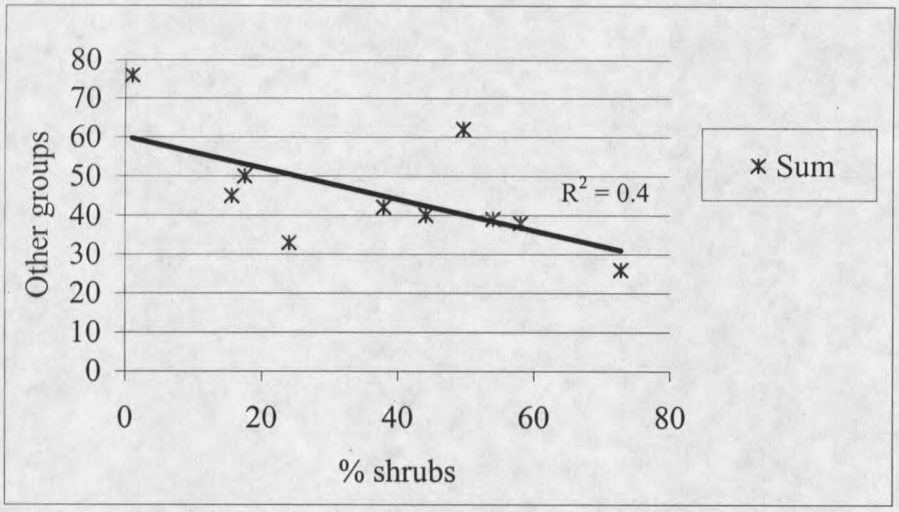


Figure 21. Total percent cover of graminoids, forbs and lichens vs shrubs

Table 4. Correlation matrix of all variables in all zones

	Variables	# spp	% gram	% forbs	% shrub	% lichen	% othrspp	shrubhgt	% leaves	bare gr	litter
Campcenter	# spp	1									
	% gram	0.39	1								
	% forbs	0.68	0.77	1							
	% shrubs	-0.28	-0.49	-0.52	1						
	% lichen	-0.09	0.28	-0.28	-0.026	1					
	% othrspp						1				
	shrubhgt	-0.28	-0.63	-0.39	0.497	-0.20		1			
	leaves	0.60	0.30	0.56	-0.487	-0.36		-0.61	1		
	bare gr	-0.26	-0.40	-0.18	-0.52	-0.37		0.06	0.21	1	
	litter	-0.27	-0.16	-0.32	-0.51	0.50		-0.02	-0.27	0.57	1
Zone 1	# spp	1									
	% gram	-0.34	1								
	% forbs	0.28	-0.06	1							
	% shrubs	-0.01	-0.84	-0.10	1						
	% lichen	0.04	-0.24	0.15	0.12	1					
	% othrspp	0.47	-0.07	0.03	-0.38	-0.13	1				
	shrubhgt	-0.08	-0.46	-0.19	0.58	-0.06	-0.21	1			
	leaves	0.36	-0.16	0.30	0.08	0.17	-0.10	-0.39	1		
	bare gr	-0.08	-0.03	-0.14	-0.13	-0.11	-0.04	0.02	-0.10	1	
	litter	-0.20	-0.24	0.10	0.30	-0.18	-0.33	0.36	-0.46	-0.19	1
Zone 2	# spp	1									
	% gram	0.01	1								
	% forbs	-0.01	0.81	1							
	% shrubs	0.10	-0.23	-0.28	1						
	% lichen	-0.12	-0.68	-0.35	-0.15	1					
	% othrspp	-0.20	0.24	0.02	-0.36	-0.26	1				
	shrubhgt	-0.01	-0.31	-0.27	0.24	0.37	-0.03	1			
	leaves	0.59	0.36	0.44	0.00	-0.15	-0.22	-0.27	1		

Table 4 continued

	bare gr	-0.05	-0.30	-0.09	-0.43	0.28	-0.10	-0.27	-0.17	1	
	litter	0.04	-0.18	-0.46	0.07	-0.30	-0.88	-0.16	-0.02	0.93	1
Zone 3	# spp	1									
	% gram	0.50	1								
	% forbs	0.51	0.58	1							
	% shrubs	0.44	0.34	0.27	1						
	% lichen	-0.48	-0.40	-0.44	-0.38	1					
	% othrspp	-0.08	-0.01	0.12	-0.34	-0.22	1				
	shrubhgt	-0.11	0.00	-0.03	-0.09	-0.32	-0.10	1			
	leaves	0.28	-0.02	0.48	0.47	-0.40	0.20	-0.32	1		
	bare gr	-0.51	-0.44	-0.39	-0.72	-0.16	0.01	0.71	-0.43	1	
	litter	-0.69	-0.08	-0.56	0.13	-0.14	-0.41	0.46	-0.71		1
Zone 4	# spp	1									
	% gram	0.57	1								
	% forbs	0.38	0.21	1							
	% shrubs	-0.36	-0.31	-0.86	1						
	% lichen	-0.58	-0.52	-0.61	0.47	1					
	% othrspp	-0.42	-0.65	-0.49	0.49	0.09	1				
	shrubhgt	-0.49	-0.58	-0.44	0.82	0.05	0.71	1			
	leaves	-0.33	-0.50	-0.08	0.46	-0.27	0.69	0.88	1		
	bare gr	-0.61	-0.59	-0.31	0.27	0.04	0.89	0.67	0.65	1	
	litter	0.11	0.38	-1.00	-1.00	0.58	-0.98	-1.00	-1.00	-1	1

Table 5. Covariance of all variables in all zones

		# spp	% gram	% forbs	% shrub	% lichen	% othrspp	shrubhgt	% leaves	bare gr	litter
Campcenter	# spp	10.6									
	% gram	25.8	394.2								
	% forbs	12.2	84.1	30.0							
	% shrubs	-24.7	-263.2	-76.4	729.0						
	% lichen	-2.9	53.6	-15.3	-7.0	96.0					
	% othrspp	0.0	0.0	0.0	0.0	0.0	0.0				
	shrubhgt	-20.7	-274.1	-46.6	296.2	-43.1	0.0	487.8			
	leaves	47.1	145.6	75.2	-319.5	-86.5	0.0	-327.6	591.0		
	bare gr	-10.4	-95.4	-11.8	-169.5	-44.0	0.0	16.9	61.0	146.0	
	litter	-16.1	-57.4	-30.6	-257.4	56.5	0.0	-8.1	-123.1	125.9	311.1
Zone 1	# spp	9.94									
	% gram	-31.04	816.40								
	% forbs	3.18	-6.47	11.96							
	% shrubs	-0.73	-737.84	-10.34	922.03						
	% lichen	0.59	-34.29	2.63	18.30	24.79					
	% othrspp	22.13	-29.75	1.64	-171.27	-9.53	220.25				
	shrubhgt	-10.19	-507.16	-26.03	719.80	-12.99	-130.64	1684.53			
	leaves	27.95	-114.17	26.19	56.92	20.56	-35.49	-394.42	595.76		
	bare gr	-1.16	-4.29	-1.49	-18.72	-2.72	-3.05	3.36	-11.73	21.88	
	litter	-8.46	-125.77	6.15	184.62	-26.15	-13.46	321.15	-253.85	-5.77	526.92
Zone 2	# spp	7.378685									
	% gram	0.3125	265.625								
	% forbs	-0.493333	34.583333	215.44							
	% shrubs	4.961451	-75	-70.48	340.72562						
	% lichen	-3.92	-142.18	-69.12	-33.64	143.14					
	% othrspp	-6.9	48.33	2.8	-85.55	-42.47	173.5				
	shrubhgt	-1.88	-270.3	-256.53	226.48	255.25	-24.55	3224.94			
	leaves	29.76	114.28	137.24	-0.36	-30.70	-44.13	-235.92	337.39		

