EFFECTS FROM LONG-TERM NONGRAZING AFTER 75 YEARS

North Dakota State University
Dickinson Research Extension Center
2013

4016a

North Dakota State University *2013*
Dickinson Research Extension Center
Rangeland Research Outreach Program DREC 13-4016a

Effects from Long-Term Nongrazing After 75 Years

Llewellyn L. Manske PhD
Research Professor of Range Science

Project Assistant
Sheri A. Schneider

Cover Photograph
John A. Urban
Range Research Technician

North Dakota State University
Dickinson Research Extension Center
1041 State Avenue
Dickinson, North Dakota 58601

Tel. (701) 456-1118
Fax. (701) 483-2005

CONTENTS

Effects from Long-Term Nongrazing After 75 Years

Llewellyn L. Manske PhD
Research Professor of Range Science
North Dakota State University
Dickinson Research Extension Center

Does removal of cattle grazing
promote development of stable climax plant communities
and preserve prairie grasslands in perpetuity?

The nonagricultural public of the United States have repeatedly been told that cattle grazing damages the nations public grasslands. Lacking conclusive scientific facts, these claims have been corroborated by locating and documenting areas of public rangelands that have deteriorated as a result of poor grazing management. With rhetoric spin, cattle grazing, not poor management, becomes the cause and effect for damage to rangeland areas. Furthermore, rather than following the rational evidence that indicates the need for implementation of better grazing management practices, this controversial argument concludes that cattle grazing should be removed from public rangelands. What are the consequences to grassland ecosystems if cattle grazing were successfully removed from public rangelands?

A long-term project for studying the effects from nongrazing compared to the effects from seasonlong grazing by large grass-eating herbivores (graminivores) on mixed grass prairie plant communities was initiated by Dr. Warren C. Whitman in 1936. This ongoing long-term project monitors changes in herbage biomass production, plant species composition, and soil characteristics on nongrazed areas inside of barbed wire exclosures and on grazed areas outside of the exclosures at four two-way rangeland ecological site reference areas.

This report quantitatively describes the effects from long-term nongrazing as determined by differences in plant community characteristics of the grazed area and ungrazed area at North Dakota's four oldest rangeland reference areas after 75 years of treatment.

Development of Study Areas

European settlement of western North Dakota was encouraged by the Homestead Act of 1862 and followed the construction of the first railroad across North Dakota. The Federal Railroad Land Grant Act of 1864 granted the Northern Pacific Railroad 39 million acres of land in a checkerboard pattern from Duluth, Minnesota to Puget Sound, Washington. Construction of the railroad started in 1870 at Superior, Wisconsin and reached Moorhead, Minnesota in December 1871. The tracks reached Bismarck, North Dakota in June 1873, Dickinson in 1880, and the Montana border in 1881. The human population of western North Dakota greatly increased during 1898 to 1915 with the peak period of activity between 1900 and 1910.

Title to 160 acres of surveyed public domain land west of the Mississippi River was transferred from the US Government to private citizens as a provision of the Homestead Act. Several attempts to adjust the law to meet the needs of the people and the natural resources were made. However, none of the many revisions of the Act met the needs of western United States. Failure of the lawmakers to address the requirements of the natural resources in semiarid regions caused numerous long-lasting management problems. In addition, the economic depression of 1929, the severe drought conditions of 1934 and 1936, and the low agricultural commodity prices received during the late 1920's and early 1930's created extreme hardships for homesteaders. The people living on lands declared to be submarginal were given the option to sell their land back to the federal government.

The Taylor Grazing Act of 1934 removed all unappropriated public domain lands from homestead, which included 68,442 acres in North Dakota. The Land Utilization Project was established in 1935 and a resettlement plan was completed that same year. Under these legislative acts, 1,104,789 homesteaded acres were purchased by the US Government in North Dakota (Hibbard 1965; Carstensen 1968; Manske 1994, 2008). The homestead acres repurchased under the Land Utilization Projects were designated for three specific purposes. The lands identified for grazing use and economic development from livestock agriculture became the Little Missouri National Grasslands, the lands identified for recreation use became the Theodore Roosevelt National Park, and the lands identified for wildlife use became Lostwood National Wildlife Refuge. The Bankhead-Jones Farm Tenant Act of 1937 provided for the implementation of followup conservation and utilization programs and for the development of improved practices of management for the repurchased lands.

Whitman (1953) reported that the United States Department of Agriculture Resettlement Administration authorized the establishment of experimental laboratory areas to conduct research on rangeland management practices for the Land Utilization Project's repurchased acres. Four rangeland reference areas were established in the Pyramid Park Region of the Little Missouri River Badlands in 1936 by an informal agreement. When the USDA Soil Conservation Service took over the administration of the Land Utilization Project, a formal lease agreement was signed in 1939 by the North Dakota Agricultural Experiment Station and the Soil Conservation Service. The lease agreement was for 50 years, and it was automatically renewable every eight years. When the USDA Forest Service took over the administration of the Little Missouri National Grasslands, the agency honored the previous lease agreement and issued an Occupancy Permit in 1955. This Terminable Permit was annually renewable as long as the requirements and conditions were met. To lengthen the term of the permit, the USDA Forest Service issued a Special Use Permit in 1987 to North Dakota State University Agricultural Experiment Station for collection of scientific data on the long term effects of grazing on four typical grassland ecosystems and for related livestock and range research. The permit was reissued in 2005 and requires renewal in 2025 and every twenty years thereafter.

Rangeland Reference Areas

Two-way rangeland reference areas that included a livestock exclosure area and a similar area exposed to livestock grazing were established on four major prairie grassland types based on the classification system developed by Hanson and Whitman (1938). These reference areas have been renamed according to current terminology. The four rangeland reference areas are the oldest scientifically documented reference areas in North Dakota and possibly in the Northern Plains. All four reference areas are located in Billings County, North Dakota, south of the city of Medora in the Pyramid Park Region on the eastern portion of the Little Missouri River Badlands.

