

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 enclosure 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 enclosure 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 enclosures 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 enclosure 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 enclosure of 2.90 acres, and was constructed in 1937.

The portions of the reference areas that are outside the enclosures 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 40.9° F (4.9° C). January is the coldest month, with a mean temperature of 11.5° F (-11.4° C). July and August are the warmest months, with mean temperatures of 68.7° F (20.4° C) and 67.0° F (19.5° 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).