Table 5 continued

	bare gr	-2.30	-84.9	-6.18	-137.19	59.28	-23.49	-255.01	-58.8	296.41	
	litter	0.5	-11.6	-7.33	5.83	-5.16	-15.83	-16.66	-1.66	83.33	23.33
Zone 3	# spp	13.57									
	% gram	17.21	85.45								
	% forbs	23.30	65.08	135.59							
	% shrubs	35.95	68.13	59.16	472.32						
	% lichen	-39.65	-85.41	-117.36	-182.50	495.88					
	% othrspp	-6.35	-2.00	17.37	-131.96	-103.99	453.09				
	shrubhgt	-11.28	1.12	-10.52	-53.47	-213.44	-64.47	765.33			
	leaves	23.30	-3.46	117.51	211.09	-218.56	98.53	-192.49	477.16		
	bare gr	-48.89	-93.40	-125.92	-411.99	-72.62	5.43	371.12	-163.54	603.81	
	litter	-13.19	-4.86	-38.89	18.06	-7.64	-20.14	16.67	-81.94	0.00	53.47
Zone 4	# spp	16.49									
	% gram	39.14	287.43								
	% forbs	32.65	76.43	445.92							
	% shrubs	-20.27	-72.57	-251.73	192.53						
	% lichen	-24.43	-92.57	-134.29	68.29	108.86					
	% othrspp	-12.37	-79.57	-73.78	49.31	7.00	51.63				
	shrubhgt	-24.20	-94.20	-124.00	148.20	7.20	61.00	136.00			
	leaves	-49.40	-252.40	-68.00	257.40	-114.60	180.00	367.00	1284.00		
	bare gr	-37.55	-150.00	-97.45	56.53	5.71	96.73	103.00	306.00	226.53	
	litter	0.67	8.33	-13.33	-2.00	11.00	-6.00	-13.33	-60.00	-10.00	2.00

Figure 22 shows the correlation between the number of years each site has been rested and percent cover of shrubs. Grazed campsites had negative (-) years of rest and ungrazed sites positive years in this figure in order to show the overall use level on the timeline (not to imply that grazing and rest necessarily have the exact opposite effect). All values used for response variables were the means calculated from all hoops within the respective zone. Best-fitted lines show the overall trend within each zone. As the number of rest years increased, percent cover of shrubs increased in Zone 1 and 2, but Zone 2 percent shrub cover had a weaker relationship. Zone 3 showed the opposite correlation. In this zone, percent cover of shrubs increases with the number of years of grazing, but not rest. This is consistent with the trend of some of the other functional groups of this zone discussed earlier in this chapter. Browsing effect on shrubs was the heaviest in valley bottoms, while lichens experienced the most impact in Zone 3. That may have opened more space for shrubs, graminoids and forbs in Zone 3, which all had higher percent cover at grazed sites.

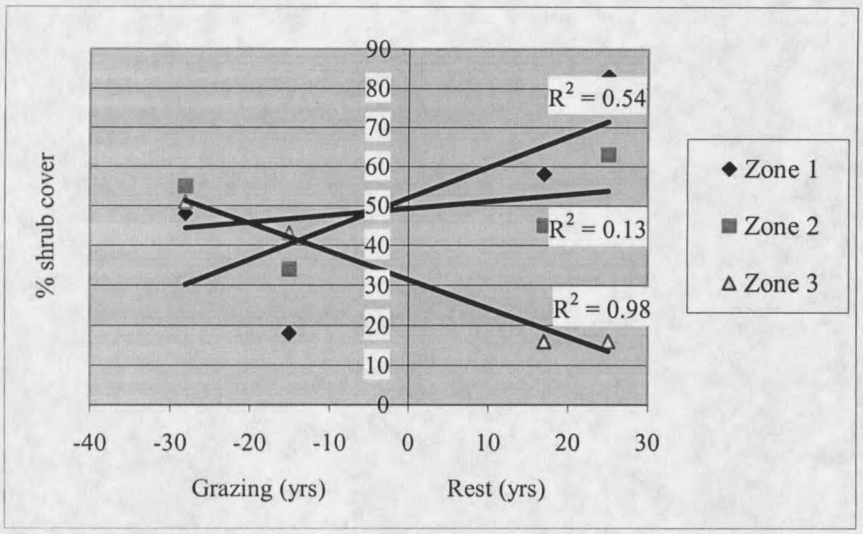


Figure 22. Rest vs percent shrub cover in all zones.

In addition to the percent shrub cover, shrub height and percent leaves were analyzed in relation to the number of years of rest. Again, years of grazing were given as negative numbers and average means from each zone were used.

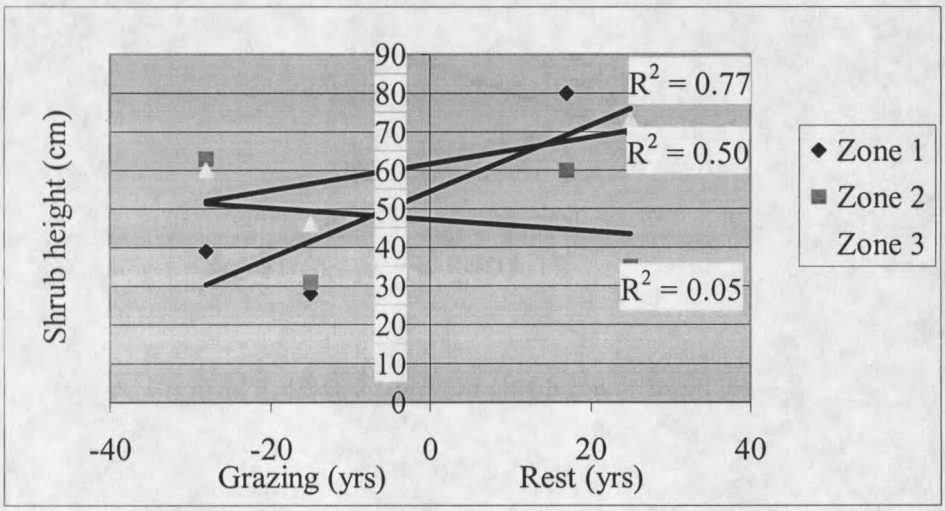


Figure 23. Rest vs shrub height in all zones.

In Zone 1 and Zone 3, shrub height increased as the number of rest years increased (Figure 23). However, Zone 2 showed no strong correlation between the two, which is consistent with the other data previously discussed. Because the R^2 was only 0.05, no conclusion can be made regarding the correlation (Figure 2). Shrub cover and other variables in Zone 2 overall did not differ significantly between grazed and ungrazed sites. This, again, might mean that species preference differs across the landscape according to the topographic position (Archer and Smeins, 1991).

Percent leaves on shrubs was used as shrub vigor indicator. Heavily browsed shrubs were expected to have less green biomass (Crete et al. 1996). However, rested sites often had taller shrubs with not much leaves on them (personal observation, 1999 and 2000) and this trend can be seen in all zones (Figure 24).

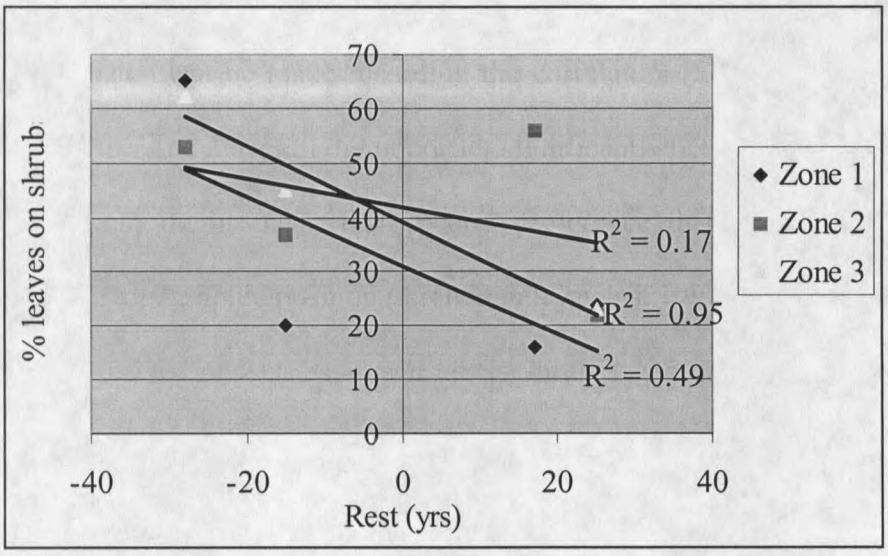


Figure 24. Rest vs percent leaves on shrubs

The Figure 24 shows that as the number of rest years increases, percent leaves on the shrubs decreases in all zones. That is shrubs at grazed sites have more green biomass and, therefore, are more vigorous.

Rangeland health assessment

A rangeland health checklist was used to monitor the overall condition of the four sites (Mosley, 1997). This checklist included 15 "Yes" and "No" questions regarding species composition and distribution, cover, erosion and soil movement. No scores were assigned to "Yes" and "No" answers, and, therefore, the descriptive information was not quantitatively analyzed. The main differences between the grazed and ungrazed sites were the number of perennial plants, age classes of plants and accessibility of desirable plants. At the ungrazed sites, there were often fewer perennial plants and mostly mature shrubs. Meanwhile, grazed sites had shrubs of all classes of age, seedling, young and mature. Deciduous shrub stands at the ungrazed sites were also very tall and dense that they prevented accessibility to grazing and browsing.