The Sandy Ecological Site Reference Area was originally labeled Sandy Upland Rangeland Area and was classified as the Sandgrass Grassland Type, with prairie sandreed (*Calamovilfa longifolia*) as the dominant grass. The reference area is located in Section 15, T 138 N, R 102 W, has slopes of 2% east, northeast, and west, has an exclosure of 6.27 acres, and was constructed in 1937.

The Shallow Ecological Site Reference Area was originally labeled Badlands Upland Rangeland Area and was classified as the Grama-Needlegrass-Sedge Grassland Type, with blue grama (*Bouteloua gracilis*), needle and thread (*Stipa comata*, *Hesperostipa comata*), and upland sedges (*Carex filifolia*, and *Carex heliophila*, *Carex inops heliophila*) as the dominant graminoids. The reference area is located in Section 5, T 138 N, R 101 W, has slopes of 3% north, has exclosures of 6.50 acres in two parts (west 4.90 acres, east 1.60 acres), and was constructed in 1937.

The Silty Ecological Site Reference Area was originally labeled Badlands Slope Rangeland Area and was classified as the Western wheatgrass-Grama-Sedge Grassland Type, with blue grama (*Bouteloua gracilis*), western wheatgrass (*Agropyron smithii*, *Pascopyrum smithii*, *Elymus smithii*), and upland sedge (*Carex filifolia*) as the dominant graminoids. The reference area is located in Section 3, T 138 N, R 101 W, has a slope of 3% south, has an exclosure of 14.10 acres, and was constructed in 1938.

The Overflow Ecological Site Reference Area was originally labeled Sagebrush Flat Rangeland Area and was classified as the Sagebrush Type, with silver sagebrush (*Artemisa cana*) as the dominant shrub and western wheatgrass (*Agropyron smithii*, *Pascopyrum smithii*, *Elymus smithii*), blue grama (*Bouteloua gracilis*), and green needlegrass (*Stipa viridula*, *Nassella viridula*) as the dominant grasses. The reference area is located in Section 11, T 138 N, R 101 W, has a slope of less than 1%, has an exclosure of 2.90 acres, and was constructed in 1937.

The portions of the reference areas that are outside the exclosures have been annually exposed to grazing by livestock, primarily cow-calf pairs, and managed with moderately stocked, 7 to 8 month seasonlong grazing treatments. The grazing treatments are part of larger grazing units that are allotments in the Little Missouri National Grasslands, administered by USDA Forest Service and managed in cooperation with North Dakota Grazing Associations. Grazing permits for these allotments run from 1 May through 31 December, however, in most years the grazing season has been shortened because of inclement weather conditions.

Long-Term Regional Weather

The western North Dakota region has cold winters and hot summers typical of continental climates. Mean annual temperature is 40.9º F (4.9º C). January is the coldest month, with a mean temperature of 11.5º F (-11.4º C). July and August are the warmest months, with mean temperatures of 68.7º F (20.4º C) and 67.0º F (19.5º C), respectively. Long-term (1892-2010) mean annual precipitation is 16.03 inches (407.15 mm). The precipitation during the perennial plant growing season (April through October) is 13.54 inches (343.92 mm) and is 84.5% of the annual precipitation. June has the greatest monthly precipitation, at 3.55 inches (90.14 mm). The precipitation received in the three month period of May, June, and July is 8.13 inches (206.50 mm) and is 50.7% of the annual precipitation (table 1) (Manske 2011c).

Water stress develops in perennial plants during water deficiency periods when the amount of rainfall is less than evapotranspiration demand. Water deficiency months were identified from historical temperature and precipitation data by the ombrothermic diagram technique (Emberger et al. 1963). The long-term (1892-2010) ombrothermic diagram (figure 1) shows near water deficiency conditions during August, September, and October, and favorable water relations during April, May, June, and July. Reoccurrence of water deficiency conditions during April, May, June, and July is 16.9%, 13.6%, 10.2%, and 38.1%, respectively, and during August, September, and October water deficiency reoccurs 52.5%, 50.0%, and 46.6% of the years, respectively. Long-term occurrence of water deficiency conditions is 32.7% of the growing season months, for a mean of 2.0 water deficient months per growing season (Manske et al. 2010).

Table 1. Long-term (1892-2010) mean monthly temperature and monthly precipitation in western North Dakota.

	º F	º C	in.	mm
Jan	11.48	-11.40	0.41	10.39
Feb	15.25	-9.31	0.41	10.34
Mar	26.21	-3.22	0.74	18.71
Apr	41.56	5.31	1.41	35.76
May	52.77	11.54	2.34	59.39
Jun	61.96	16.65	3.55	90.14
Jul	68.74	20.41	2.24	56.92
Aug	67.01	19.45	1.71	43.38
Sep	56.09	13.38	1.34	33.97
Oct	43.74	6.52	0.95	24.20
Nov	28.44	-1.98	0.54	13.62
Dec	16.89	-8.39	0.41	10.33
	MEAN		**TOTAL**	
	40.85	**4.91**	**16.03**	**407.15**