A utilization and apparent trend score card was used for the same overall purpose (Taylor and Lacey, 1996). It has 7 questions regarding vegetation cover, composition, distribution, vigor and soil erosion and appoints scores to each possible answer (see Appendix A for the score card). +2 and +1 are appointed to positive answers and –2 and -1 to negative answers, while "Maybe" gets 0 score (Appendix A). The seven questions are worth 10 points in total, when a rangeland is in excellent condition and –10, when in very poor condition. To compare the overall rangeland condition and its trend at grazed

and ungrazed sites, all scores from each treatment were added and then divided by the number of observations. Average apparent trend score for grazed sites was 7 and 4 for ungrazed sites. This indicates that the grazed sites were in better condition than the ungrazed.

Landscape and Vegetation

Figures 25, 26, 27 and 28 show topographic and vegetative features from each campsite.

Soils

Nineteen soil profiles were described at Terturag site, 24 at Urtun Khyarkh, 27 at Joshim site, and 11 profiles at Dood Saalig site were described. Soil profile characteristics and development were closely associated with their topographic position (see Appendix B for detailed profile descriptions). Since all four sites had similar landscape features, the soil profile positions and their overall characteristics had some similarities. Figure 24 shows typical characteristics of the topography, vegetation and soil profiles of these glaciated valleys with their common soil profiles (Zone 4 not included since not all sites had Zone 4).

Figure 25: Joshim vegetation and landscape

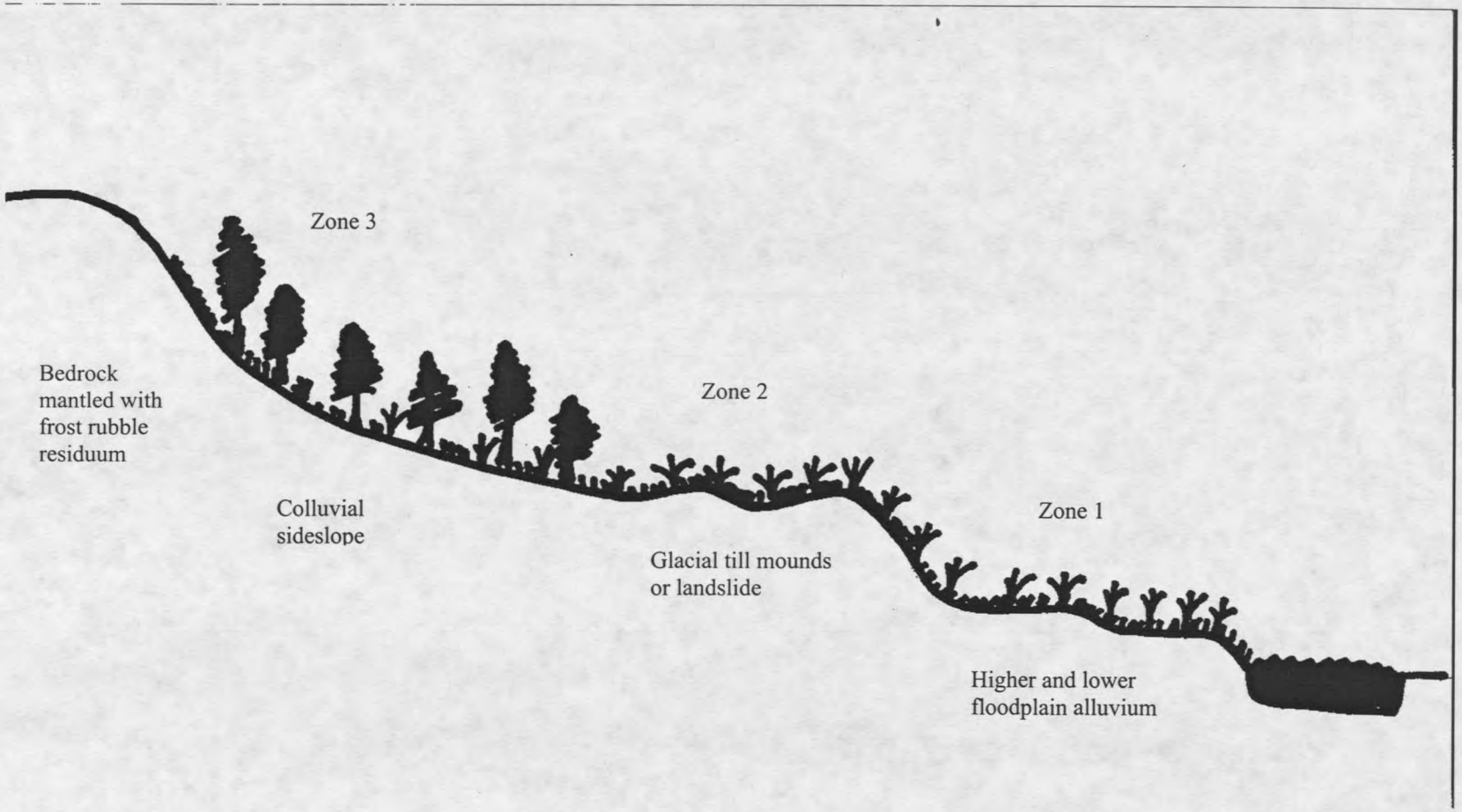


Figure 26: Urtun Khyarkh landscape and vegetation

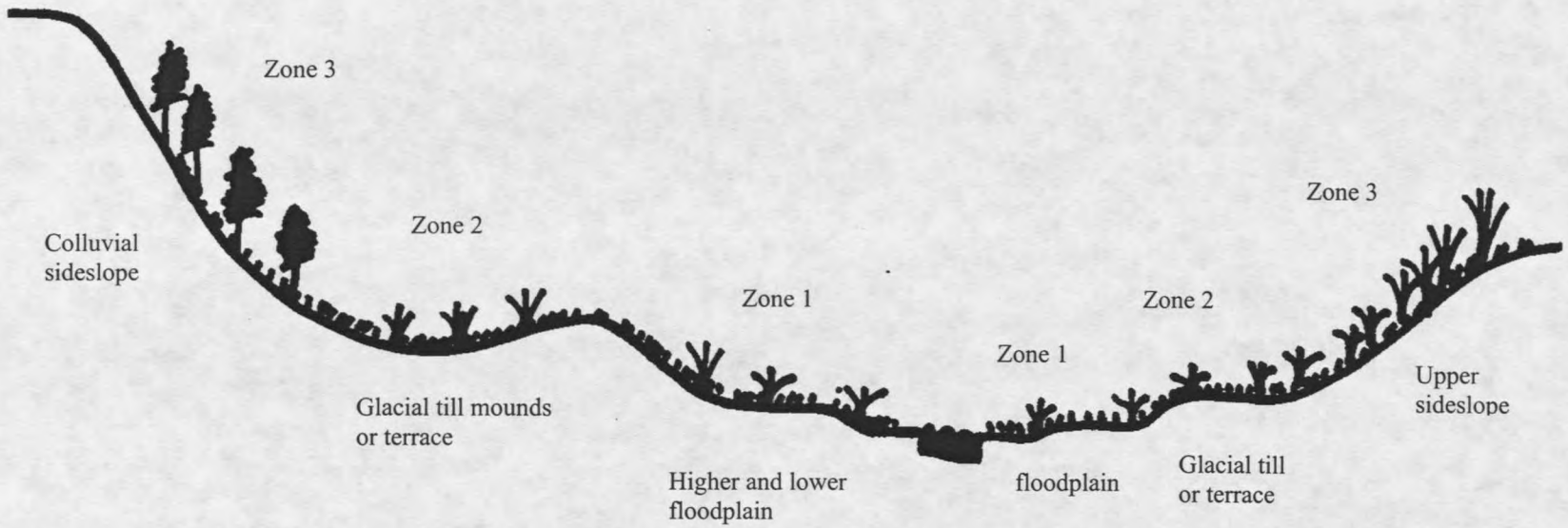


Figure 27: Dood Saalig landscape and vegetation

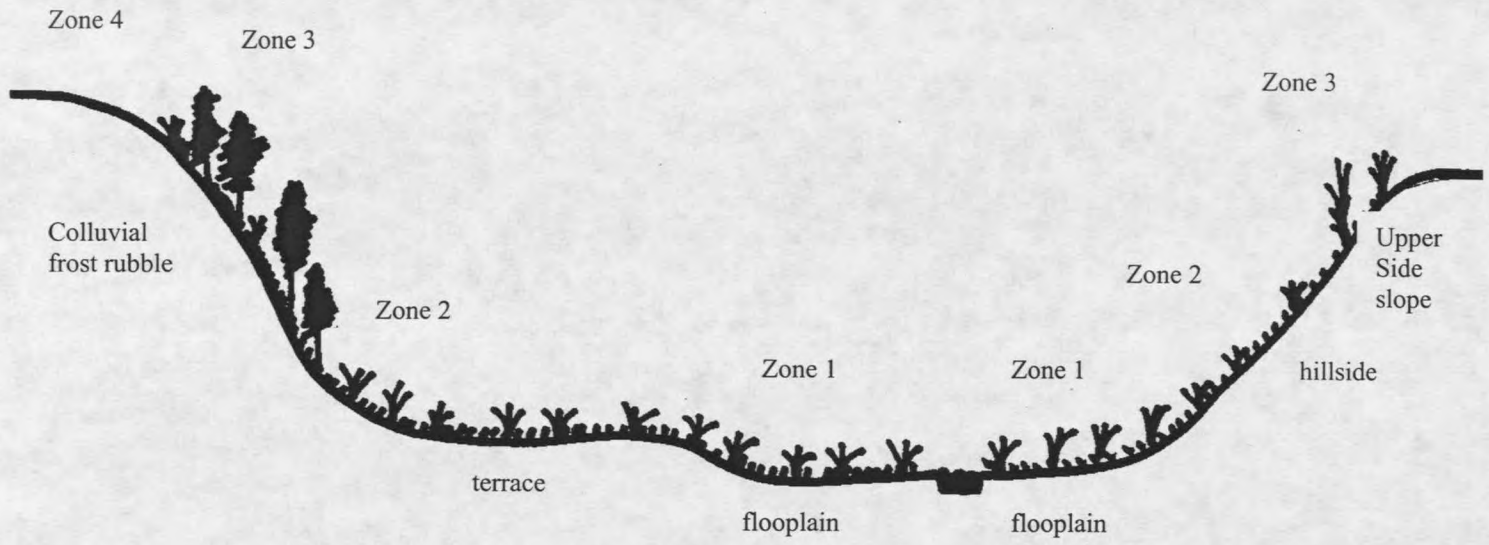
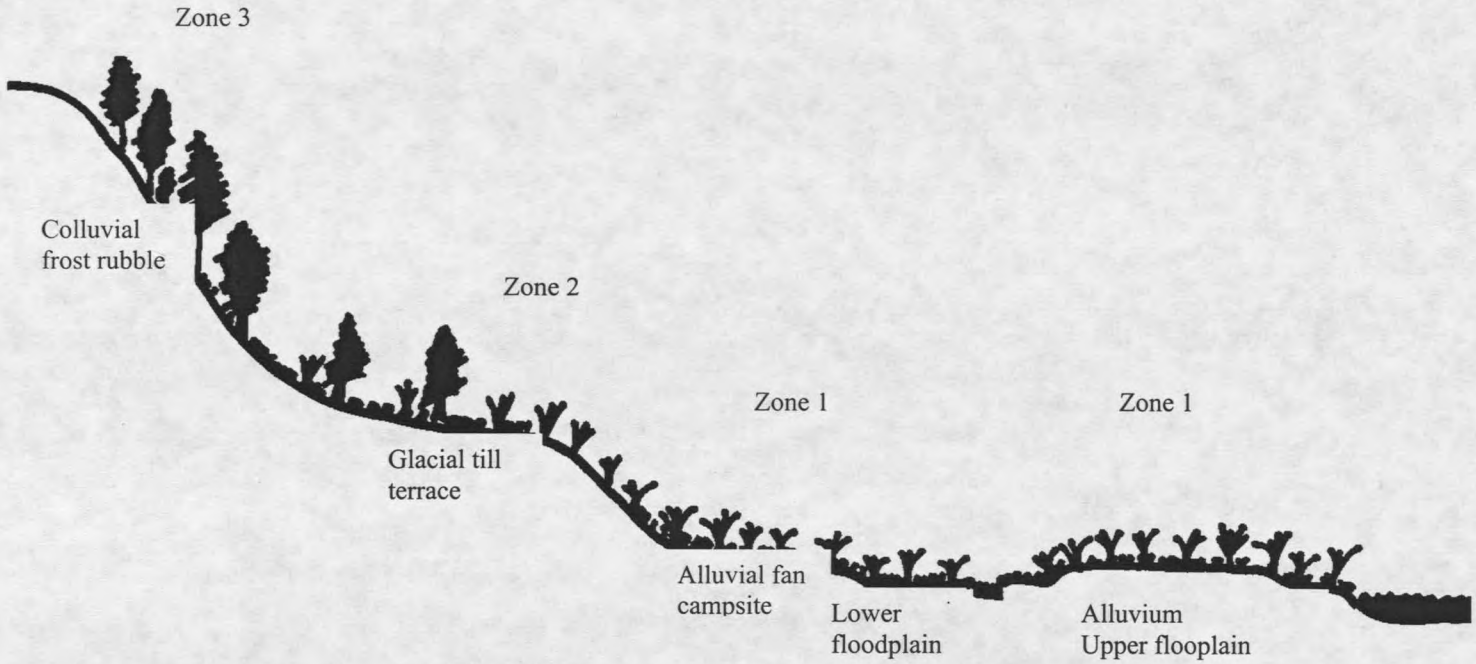


Figure 28: Terturag landscape and vegetation



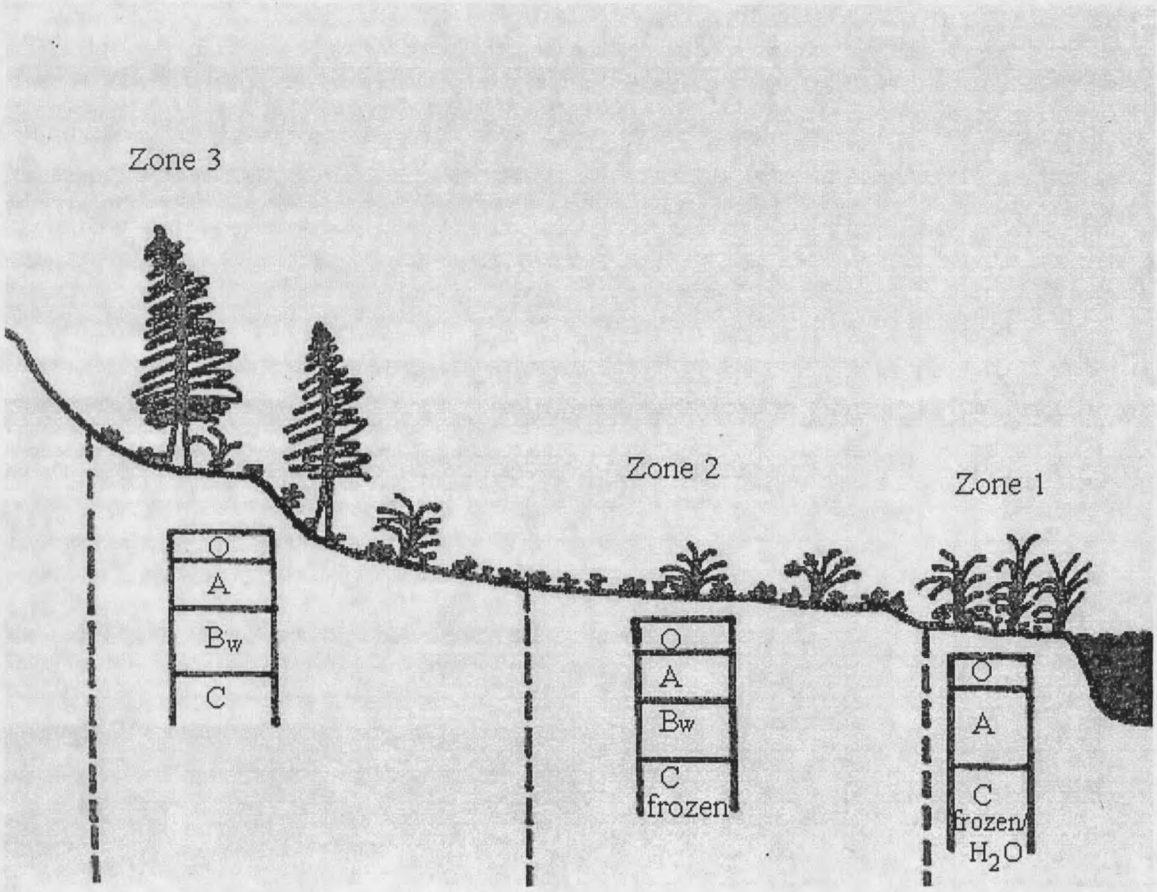


Figure 25. Landscape, vegetation and soil profiles

Zone 1

Joshim

Carex-and *Betula*-dominated valley bottom soil profiles at the Joshim site were shallow to ground water and often had O horizons of 4-6 cm. They often had very dark and thick A horizons 40-60 cm in thickness. These 5Y3/2 and 10YR2/1 colored A horizons were often frozen at the bottom and/or underlain by gravelly, sandy C horizons.