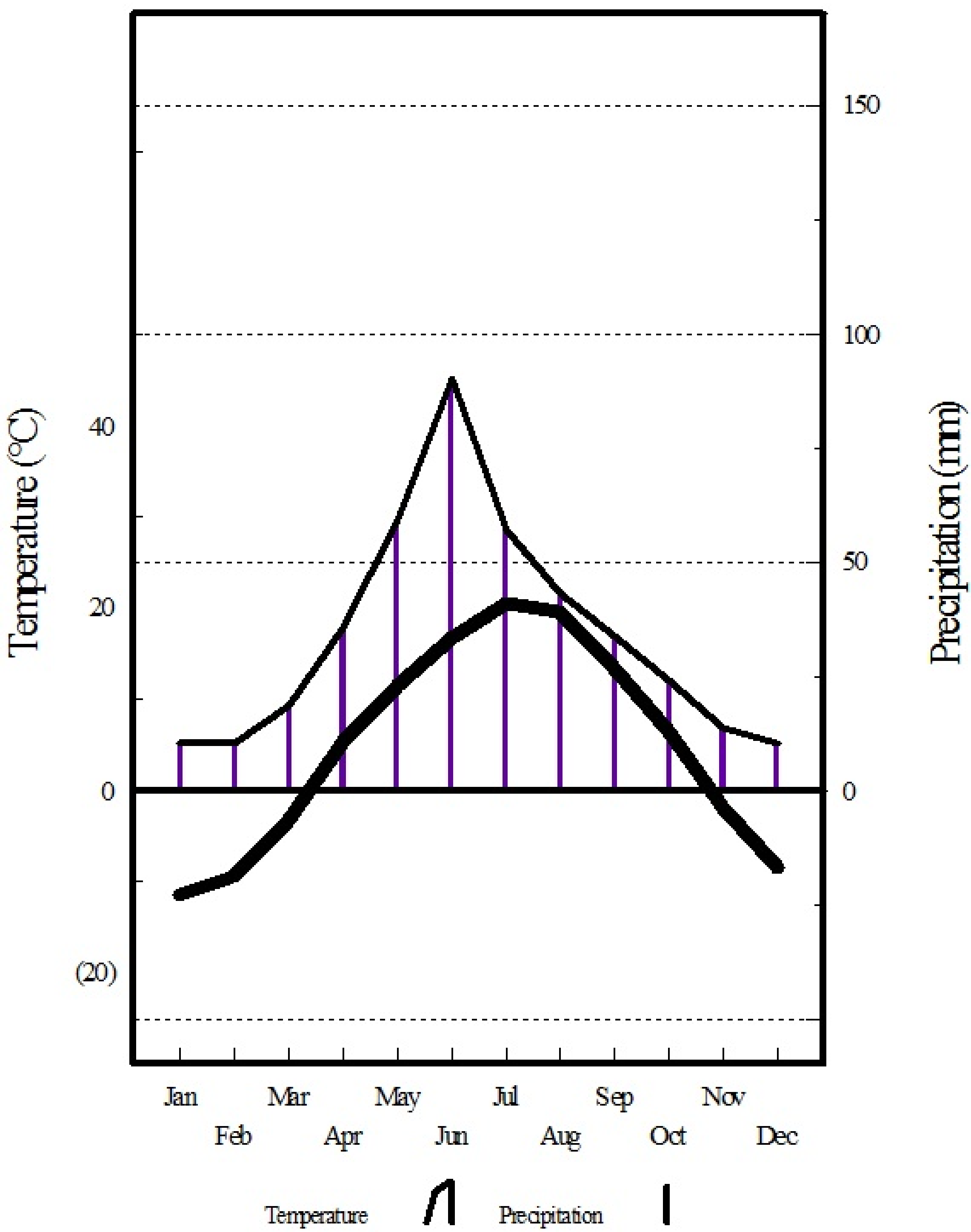

Figure 1. Ombrothermic diagram of long-term (1892-2010) mean monthly temperature and monthly precipitation in western North Dakota.

Procedures

The effects from long-term nongrazing after 75 years was compared to the effects from seasonlong grazing by large graminivores on four major plant communities of the mixed grass prairie at the two-way rangeland reference areas established by Dr. Warren C. Whitman in 1936. Vegetation changes in aboveground herbage biomass, grass basal cover, forb density, shrub density, belowground plant root biomass, rhizosphere biomass, and available soil mineral nitrogen were evaluated with data collected during the growing season from late June through mid September, 2011.

Aboveground herbage biomass was collected by the standard clipping method (Cook and Stubbendieck 1986). Vegetation on the grazed areas outside of the exclosures was protected from grazing during the growing season of 2011 by steel wire quonset type cages measuring 3 X 7 foot placed on the reference areas prior to livestock turnout. The herbage material from five 0.25 m^2 quadrats (frames) at each sample site both inside (ungrazed) and outside (grazed) each exclosure was hand clipped to ground level and sorted in the field by biotype categories: domesticated grasses, cool-season grasses, warm-season grasses, sedges, forbs, standing dead, and litter. The herbage of each biotype category from each frame was placed in labeled paper bags of known weight, oven dried at 140° F (60° C), and weighed. Herbage biomass in pounds per acre for each category were determined from the clipping data. Relative composition of herbage biomass biotype categories were determined.

Plant species basal cover was determined by the ten-pin point frame method (Cook and Stubbendieck 1986), with 2000 points collected in the near vicinity of long-term transect lines both inside (ungrazed) and outside (grazed) each exclosure. The major transect lines were parallel to each other on opposite sides of the exclosure fence. The minor transect lines were perpendicular to the major transect lines and were parallel to each other. Basal cover plant species data were sorted into biotype categories: domesticated grasses, native grasses, sedges, forbs, woody species, and litter. Native grass species were categorized by three methods for analysis: 1) cool-season grasses, and warm-season grasses, 2) tall grasses, mid grasses, and short grasses, and 3) grasses with short shoots and basal leaves, and grasses with long shoots and stem leaves. Basal cover, relative basal cover, percent frequency, relative percent frequency, and importance value were determined from the ten-pin point frame data. Relative composition of basal cover biotype categories were determined.

Density of forbs were determined by counting individual stems of each forb species rooted inside twenty five 0.1 m^2 quadrats placed in the near vicinity of long-term transect lines both inside (ungrazed) and outside (grazed) each exclosure. The major transect lines were parallel to each other on opposite sides of the exclosure fence. The minor transect lines were perpendicular to the major transect lines and were parallel to each other. Forb species were categorized for analysis as: late succession forbs, mid succession forbs, and early succession forbs. Density per 0.1 m^2 quadrat, relatively density, percent frequency, relative percent frequency, and importance value were determined from the forb density data. Relative composition of forb categories were determined.