Most horizons were silt loam textured and often showed characteristics of Histic epipedons.

Urtun Khyarkh

The grazed Zone 1 of Urtun Khyarkh site, dominated by graminoids and forbs, mostly had 4-8 cm of O horizon above silty, loamy textured A horizons. The A horizons were often underlain by sandy C horizons at 8-20 cm. Again, most profiles had 10 YR 2/1, 2/2 and 3/1 colors.

Dood Saalig

The frequently flooded valley bottom at this site had O horizons up to 6 cm thick. These ochric A horizons often had loamy and sandy loam textures. Their thickness often varied between 7-13 cm above C horizons (Hall, 2000).

Terturag

The Terturag valley had O horizons of varying thickness (2-20 cm) over silt loam and loamy A horizons, which were commonly 5-10 cm in depth. The C horizons beneath them were often loamy and gravelly. They were water saturated and commonly showed redoximorphic features. These profiles had mostly 10YR colors of 2/1, 2/2 and 3/2, although C horizons usually had values and chromas of 4 and 6.

Zone 2

Joshim

The upstream transect in Zone 2 was on a densely vegetated hummocky surface and had thick O horizons over very dark and thick A horizons. The 10YR 2/1 and 4/4

colored A horizons along this transect had silt loam textures and were all frozen at the bottom. Even though the profiles from this transect are in vegetation Zone 2, they share common characteristics with valley bottom profiles in Zone 1 due to their common topographic position. The terrace zone on the downstream transect often showed sandy C below the A horizons of 8-13 cm in thickness. A horizon textures were loam and silt loam.

Urtun Khyarkh

Its wide terrace had mollic A horizons under very shallow O horizons. It also had brown B_w to 30-40 cm. Both A and B_w horizons had silty and loamy textures. The C horizons underneath them also had silty and, sometimes, gravelly textures with free standing water. Most horizons in this zone had 10YR 2/2 and 3/2 colors.

Dood Saalig

This zone also had thick O horizons over shallow A horizons with 10YR 2/1 color. They were followed by often frozen or saturated B_w horizons up to 48 cm deep. The texture of the surface horizons was loam, while the B_w had sandy loam texture and, sometimes, silty and clayey textures.

Terturag

This terrace also had thin O horizons. Its A horizons, with colors of 10YR 2/2 and 3/2, were only to 8-15 cm above silty clay loam and silt loam C horizons. The A horizons all had silt loam textures.

Zone 3

Joshim

Zone 3 on upper sideslopes were often covered with larch trees and sparse shrubs. These soils had O horizons of 5-9 cm in thickness above very dark A horizons, mostly of 5Y 3/2 color. A horizons extended to 4-30 cm. The C horizons were gravels and gravely loams with 7-20 cm of thickness. They were also 5YR hues of 5/2 and 6/2.

Urtun Khyarkh

Urtun Khyarkh larch covered upper sideslopes had 3-10 cm of O horizons above A and B_w horizons. A horizons were all 10YR 2/1 color, 10-20 cm in thickness and loams. The B_w horizons extended to 28-30 cm above the C horizons of mostly sandy loam texture.

Dood Saalig

Dood Saalig upper sideslopes had skeletal, gravelly and silty horizons. A horizons were often to 10-12 cm thick gravelly silt loams of 10YR 3/3 and 3/1 color. They were all followed by gravelly loam or gravelly clay C horizons of 8-28 cm of thickness. One of the profiles had free standing water at 38 cm.

Terturag

Terturag upper sideslopes had thick O horizons of 13-23 cm. However, the silt loam A horizons of 10YR 3/3 and 3/2 were only 3-6 cm thick. The C horizons were gravelly loam with 10YR 4/4 color.

Summary of soils data

No significant differences were observed in soil profile descriptions between the study sites (see Appendix B for detailed profile descriptions). This prevents a conclusion that the vegetation differences observed between the grazed and ungrazed sites were due to soils differences and indicates that they are caused by differences in grazing regime.

Many of the soil profiles were Gelisols. This order contains characteristics of permafrost within 200 cm (Buol et al., 1997). Permafrost is defined as a thermal condition in which soil temperature stays at 0° C or below for two or more consecutive years (Bockheim et al., 1997). The tundra vegetation on permafrost soils often includes mosses, lichens, dwarf shrubs, graminoids and forbs (Gross et al., 1990), which were the typical vegetation observed at these four sites.

At a landscape level, freezing and thawing causes patterned ground, such as polygons, nets, sorted and unsorted circles and raised strings (Hofle et al., 1998, Bockheim et al., 1997). The landscapes at the four sites showed these features and had dark organic matter rich soils as well as raised skeletal beds, polygons and frost rubbles.

The thicker organic horizons are found in the low topographies, while thinner organic horizons are on the uplands (Hofle, 1998). Bottom lands are the wettest and the upland soils are the driest. Wet meadows also have deeper active layers (Gross et al., 1990).

Many of the valley bottom profiles had histic upper horizons and free standing water, which are indicators of high permafrost table underneath. Saturated soils are

caused by shallow permafrost tables (Hofle et al., 1998). Broken soil horizon boundaries and frost convoluted layers of organic matter, which are the most obvious cryoturbation characteristics of permafrost soils, were also observed in these profiles (Bockheim et al., 1997). Freezing and thawing break the soil horizon boundaries and accumulate organic matter in the upper 30-100 cm of the permafrost as well as the sub-soil (Bockheim et al., 1997). But some low land profiles may not have the cryoturbation features because they are composed of eroded materials from the adjacent higher lands (Hofle et al., 1998)

The commonly observed skeletal soils had silt and silt loam textured fine material throughout the profiles. These silt cappings on the coarse fragments and layers rich with silt are also indicators of cryoturbations (Bockheim et al., 1997). Mostly 2.5Y and 5Y colors were observed in the silt textured profiles and these reduced colors are caused by water perched on frozen soils (Hofle et al., 1998).

CONCLUSION

Zones 1, 2 and 4 at grazed sites had less percent shrub cover than at ungrazed sites, although Zone 3 showed the opposite trend. Grazed site shrubs were significantly shorter than those at ungrazed sites. Shrub leaf biomass was expected to be higher at ungrazed sites (Doucet, 1998), but this study showed that the percent leaves was greater at the grazed sites. This implies that shrubs at the grazed sites were more vigorous than at ungrazed sites.

Increased shrub cover at the ungrazed sites reduced the percent cover of other functional groups: graminoids, forbs and lichens. Unrgazed sites also had fewer number of species than grazed sites.

Implications and Recommendations

Reindeer grazing and browsing need to be more evenly distributed throughout the West Taiga. Currently used campsites need to be rested to recover their lichen mats, while ungrazed campsites should be utilized to better balance the species in the plant communities. Ungrazed campsites can benefit from utilization, because grazing and browsing will provide better competition among the plant species and improve plant vigor.

The West taiga can also benefit from a larger population of wild ungulates. Areas that are not used by the domestic reindeer herd could then be utilized. Ungulate browsing will impact the shrubs, which may improve plant species richness and vigor.

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APPENDICES

APPENDIX A

VEGETATION

List of Common Plant Species in Tenggis river drainage (identified by Skovlin and Skovlin, 1999 and Tsetsegmaa, 2000)

Carex spp

Aumix acetosa

Poaceae spp

Hierochloe spp

Helictotrichon spp

Equisetum palustre

Trollius asiaticus L.

Aconitum chenoxavskii

Pedicularis flavessdina

Sedum spp

Aqulica sibirica

Paeonia spp

Anemone crinita

Clatonia joneniana

Senecia spp

Saussceria spp

Veronica spp

Astra spp

Rhododendron Adamstii

Ledum palustre

Ribes nigrum

Spiraea spp

Spiraea alpina

Rosa acicularis lindl.

Leonthopodium spp

Hedysarum spp

Juniperus sibirica

Juniperus pseudosabina

Betula rotundifolia

Betula fusca

Betula fruticosa

Betula berberis

Salix glauca

Salix divaricata

Salix caesia

Potentilla fruticosa

Aconitum spp

Carum carvi

Laphanthus chinensis

Gentiana gargata Froel.

Viola spp

Myosotis spp

Ranunculus acer

Potentilla nivea

Allium spp

Geranium spp

Limonium spp

Draba nemorosa L.

Atragene sibirica L.

Valeriana dubla

Euphorbia spp

Pedicularis spp

Tanacetum valgare L.

Sedum spp

Aquilegia sibirica Lam.