Density of shrubs were collected by counting individual plants of each shrub species rooted inside twenty five 1.0 m^2 quadrats placed in the near vicinity of long-term transect lines both inside (ungrazed) and outside (grazed) each exclosure. The major transect lines were parallel to each other on opposite sides of the exclosure fence. The minor transect lines were perpendicular to the major transect lines and were parallel to each other. Density per 1.0 m^2 quadrat, relatively density, percent frequency, relative percent frequency, and importance value were determined from the shrub density data. Relative composition of shrub species were determined. This procedure adequately represented the shrub component of the plant community at the sample sites outside (grazed) each exclosure, however, because of the great extent and high number of woody species growing inside the exclosures, this method greatly undersampled the woody plants located within each exclosure. A species present list of shrubs, cacti, and trees was compiled for inside and outside each exclosure.

Digital plant community maps of the four exclosures were developed. Shrub and tree infested plant communities were separated from grass plant communities into distinct map units on the long-term exclosure areas by ocular assessment of USDA National Agriculture Imagery Program 2009 orthoimages as displayed by Google Earth. Surface area of the woody shrub and tree infested map units and the nonwoody grass map units were determined in acres as digital data in ArcGIS. Technical mapping procedures were completed by student ArcGIS technicians, with direction from Tobias L. Stroh, Assistant Professor, Department of Agriculture and Technical Studies, Dickinson State University, Dickinson, North Dakota.

Belowground plant root biomass was collected inside (ungrazed) and outside (grazed) each exclosure by two replicated soil cores 3 inches (7.6 cm) in diameter and 4 inches (10.2 cm) in depth. The proportion of live and dead roots in the total belowground plant biomass was not known because root material requires considerable time, one to four or more years, to decompose. Root material was separated from soil in a water bath assisted with gentle manual agitation, placed in labeled paper bags of known weight, oven dried at 140° F (60° C), and weighed. Root biomass per volume of soil at a one half foot depth was determined from the soil core root weight data and reported as pounds per acre and kilograms per cubic meter.

Rhizosphere biomass was collected inside (ungrazed) and outside (grazed) each exclosure by three replicated soil cores 3 inches (7.6 cm) in diameter and 4 inches (10.2 cm) in depth using a humane soil beastie catcher (Manske and Urban 2012). The fresh rhizosphere material, which included the rhizosphere organisms, the active plant roots, and the adhered soil particles, was separated from matrix soil by meticulous excavation with fine hand tools. Both wet and dry rhizosphere weights were collected. Rhizosphere biomass per volume of soil at a one half foot depth was determined from the soil core rhizosphere weight data and reported as pounds per acre and kilograms per cubic meter.

Soil mineral nitrogen, nitrate and ammonium, was sampled inside (ungrazed) and outside (grazed) each exclosure by three replicated soil cores with 6 inch (15.2 cm) increments to a 12 inch (30.5 cm) depth collected using a Veihmeyer soil tube with 1 inch (2.5 cm) diameter. Soil cores were placed on ice immediately and were frozen within 4 to 6 hours of collection. Analysis of soil core samples for available mineral nitrogen (NO_3-NH_4) was conducted by the North Dakota State University Soil Testing Laboratory. Total available mineral nitrogen at a one foot depth was determined from the soil core data and reported as pounds per acre and milligrams per kilogram.

Early exclosure studies were typically established without replication. Interpretation of treatment effects on plant community characteristics assumes only minor differences in the vegetation of the grazed area and ungrazed area at the time of exclosure constuction on each reference area.

Mathematical comparison of plant community vegetation between the grazed area and the ungrazed area of each reference area was determined by the index of similarity method (Mueller-Dombois and Ellenberg 1974). Similarity index of herbage biomass compared percent composition of biotype categories in common between the grazed area and the ungrazed area as related to the total percent composition of all biotype categories on both areas. Similarity index of basal cover compared importance value of grass species in common between the grazed area and the ungrazed area as related to the total importance value of all grass species on both areas. Similarity index of forb density compared importance value of forb species in common between the grazed area and the ungrazed area as related to the total importance value of all forb species on both areas. Similarity index of woody shrubs and trees compared the number of shrub and tree species present in common between the grazed area and the ungrazed area as related to the total shrub and tree species present on both areas. Similarity index of range condition compared percent herbage dry weight of plant species in the current plant community on the grazed area and on the ungrazed area as a percentage of the hypothetical historic ecological site plant community. Index values of 80% and greater are considered to be similar. Index values greater than 50% are degrees of similarity. Index values of less than 50% are degrees of dissimilarity. And index values of 20% and less are considered to be dissimilar.

A standard t-test was used to analyze differences among means (Mosteller and Rourke 1973). Nomenclature of plant species on the long-term rangeland reference areas follows Flora of the Great Plains (1986)

Results

Sandy Ecological Site

The Sandy Ecological Site (figures 2, 3, and 4) was classified by Hanson and Whitman (1938) as the Sandgrass Grassland Type with prairie sandreed, upland sedges, blue grama, needle and thread, and prairie Junegrass as the major vegetation. The loamy fine sand soil was the Blanchard series, mixed, frigid Typic Ustipsamments. The plant community and belowground characteristics data after 75 years of treatment are on tables 2 to 10 and figures 5 and 6.

Herbage biomass of native grasses was 1777.58 lbs/ac on the grazed area and 545.19 lbs/ac on the ungrazed area, with a 69.3% decrease on the ungrazed area. Herbage biomass of cool season grasses, warm season grasses, and sedges decreased 70.2%, 78.2%, and 59.8%, respectively, on the ungrazed area. Herbage biomass of domesticated grasses was 0.0 lbs/ac on the grazed area and 1158.89 lbs/ac on the ungrazed area, with a 100.0% increase on the ungrazed area. Herbage biomass of forbs was 147.72 lbs/ac on the grazed area and 156.99 lbs/ac on the ungrazed area, with a 6.3% increase on the ungrazed area. Native cool season grasses had the greatest herbage biomass on the grazed area and domesticated grasses had the greatest herbage biomass on the ungrazed area. Total live herbage biomass was 1925.29 lbs/ac on the grazed area and 1861.07 lbs/ac on the ungrazed area, with a 3.3% decrease on the ungrazed area. Standing dead biomass was 353.23 lbs/ac on the grazed area and 230.49 lbs/ac on the ungrazed area, with 34.8% decrease on the ungrazed area. Litter was 104.90 lbs/ac on the grazed area and 791.38 lbs/ac on the ungrazed area, with a 654.4% increase on the ungrazed area. Total dead biomass was 458.13 lbs/ac on the grazed area and 1021.87 lbs/ac on the ungrazed area, with a 123.1% increase on the ungrazed area. The total aboveground plant biomass was comprised of 35.5% dead biomass on the ungrazed area (table 2).

Relative composition of native grass biomass was 92.3% on the grazed area and 29.3% on the ungrazed area, with a 68.3% decrease on the ungrazed area. Composition of cool season grasses, warm season grasses, and sedges decreased 69.1%, 77.5%, and 58.4%, respectively, on the ungrazed area. Composition of domesticated grass biomass was 0.0 % on the grazed area and 62.3% on the ungrazed area, with a 100.0% increase on the ungrazed area. Composition of forb biomass was 7.7% on the grazed area and 8.4% on the ungrazed area, with a 10.0% increase on the ungrazed area. Composition of total live herbage biomass was 80.8% on the grazed area and 64.6% on the ungrazed area, with a 20.1% decrease on the ungrazed area. Composition of total dead biomass was 19.2% on the grazed area and 35.5% on the ungrazed area, with an 84.4% increase on the ungrazed area (table 2). Similarity index of herbage biomass was 18.9% indicating that the composition of biotype categories on the grazed area and on the ungrazed area were dissimilar (table 2).

Basal cover of native grasses was 29.1% on the grazed area and 10.9% on the ungrazed area, with a 62.5% decrease on the ungrazed area. Basal cover of cool season grasses, warm season grasses, and sedges decreased 49.2%, 84.6%, and 39.2%, respectively, on the ungrazed area. Basal cover of domesticated grasses was 0.2% on the grazed area and 5.7% on the ungrazed area, with a 3700.0% increase on the ungrazed area. Blue grama and upland sedges had the greatest basal covers on the grazed area and upland sedges and Kentucky bluegrass had the greatest basal covers on the ungrazed area. Total live basal cover was 30.2% on the grazed area and 17.0% on the ungrazed area, with a 43.8% decrease on the ungrazed area (table 3).

Basal cover of tall grasses, mid grasses, short grasses, and upland sedges were 0.6%, 1.3%, 15.7%, and 11.6%, respectively, on the grazed area and were 2.0%, 1.5%, 0.4%, and 7.1%, respectively, on the ungrazed area. Tall grass and mid grass basal cover increased 225.0% and 20.0%, respectively, and short grass and upland sedge basal cover decreased 97.4% and 39.2%, respectively, on the ungrazed area. Basal cover of short grasses and upland sedges were greater on the grazed area and basal cover of tall grasses, mid grasses, and domesticated grasses were greater on the ungrazed area.

Basal cover of native grasses with short shoots and basal leaves was 28.2% on the grazed area and 8.1% on the ungrazed area, with 71.4% decrease on the ungrazed area. Basal cover of native grasses with long shoots and stem leaves was 1.0% on the grazed area and 2.9% on the ungrazed area, with a 200.0% increase on the ungrazed area. Grasses with short shoots and basal leaves protect the soil and restrict invasion by undesirable plants. The high losses of grasses with short shoots and basal leaves provided the open spaces for the great increase of domesticated grasses on the ungrazed area.

Relative composition of native grass basal cover was 96.5% on the grazed area and 64.3% on the ungrazed area, with a 33.4% decrease on the ungrazed area. Composition of cool season grasses and warm season grasses decreased 9.7% and 72.5%, respectively, and composition of sedges increased 8.1% on the ungrazed area. Composition of domesticated grass basal cover was 0.5% on the grazed area and 33.6% on the ungrazed area, with a 6626.0% increase on the ungrazed area (table 3). Similarity index of basal cover was 49.0% indicating that the importance value of the grass species on the grazed area and on the ungrazed area were more dissimilar than similar (table 3).

Total forb density was 5.8 forbs/0.10 m^2 on the grazed area and 3.5 forbs/0.10 m^2 on the ungrazed area, with a 40.4% decrease on the ungrazed area.

The forb component was composed mostly of native plants, 93.8% on the grazed area and 98.8% on the ungrazed area, and introduced forbs comprised 6.2% on the grazed area and 1.2% on the ungrazed area. Density of late and early succession forbs decreased 75.8% and 88.9%, respectively, and density of mid succession forbs increased 980.0% on the ungrazed area (table 4). Six late succession forbs grew only on the grazed area and were not present on the ungrazed area (table 42). The ungrazed area had a 53.9% decrease in the number of forb species present. Pussytoes, blazing star, and silverleaf scurfpea had the greatest densities on the grazed area and blue wild lettuce, blazing star, and silverleaf scurfpea had the greatest densites on the ungrazed area. Blue wild lettuce had the greatest increase of the forbs on the ungrazed area.