Senecio spp

Hedysarum spp

Larix sibirica

Lonicera microphylla

Pinus sibirica

Picea oborata

Vaccinium uligonum

Rhododendron parvisolium

Rhododendron aureum Georgi

Dryas oxyodonta Juz.

Vaccinium vitis-idaea

Table 6: Campcenter vegetation data from large hoops

Treat-ment	Site	Transct	Hoop	# spp	Gram	Forbs	Shrubs	Lichens	Other spp	Shrub height	% leaves	Bare ground	Litter
G	J	1	1	8	10	5	15	0	0	55	60	35	40
G	J	1	2	14	70	20	5	0	0	3	100	0	5
G	J	1	3	6	10	5	10	0	0	50	50	25	50
G	J	1	4	11	7	3	40	5	0	55	55	10	35
G	J	1	5	16	15	10	50	5	0	60	60	0	20
U	TT	1	1	8	30	1	40	30	0	35	45	0	
U	TT	1	2	6	15	0	75	10	0	30	30	0	30
U	TT	1	3	7	10	5	80	0	0	80	45	0	5
U	TT	1	4	7	15	5	75	0	0	80	15	0	5
U	TT	1	5	9	50	10	20	20	0	60.0	10	0	50

Table 7: Campcenter vegetation data from small hoops

Treat-ments	Sites	Transct	Hoops	# spp	Gramin	Forbs	Shrubs	Lichens	Other spp	Shrub height	Leaves	Bare ground	Litter	Weight
G	J	1	1	4	2	5	0	0	0	0	0	5	88	1
G	J	1	2	8	70	10	0	0	0	0	0	0	20	23
G	J	1	3	4	10	15	0	0	0	0	0	35	50	9
G	J	1	4	5	3	0	10	7	70	40	50	0	10	6
G	J	1	5	5	45	30	0	5	5	0	0	0	15	20
U	TT	1	1	9	30	10	0	30	0	0	0	0	30	29
U	TT	1	2	3	10	1	5	0	70	15	0	0	15	3
U	TT	1	3	1	0	0	100	0	0	80	5	0	0	15
U	TT	1	4	8	20	20	30	0	0	20	70	0	30	14

Table 7 continued

U	TT	1	5	5	15	40	0	20	20	0	0.0	0	5	10

Table 8: Zone 2 vegetation data from large hoops

Treatmt	Sites	Transct	Hoops	# spp	Gram	Forbs	Shrubs	Lichens	Othrspp	Shrubht	%leaves	Bare gr	Litter
G	J	1	1	10	15	5	75	0	5	40	50	0	5
G	J	1	2	11	10	5	65	0	5	40	70	5	10
G	J	1	3	8	20	5	70	0	0	35	70	0	70
G	J	2	1	8	80	5	15	0	0	45	70	0	0
G	J	2	2	7	60	5	10	0	0	45	55	0	25
G	J	2	3	7	30	5	55	0	0	30	75	0	10
G	UK	1	1	7	40	10	10	0	40	10	0	0	
G	UK	1	2	5	65	0	20	0	15	40	0	0	
G	UK	1	3	15	0	0	30	0	70	60	40	0	
G	UK	2	1	5	50		35		15	40	20		
G	UK	2	2	4	40		35	0	5	60	30	20	
U	DS	1	1	1	0	0	100	0	0	135	10	0	
U	DS	1	2	4	30	0	70	0	0	110	15	0	
U	DS	1	3	2	30	0	70	0	0	45	45	0	
U	DS	1	4	3	10	10	70	10	0	45	45	0	
U	DS	1	5	3			70		0	30	55	0	
U	DS	2	1	2	100	0	0	0	0	0	0	0	
U	DS	2	2	6			90	0	0	150	15	0	
U	DS	2	3	4	90	0	10	0	0	75	0	0	
U	DS	2	4	4	10	0	90	0	0	105	25	0	
U	DS	2	5	6	10	0	55	0	0	90	0	15	
U	TT	1	1	10	15	5	55	20	0	50	50	0	5
U	TT	1	2	6	10	0	90	0	0	40	30	0	10
U	TT	1	3	5	1	0	85	15	0	85	30	0	30

Table 8 continued

U	TT	1	4	7	0	0	100	0	0	140	10	0	40
U	TT	2	1	8	10	10	80	0	0	160	10	0	40
U	TT	2	2	9	15	5	80	0	0	70	5	0	70
U	TT	2	3	11	1	3	90	1	0	60	50	0	10

Table 9: Zone 1 vegetation data from small hoops

Treatmt	Sites	Transct	Hoops	# spp	Gramin	Forbs	Shrubs	Lichens	Othrspp	Shrbhgt	%leaves	Bare gr	Litter	Weight
G	J	1	1	10	20	10	40	0	30	22	70	0	10	13
G	J	1	2	7	10	5	80	1	4	35	85	0	0	27
G	J	1	3	4	10	10	80	0	0	20	60	0	10	30
G	J	2	1	6	95	5	5	0	0	20	50	0	0	61
G	J	2	2	3	40	0	0	0	0	0	0	0	60	10
G	J	2	3	5	40	15	15	0	0	10	50	30	10	6
G	UK	1	1	1	100									13
G	UK	1	2	3	20		70							
G	UK	1	3	5	5		40		10					21
G	UK	2	1	4	15	40	5		5			0		
G	UK	2	2		10	10	25		10			30		
U	DS	1	1	1	0	0	100	0	0			0		41
U	DS	1	2	1	0	0	100	0	0			0		24
2	DS	1	3	2	30	0	70	0	0			0		16
2	DS	1	4	5			70		0			0		115
U	DS	1	5	3		0	70		0			0		38
U	DS	2	1	2	100	0	0	0	0			0		16
U	DS	2	2	3	0	0	100	0	0			0		67
U	DS	2	3	2	90	10	0	0	0			0		19
U	DS	2	4	4	0	0	100	0	0			0		26
U	DS	2	5	4				0	0			0		20

Table 9 continued

U	TT	1	1	1	0	0	100	0	0	60	60	0	10	26
U	TT	1	2	2	50	0	50	0	0	35	20	0	0	20
U	TT	1	3	6	0	1	60	40	0	30	40	0	40	113
U	TT	1	4	1	0	0	100	0	0	150	5	0	50	20
U	TT	2	1	4	10	30	70	0	0	0	0	0	70	14
U	TT	2	2	4	50	0	50	0	0	45	0	0	50	20
U	TT	2	3	3	1	0	95	4	0	35	30	0	10	27

Table 10: Zone 2 vegetation data from large hoops

Treatmt	Sites	Transct	Hoops	#spp	Gram	Forbs	Shrubs	Lichens	Othrspp	Shrbhgt	% leaves	Bare gr	Litter
G	J	1	1	7	20	5	60	0	10	45	40	0	5
G	J	1	2	9	25	1	50	1	0	55	50	50	18
G	J	1	3	6	15	0	70	0	10	110	20	0	5
G	J	2	1	12	5	3	75	2	5	65	60	0	10
G	J	2	2	11	25	5	50	10	10	50	70	0	5
G	J	2	3	13	50	10	25	5	5	55	80	0	5
G	UK	1	1	3	50		30	0	15	40	35	5	
G	UK	1	2	4	35		10	0	50	40		5	
G	UK	1	3	3	40		50	0	10	60	45		
G	UK	1	4	7			65	5	30	1	50		
G	UK	2	1	6		60	30	0	10	25	70		
G	UK	2	2	3	20		70	10		60	40		
U	DS	1	1	6	0	0	10	20	25		0	45	
U	DS	1	2	5	5	0	35	30	10	15		20	
U	DS	1	3	6	20	0	60	5	15	30	35	0	
U	DS	1	4	6	0	0	60	35	5	180	50	0	
U	DS	1	5	5	10	0	50	30	0	210	35	10	
U	DS	1	6	8		5	47	5	40	180	50	3	

Table 10 continued

U	DS	2	1	5			60	0	0	50	40	0	
U	DS	2	2	8		10	40		10	30	70	40	
U	DS	2	3	6	0	0	30	30	0	20	50	30	
U	DS	2	4	11				5	75	50	75	10	
U	DS	2	5	6	5	0	50	40	5	50	70	0	
U	DS	2	6	8	5	10	50	10	10	2	90	0	
U	TT	1	1	6	15	0	80	10	5	40	5	0	10
U	TT	1	2	8	40	1	40	10	0	40	30	0	9
U	TT	1	3	4	70	0	70	15	0	25	30	0	5