Relative composition of late, mid, and early succession forb density was 89.8%, 3.4%, and 6.1%, respectively, on the grazed area and 36.8%, 62.1%, and 1.2%, respectively, on the ungrazed area. Composition of late and early succession forbs decreased 59.0% and 81.2%, respectively, and composition of mid succession forbs increased 1725.6% on the ungrazed area (table 4). Relative composition of forbs was primarily late succession forbs on the grazed area and was mostly mid succession forbs on the ungrazed area. Similarity index of forb density was 42.8% indicating that the importance value of the forb species on the grazed area and on the ungrazed area were more dissimilar than similar (table 4).

Shrub density collected by the 1.0 m^2 quadrat method measured no shrubs on the grazed and ungrazed sample transect lines (table 5). This quantitative method greatly undersampled the woody plants located within the exclosure. Compilation of the woody species present list identified one shrub species and two cacti species on the grazed area and five shrub species, two cacti species, and one tree species on the ungrazed area (table 6). Similarity index of woody shrubs and trees present was 37.5% indicating that the number of woody species present on the grazed area and on the ungrazed area were more dissimilar than similar (table 6). A greater number of woody species and a greater number of individual woody plants were present on the ungrazed exclosure than were on the grazed area (figure 5). The ArcGIS mapping procedures identified 2.93 acres (46.7%) of nonwoody grass plant communities and 3.34 acres (53.3%) of woody shrub and tree infested plant communities on the 6.27 acre Sandy Ecological Site exclosure (figure 6 and table 7). The woody plant communities occupy a greater proportion of the ungrazed exclosure.

After 75 years of seasonlong grazing, the aboveground vegetation biomass on the grazed area consisted of 19.2% standing dead and litter and 80.8% live herbage. The live herbage was 0.0% domesticated grasses, 92.3% native grasses (41.7% cool season grasses, 26.2% upland sedges, and 24.4% warm season grasses), and 7.7% forbs. After 75 years of nongrazing, the aboveground vegetation biomass on the ungrazed exclosure consisted of 35.5% standing dead and litter and 64.5% live herbage. The live herbage was 62.3% domesticated grasses, 29.3% native grasses (12.9% cool season grasses, 10.9% upland sedges, and 5.5% warm season grasses), and 8.4% forbs (table 2).

Total belowground plant root biomass was 44,175.84 lbs/ac (32.48 kg/m^3) on the grazed area and 19,517.34 lbs/ac (14.35 kg/m^3) on the ungrazed area, with a 55.8% decrease on the ungrazed area (table 8). The 55.8% decrease of the total belowground plant root biomass on the ungrazed area coincided with the 43.8% decrease of the total aboveground live plant basal cover on the ungrazed area.

Rhizosphere biomass was 232,589.59 lbs/ac (171.01 kg/m^3) on the grazed area and 141,196.10 lbs/ac (103.74 kg/m^3) on the ungrazed area, with a 39.3% decrease on the ungrazed area (table 8). Basal cover of native grasses was 29.1% on the grazed area and 10.9% on the ungrazed area. Basal cover of domesticated grasses was 0.2% on the grazed area and 5.7% on the ungrazed area. The 39.3% decrease of rhizosphere biomass on the ungrazed area preceded the 62.5% decrease in native grass basal cover, that was followed by the large increase in domesticated grass basal cover on the ungrazed area.

The total available soil mineral nitrogen of nitrate and ammonium was 31.52 lbs/ac on the grazed area and 23.52 lbs/ac on the exclosure, with a decrease of 25.4% on the exclosure. The quantity of total mineral nitrogen was greater on the grazed area than on the ungrazed exclosure. The quantities of mineral nitrogen were not significantly different on the grazed area and the exclosure. The quantity of nitrate was 6.33 lbs/ac on the grazed area and 7.33 lbs/ac on the exclosure, with an increase of 15.8% on the ungrazed exclosure. The quantity of ammonium was 25.19 lbs/ac on the grazed area and 16.19 lbs/ac on the exclosure, with a decrease of 35.7% on the ungrazed exclosure (table 9). The exclosure had greater nitrate and lower ammonium and the grazed area had lower nitrate and greater ammonium. The greater quantities of nitrate appear to be related to the greater quantities of easily decomposed labile roots of domesticated grasses. The greater quantities of ammonium appear to be related to the greater quantities of native grass roots and greater rhizosphere biomass.

Similarity index of range condition on the grazed area was 59.8%, low good condition, indicating that the relative percent herbage dry weight of plant species of the current plant community was a little more similar than dissimilar to the relative percent herbage dry weight of plant species of the hypothetical historical plant community (table 10). Similarity index of range condition on the ungrazed area was 36.8%, low fair condition, indicating that the relative percent herbage dry weight of plant species of the current plant community was more dissimilar than similar to the relative percent herbage dry weight of plant species of the hypothetical historical plant community (table 10). The current plant community of the ungrazed area had degraded from the hypothetical historical sandy ecological site plant community 38.4% greater than the degradation of the current plant community on the grazed area after 75 years (table 10).

The effects from long-term nongrazing on the sandy ecological site were great after 75 years. Native grass herbage biomass decreased 69.3% and basal cover decreased 62.5% on the ungrazed area. Cool season grass, warm season grass, and sedge herbage biomass decreased 70.2%, 78.2%, and 59.8%, respectively, and basal cover decreased 49.2%, 84.6%, and 39.2%, respectively, on the ungrazed area. Domesticated grass herbage biomass increased 100.0% and basal cover increased 3700.0% on the ungrazed area. Forb herbage biomass increased 6.3%, forb density decreased 40.8%, and the number of forb species present decreased 53.9% on the ungrazed area. The number of shrub and tree species present increased 166.7% of the ungrazed data. Woody plants infested 53.3% of the area on the ungrazed exclosure. Total live plant basal cover decreased 43.8% on the ungrazed area. Total live herbage biomass decreased only 3.3% because the decrease in native grasses was a little greater than the increase in domesticated grasses on the ungrazed area. Total dead biomass increased 123.1% on the ungrazed area (tables 2, 3, 4, 5, 6, and 7). Belowground plant root biomass decreased 55.8% on the ungrazed area (table 8). Rhizosphere biomass decreased 39.3% on the ungrazed area (table 8). Mineral nitrogen decreased 25.4% on the ungrazed area (table 9).

Similarity indices of herbage biomass, basal cover, forb density, and shrubs present were 18.9%, 49.0%, 42.8%, and 37.5%, respectively. Similarity index of herbage biomass indicated that the plant communities on the grazed area and on the ungrazed area were dissimilar. Similarity indices of basal cover, forb density, and shrubs present all indicated that the plant communities on the grazed area and on the ungrazed area were more dissimilar than similar. Similarity index of range condition indicated that the current plant community on the ungrazed area had degraded 38.4% greater than the current plant community on the grazed area.

Figure 2. Sandy Ecological Site, located in Sec. 15, T 138 N, R 102 W, exclosure of 6.27 acres, built in 1937, looking North.

Figure 3. Sandy Ecological Site, located in Sec. 15, T 138 N, R 102 W, exclosure of 6.27 acres, built in 1937, looking East.

Figure 4. Sandy Ecological Site, located in Sec. 15, T 138 N, R 102 W, exclosure of 6.27 acres, built in 1937, looking South.

Table 2. Herbage biomass (lbs/ac) and relative composition (%) for native rangeland on the reference areas in the Little Missouri River Badlands, 1936-2011.

	Herbage Biomass			Relative Composition		
Site: Sandy	lbs/ac Grazed	lbs/ac Exclosure	% Difference	% Grazed	% Exclosure	% Difference
Domesticated Cool Season	0.00	1158.89	+100.00	0.00	62.27	+100.00
Native Cool Season	803.51	239.77	-70.16	41.73	12.88	-69.13
Native Warm Season	468.84	102.04	-78.24	24.35	5.48	-77.49
Sedges	505.23	203.38	-59.75	26.24	10.93	-58.35
Native Grass	1777.58	545.19	-69.33	92.33	29.29	-68.28
Total Grass	1777.58	1704.08	-4.13	92.33	91.56	-0.83
Forbs	147.72	156.99	+6.28	7.67	8.44	+10.04
Total Live	1925.29	1861.07	-3.34	80.78	64.55	-20.09
Standing Dead	353.23	230.49	-34.75	14.82	7.99	-46.09
Litter	104.90	791.38	+654.41	4.40	27.45	+523.86
Total Dead	458.13	1021.87	+123.05	19.22	35.45	+84.44
Total Live & Dead	2383.42	2882.94	+20.96			

	Similarity Index of Herbage Biomass	
Similarity Index	18.9%	(Dissimilar)

Table 3. Basal cover (%) and relative composition (%) for native rangeland on the reference areas in the Little Missouri River Badlands, 1936-2011.

	Basal Cover			Relative Composition		
Site: Sandy	% Grazed	% Exclosure	% Difference	% Grazed	% Exclosure	% Difference
Domesticated Cool Season	0.15	5.70	+3700.00	0.50	33.63	+6626.00
Native Cool Season	3.25	1.65	-49.23	10.78	9.73	-9.74
Native Warm Season	14.25	2.20	-84.56	47.26	12.98	-72.53
Sedges	11.60	7.05	-39.22	38.47	41.59	+8.11
Native Grass	29.10	10.90	-62.54	96.52	64.31	-33.37
Total Grass	29.25	16.60	-43.25	97.01	97.94	+0.96
Forbs	0.85	0.35	-58.82	2.82	2.06	-26.95
Woody Species	0.05	0.00	-	0.17	0.00	-
Total Live	30.15	16.95	-43.78	30.15	16.95	-43.78
Litter	69.85	83.05	+18.90	69.85	83.05	+18.90
Total Live & Dead	100.00	100.00				

	Similarity Index of Basal Cover
Similarity Index	49.0% (More dissimilar than similar)

Table 4. Forb density (#/0.10 m^2) and relative composition (%) for native rangeland on the reference areas in the Little Missouri River Badlands, 1936-2011.

	Density			Relative Composition		
Site: Sandy	#/0.10 m^2 Grazed	#/0.10 m^2 Exclosure	% Difference	% Grazed	% Exclosure	% Difference
Late Succession Forbs	5.28	1.28	-75.76	89.80	36.78	-59.04
Mid Succession Forbs	0.20	2.16	+980.00	3.40	62.07	+1725.59
Early Succession Forbs	0.36	0.04	-88.89	6.12	1.15	-81.21
Woody Species	0.04	0.00	-	0.68	0.00	-
Total Live	5.88	3.48	-40.82			

	Similarity Index of Forb Density	
Similarity Index	42.8%	(More dissimilar than similar)

Table 5. Shrub density (#/1.0 m^2) and relative composition (%) for native rangeland on the reference areas in the Little Missouri River Badlands, 1936-2011.

	Density			Relative Composition		
Site: Sandy	#/1.0 m^2 Grazed	#/1.0 m^2 Exclosure	% Difference	% Grazed	% Exclosure	% Difference
Artemisia cana	0.00	0.00	-	0.00	0.00	-
Rosa arkansana	0.00	0.00	-	0.00	0.00	-
Symphoricarpos occidentalis	0.00	0.00	-	0.00	0.00	-
Total Live	0.00	0.00	-			

Table 6. Shrubs, cacti, and trees present on the reference areas in the Little Missouri River Badlands, 1936-2011.