Table 11: Zone 2 vegetation data from small hoops

Treatmt	Sites	Transct	Hoops	# spp	Gram	Forbs	Shrubs	Lichens	Othrspp	Shrbhgt	%leaves	Bare gr	Litter	Weight
G	J	1	1	4	5	5	65	0	10	45	20	0	15	9
G	J	1	2	5	50	0	45	0	0	50	45	0	5	10
G	J	1	3	3	5	0	85	0	10	95	10	0	50	16
G	J	2	1	7	30	15	0	0	0	0	0	0	50	20
G	J	2	2	6	25	3	35	20	5	25	5	0	12	9
G	J	2	3	6	40	15	0	5	10	0	0	0	30	22
G	UK	1	1	4	15	5	80							12
G	UK	1	2	4	10			5						1
G	UK	1	3		20		40							
G	UK	1	4		5	5	1.5		5	0				3.5
G	UK	2	1	3	10	10			15					15
G	UK	2	2		5		50		25			20		25
U	DS	1	1	2				15	25			0		
U	DS	1	2	2	0	0	5	0	35			60		1
U	DS	1	3	4	10	3	40	5				0		29
U	DS	1	4	5	10	0	40	30	10			0		20

Table 11 continued

U	DS	1	5	3	0	40	10	15				0		8
U	DS	1	6	7	15	15	15	5	20			0		14
U	DS	2	1	5			10							28
U	DS	2	2	5								0		142
U	DS	2	3	5								0		54
U	DS	2	4	4				30				0		24
U	DS	2	5	3	5	0	20	75	0			0		93
U	DS	2	6	6	30	0	60	10	51			0		33
U	TT	1	1	4	10	0	30	20	35	6	100	0	5	9
U	TT	1	2	3	70	0	10	0	0	30	10	0	20	26
U	TT	1	3	2	5	0	90	0	0	25	30	0	5	18

Table 12: Zone 3 vegetation data from large hoops

Treatmt	Sites	Transct	Hoop	#spp	Gram	Forbs	Shrubs	Lichens	Othrspp	Shrbhgt	%leaves	Bare gr	Litter
G	J	1	1	14	25	25	40	0	5	60	50	0	5
G	J	1	2	9	10	5	60	5	0	65	40	0	20
G	J	1	3	13	5	5	85	0	5	65	70	0	0
G	J	2	1	11	10	25	25	20	20	50	90	0	0
G	J	2	2	15	10	25	50	10	5	60	60	0	0
G	J	2	3	17	25	25	50	0	0	60	60	0	0
G	UK	1	1	6	10	0	15	0	55	50	45	20	0
G	UK	1	2	6	20	35	0	5	30		0	10	0
G	UK	2	1	7	15	0	30	5	50	60	50	0	0
G	UK	2	2	6	20	0	70	0	10	60	70	0	0
G	UK	3	1	13	30	5	35	5	0	60	25	0	0
G	UK	3	2	9	20	5	55	5	0	60	55	0	0
U	DS	1	1	6	0	0	25	40	25			10	0
U	DS	1	2	11	0	0	20	20	40	30		20	0

Table 12 continued

U	DS	1	3	5	0	0	0	3	4			90	0
U	TT	1	1	6	10	0	9	80	1	30	30	0	0
U	TT	1	2	4	0	1	10	10	10	150	30	60	0
U	TT	1	3	5	1	0	30	65	1	40	10	5	0

Table 13: Zone 3 vegetation data from small hoops

Treatmt	Sites	Transct	Hoops	# spp	Gram	Forbs	Shrubs	Lichens	Othrspp	Shrbhgt	%leaves	Bare gr	Litter	Weight
G	J	1	1	9	10	30	10	0	50	40	60	0	0	20
G	J	1	2	6	15	20	30	5	0	30	40	0	30	13
G	J	1	3	5	5	5	90	0	0	50	40	0	0	20
G	J	2	1	9	3	5	40	7	35	10	90	0	0	13
G	J	2	2	7	30	30	20	0	20	35	65	0	0	1
G	J	2	3	7	30	5	50	0	0	45	70	0	15	25
G	UK	1	1	1	50							50		5
G	UK	1	2	3	5			5	20			70		4
G	UK	2	1	6	5	5	20	5	50			0		15
G	UK	2	2		5		10							14
G	UK	3	1	2	5			25						2
G	UK	3	2		5		70							27
U	DS	1	1	5	5	0	0	30				0		100
U	DS	1	2	2								99		
U	DS	1	3											
U	TT	1	1	3	5	0	0	90	1	0	0	0	4	148
U	TT	1	2	1	0	0	0	0	0	0	0	95	5	0
U	TT	1	3	4	0.5	0	30	69	0.5	20	20	0	0	111

Table 14: Zone 4 vegetation data from large hoops

Treatmt	Sites	Transct	Hoops	#spp	Gram	Forbs	Shrubs	Lichens	Othrspp	Shrbhgt	%leaves	Bare gr	Litter
G	J	1	1	11	10	60	3	0	10	20	90	15	2
G	J	1	2	17	40	40	0	3	2	0	0	0	5
G	J	1	3	7	5	40	0	30	0	0	0	0	5
U	DS	2	1	6	5	0	20	20	20	15	50	35	
U	DS	2	2	4	5	45	0	10	13			40	
U	DS	2	3	6	2	0	40	25	13	30	65	20	
U	DS	2	4	7	45	30	10	10	0			5	

Table 15: Zone 4 vegetation data from small hoops

Treatmt	Sites	Transct	Hoops	# spp	Gram	Forbs	Shrubs	Lichens	Othrspp	Shrbhgt	%leaves	Bare gr	Litter	Weight
G	J	1	1	3	3	80	0	2	0	0	0	15	0	1
G	J	1	2	6	40	50	0	0	0	0	0	8	2	46
G	J	1	3	5	5	40	0	35	0	0	0	6	14	25
U	DS	2	1	4	15	0	20	15	5			30		49
U	DS	2	2	4	5	0	30	45	0			15		128
U	DS	2	3	10				15						
U	DS	2	4											

APPENDIX B

SOILS

Table 16: Joshim Transect 1 soil profiles

		Zone 1				Zone 2			Zone 3			
		H1	H2	H3	H4	H1	H2	H3	H1	H2	H3	H1
Horizons	Profiles											
Surf. Hor.	O /depth		5	4	6	18	24	30	5	6	9	
	Rdeer lichen											
	Green moss											
	R.lich+moss											
	Depth	60	40	14	30	32	40	10	12	10	31	40
	Hue	10YR	10YR	10YR	10YR	10YR	10YR	5YR	5Y	10YR	5Y	10YR
	Value	2	2	2.5	2	5	4	4	3		3	2
	Chroma	1	1	1	1	6	4	2	2	2	1	1
	Tex/% clay	si l	si	si l	si l	si l	si l	sivfs	l sl	si l	si l	si l 10
	% cf.	0	0	0	0	0	0	0	0	0	20	0
B hor.	Depth											
	Hue											
	Value											
	Chroma											
	Tex/% clay											
	% cf.											
C hor.	Depth to			30					50	40	50	
	Hue			5YR					5Y	5Y	5Y	
	Chroma			4					5	5	4	
	Tex/% clay			2					l 20	gr l 13	grsicl 27	
	% cf.								40		30	
Diagn.	Moll/Umb/His/Cam											His

Hor

Table 16 continued

Site	Slope degrees							10	10	5
	Slope aspect									
Other	gley									
	redoximorphic		y							
	skeletal									
	fragmental									
	frozen	y	y		y	Y	y	y		
	saturated									
	depth									
	drainage									
Landsc.pos	all.plain. Low									
	all.plain.higher									
	all.fan									
	till/terrace									
	valley sideslope									
	mount.sideslope									
Comment										
Veg.	grass									
	grass/shrub									
	shrub									

larch

Table 17: Joshim Transect 2 soil profiles

		Zone 1			Zone 2						Zone 4
Horizons	Profiles	H1	H2	H3	H1	H2	H3	H1	H3	H1	H2
Surf. Hor.	O /depth										
	Rdeer lichen		6	2		12	2	12	7		
	Green moss										
	R.lich+moss										
	Depth										
	Hue	40	50	53	8	46	13	37	29	9	10
	Value	10YR	7.5YR	2.5Y	7.5YR	7.5YR	10YR	2.5YR	5YR	10YR	5Y
	Chroma	2	5	3	5	3	5	2.5	3	2.5	2.5
	Tex/% clay	1	4	1	4	2	4	2	2	1	1
	% cf.	si l 10		si l	1	si l	si l 20	si l	sl 10	si l	l 12
B hor.	Depth	0	0	0	0	0				15	70
	Hue				27						
	Value				7.5YR						
	Chroma				5						
	Tex/% clay										
	% cf.				l 18						
C hor.	Depth to				20						
	Hue			25	42		48		50	30	