	Sandy	
	Grazed	Exclosure
Prunus virginiana		X
Rhus trilobata		X
Rosa arkansana	X	X
Symphoricarpos occidentalis		X
Yucca glauca		X
Escobaria vivipara	X	X
Opuntia polyacantha	X	X
Juniperus scopulorum		X
Similarity Index of Shrubs Present		
Similarity Index	37.5% (More dissimilar than similar)	

Figure 5. Sandy Ecological Site, exclosure with increased woody vegetation

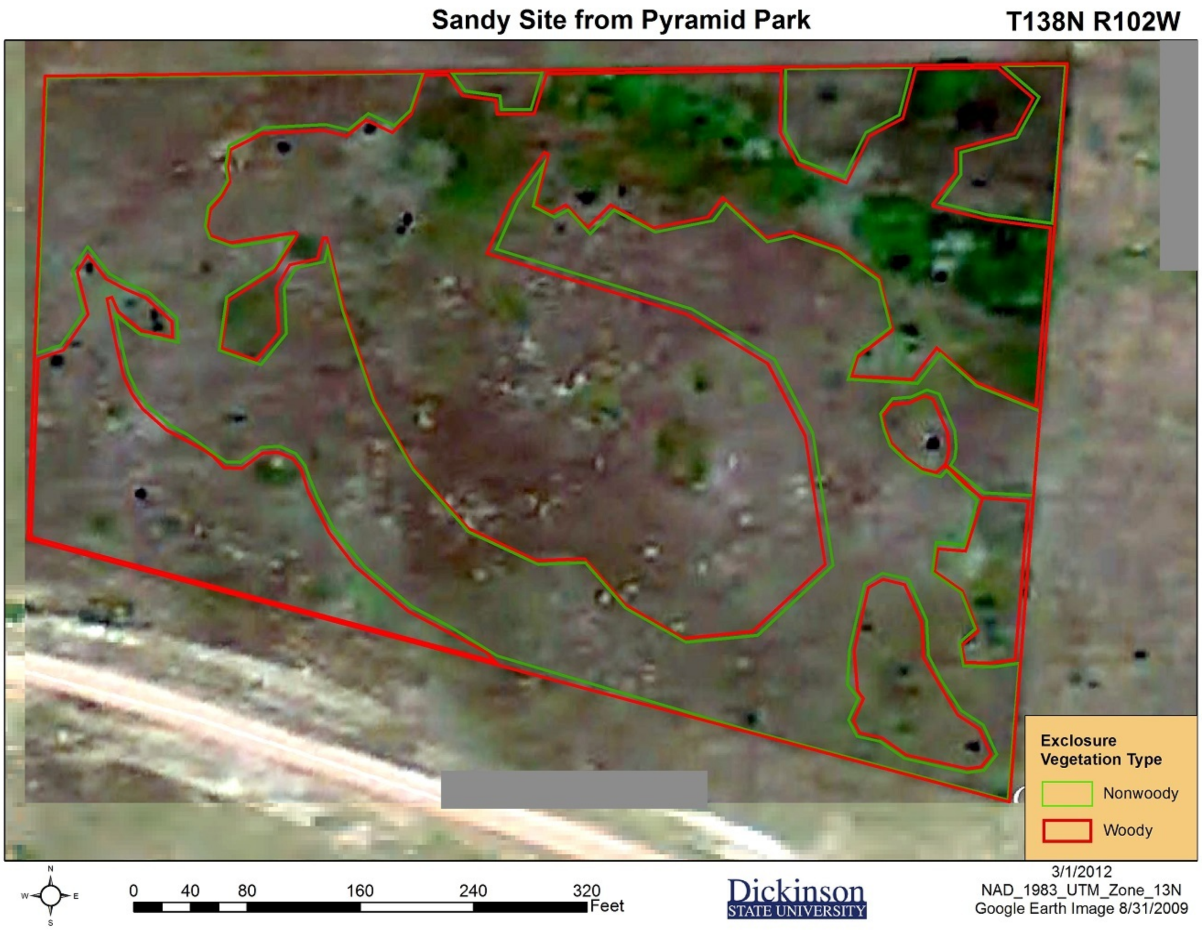

Figure 6. Sandy Ecological Site exclosure with Woody shrub and tree infested plant communities and Nonwoody grass plant communities in the Little Missouri River Badlands, 1936-2011.

Table 7. Woody shrub and tree infested plant communities and Nonwoody grass plant communites in the Little Missouri River Badlands, 1936-2011.

		Major Plant Communities	
Site: Sandy			
	Total Exclosure Area	Nonwoody Grass	Woody Shrub and Tree Infested
Acres	6.27	2.93	3.34
Percentage		46.67	53.33

Determined by ArcGIS mapping procedures.

Table 8. Belowground biomass for plant root weight (lbs/ac and kg/m^3) and rhizosphere weight (lbs/ac and kg/m^3) for native rangeland on the reference areas in the Little Missouri River Badlands, 1936-2011.

	Belowground Biomass				
Site: Sandy	lb/ac Grazed	kg/m^3 Grazed	lbs/ac Exclosure	kg/m^3 Exclosure	% Difference
Root Biomass	44,175.84	32.48	19,517.34	14.35	-55.82
Rhizosphere Biomass	232,589.59	171.01	141,096.10	103.74	-39.34

Table 9. Soil available mineral nitrogen, nitrate and ammonium, (lbs/ac and mg/kg) for native rangeland on the reference areas in the Little Missouri River Badlands, 1936-2011.

	Nitrate-Ammonium (NO_3-NH_4)				
Site: Sandy	lbs/ac Grazed	mg/kg Grazed	lbs/ac Exclosure	mg/kg Exclosure	% Difference
Mineral Nitrogen	31.52	9.66	23.52	7.21	-25.38
Nitrate	6.33	1.94	7.33	2.25	15.80
Ammonium	25.19	7.72	16.19	4.96	-35.73

Table 10. Similarity index of range condition for the grazed area and ungrazed area on the reference areas in the Little Missouri River Badlands, 1936-2011.

Ecological Reference Area	Similarity Index of Range Condition		
	Grazed Area	Ungrazed Area	% Difference
Sandy	59.8	36.8	-38.4
	Low Good	Low Fair	