Table 17 continued

	Chroma			2.5YR			5Y	5Y	5YR	5YR	2.5Y
	Tex/% clay			3			4	4	5	5	5
	% cf.			grl	s			grcl	sl 11	gr sl	l 12
Diagn. Hor	Moll/Umb/His/Cam			60	70		45	40	10	10	80
Site	Slope degrees	His	His	His							
	Slope aspect										20
Other	gley										
	redoximorphic										
	skeletal			y			y				
	fragmental										
	frozen										
	saturated			y		y					
	depth										
	drainage										
Lands c.pos	all.plain. Low										
	all.plain.higher										
	all.fan										
	till/terrace										
	valley sideslope										
	mount.sideslope										
Comment											

Table 17 continued

Veg.	grass
	grass/shrub
	shrub
	larch

Table 18: Urtun Khyarkh soil profiles

	Zone 1				Zone 2				Zone 3			
Horizons	Depth	Color	% co.fr.	Texture	Depth	Color	% co.frag.	Texture	Depth	Color	% co.frag.	Texture
O					3				granitic bedrock			
A1	5				5	mollic		silt				
A2												
Bw1					30	brown	30	sil				
Bw2												
C1												
C2												
O	5								None			
A1	8		mollic		15	mollic		silt				
A2					20							
Bw1	16		35		31	grey	70	silt				
Bw2												
C1	20											
C2												
O	3											
A1	2											
A2												

Table 18 continued

Bw1						
Bw2						
C1						
C2						
C1	5 grey	10 sand				
O	6.5		4			
A1			3	35 silt		
A2						
Bw1						
Bw2						
C1			32 grey	65 silt		
C2	11 grey	20 sand	grey	80 silt		
Ob2	14 grey	85 sand				
O	3		5:05		3	
A1	8 10YR2/1	10 loam	20 10YR 2/1		10 10YR 2/1	20 loam
A2						
Bw1					28 10YR 4/3	40 sandyloam
Bw2						
C1	21 10YR4/3	55 loamsand	60 10YR 3/2		50 7.5YR 4/2	60 sandyloam
C2	38 10YR 3/4	55 loamsand				
O	8		2		10	
A1	18 10YR 2/1	50 silt	16 10YR 2/2	10 silt	20 10YR 2/1	45 loam
A2						
Bw1			38 10YR 3/6	35 grav.loam	35 10YR 4/3	60 sandyloam

Table 18 continued

Bw2									
C1	23	10YR 3/4	50	silt	52	10YR 4/3	45	grav.silt	50 10YR 4/4	70 sandyloam
C2	33	10YR 4/4	60	loamysand						
O									5	
A1	4	10YR 2/1		loam	6	10YR 2/1		loam	10 10YR 2/1	loam
A2										
Bw1	19	10YR 3/2		silt	15	10 YR 3/2	30	silt	15 10YR 2/2	30 loam
Bw2										
C1	40	10YR 4/2		claysilt	60	10 YR 3/2		silt	50 10YR 3/1	90 silt
C2										
Oe1	10	10YR 2/1								
Oe2	28	10YR 3/1								
Oe3	50	10YR 2/2								
O										
A1	9	10YR 2/2		loam	22	10YR 2/1		loam		
A2										
Bw1	25	10YR 3/4	20	silt	40	10YR 2/2	0	silt		
Bw2										
C1	50	10YR 4/2	85	Silt lm	70	10YR 4/2	65	cls		
C2										
O									4	
A1					16	10 YR 2/1		siltloam	9 10YR 2/1	loam
A2									Bg 30 5Y 5/2 10YR4/6	silt
Bw1					25	10YR 3/1	45	ls	Bg2 60 10YR5/3:10YR5/4	silt
Bw2										
C1					30	10YR 4/2	60	cls		

Table 18 continued

C2			
O			
A1		8 10YR2/1	10 loam
A2			
Bw1		22 10YR4/3	45 silt
Bw2			
C1		45 10YR5/4	60 loam
C2			

Table 19: Dood Saalig soil profiles

		Zone 1					Zone 2			Zone 3	
Horizons	Profiles	H1	H2	H3	H4	H5	H1	H2	H3	H1	H2
Surf. Hor.	O /depth										
	Rdeer lichen		6	2		12	2	12	7		
	Green moss										
	R.lich+moss										
	Depth										
	Hue	40	50	53	8	46	13	37	29	9	10
	Value	10YR	7.5YR	2.5Y	7.5YR	7.5YR	10YR	2.5YR	5YR	10YR	5Y
	Chroma	2	5	3	5	3	5	2.5	3	2.5	2.5
	Tex/% clay	1	4	1	4	2	4	2	2	1	1

Table 19 continued

	% cf.	si l 10		si l	1	si l	si l 20	si l	sl 10	si l	l 12
B hor.	Depth	0	0	0	0	0				15	70
	Hue				27						
	Value				7.5YR						
	Chroma				5						
	Tex/% clay										
	% cf.				l 18						
C hor.	Depth to				20						
	Hue			25	42		48		50	30	
	Chroma			2.5YR			5Y	5Y	5YR	5YR	2.5Y
	Tex/% clay			3			4	4	5	5	5
	% cf.			grl	s			grcl	sl 11	gr sl	l 12
Diagn. Hor	Moll/Umb/His/Cam			60	70		45	40	10	10	80
Site	Slope degrees	His	His	His							
	Slope aspect										20
Other	gley										
	redoximorphic										
	skeletal			y			y				
	fragmental										
	frozen										
	saturated			y		y					
	depth										
	drainage										

Table 19 continued

Landsc.pos	all.plain. Low
	all.plain.higher
	all.fan
	till/terrace
	valley sideslope
	mount.sideslope

Table 20: Terturag soil profiles

		Transect 1											Transect 2							
		Zone 1				Zone 2				Zone 3			Zone 1			campsite				
Horzn	Profiles	H1	H2	H3	H4	H1	H2	H3	H4	H1	H2	H3	H1	H2	H3	H1	H2	H3	H4	H5
Surf. Hor.	O /depth	n	12	2	10	17	2	3		23	12	16	7	4	4	2	2	2	n	2
	Rdeer lichen			y		y		y				y			y		y			
	Green moss		y			y		y			y		y	y				y		y
	R.lich+moss																			
	Depth	10	10	8	22	15	2	8		3	5	6	49	5	10	15	12	7	13	5
	Hue	10YR	10YR	10YR	2.5Y	5Y	10YR	10YR		10YR	10YR	10YR	2.5Y	2.5Y	10YR	10YR	10YR	10YR	10YR	10YR
	Value	2.5	2	3.5	5	3	3	2		2	3	3	5	6	3.5	2	3	3	5	3
	Chroma	2	0	3	4	2	2	2		1	3	2	2	2	1	2	2	2	3	2
	Tex	si, l	si, l	l	vfs	si.l	si.l	si.l		si.l	si.l	si.l	fs	si	si.l	si.l	si.l	si.l	si.l	si.l
	% clay	16	15	16											15	12	17			
	% cf.	50	0	0	0	0	0	0		80	20	0	0		60	70	15	0	15	0
B hor.	Depth																23	13	2	
	Hue																10YR	10YR	10YR	
	Value																6	4	6	
	Chroma																	4	4	
	Tex																si.l	si.l	sa.cl.l	
	%clay																17	20		
	% cf.																	20	45	
C hor.	Depth	10	21	23	22	15	2	17		3					45	67				13
	Hue	10YR	10YR	10YR	2.5Y	5Y	10YR	10YR		10YR			2.5Y		10YR	10YR				10YR

Table 20 continued

	Value	4	6	6	6	5	4	6	4		5		4	4			6
	Chroma	4	4	6	2	3	4	2	4		2		4	4			4
	Tex	gr	si.l	gl	gr	si.cl.l	si.l	gr.cl. l	gr.cl. l		gr		gr	gr			gr.sand
	%clay	2				25	1										
	% cf.	90	0	80	80	60	15	60	80		90		90	85			60
Diagn. Hor	Moll/Umb/His/Cam																
Site	Slope degrees	0							30	30							
	Slope aspect	0							n	n							
Other	gley				22						30	5		y			
	redoximorphic				22			y				5					
	skeletal													y			
	fragmental																
	frozen								y			y					
	depth											23					
	saturated	y	y	y							y						
	depth	45	60	30							60						
	drainage	p	p														
Lands c.pos	all.plain. Low	y	y		y						y	y					
	all.plain.higher			y									y				
	all.fan							y						y	y	y	y	y
	till/terrace					y		y									
	valley sideslope																

Table 20 continued

	mount.sideslope				y							
Comment												
Veg.	grass		y					y	y		y	y
	grass/shrub					y	y			y		
	shrub				y			y				
	larch	y										

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