Vegetation of the Yellow Water Triangle, Montana

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by
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(photos by the author)

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FOREWORD

To the casual observer, vegetation appears to be a random assortment of various plant species, arranged by a mosaic of plant communities into a pleasant landscape. While the pattern of vegetation types may appear to be random, the relationship between a site and its associated vegetation is actually a very specific and predictable one, with site potential resulting from the subtle blend of soil, topography and climate.

Needless to say, the more knowledge a land or wildlife manager has of the intimate relationship between site and vegetation, the better he will be able to manage. This bulletin presents a habitat type classification system for a portion of the plains region of central Montana, an extension of the habitat type concept already in wide use in the mountain and foothill areas. This information should prove useful to anyone interested in a better understanding of Montana's vegetation resource.

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INTRODUCTION

Effective and efficient management of rangeland resources requires an understanding of existing natural and disturbed vegetation and the relationships of the component plant species and communities to various environmental factors and forces. It also requires an understanding of the potential of various land units to support various kinds and amounts of vegetation. Before this knowledge can be useful to the land manager, however, it must be organized into some sort of vegetation or land unit classification system.

Vegetation classification, as opposed to ordination, provides a basis for vegetation mapping, the usual first step in range surveys and development of management plans, as well as for evaluating other resource values such as wildlife habitat (not to be confused with *vegetation* habitat types). Classification also provides a framework within which results of local studies can be correlated, as well as point out gaps in knowledge and indicate new avenues of needed research or management effort. Basic knowledge of successional patterns and relationships of important plant species and communities to climatic and disturbance factors, together with information on site potentials, can provide resource managers with a means of readily and effectively predicting expected vegetation trends or changes under various management practices.

Vegetation classification efforts in the steppe regions of eastern and central Montana have been few, limited in area, and varying in approach. Attempts to classify vegetation in the Montana steppes, or in climatically similar regions, include: Coupland (1950, 1961) and Looman (1963) in the mixed prairie of southern Saskatchewan; Hanson and Whitman (1938), Quinnild and Cosby (1958) and Dix (1958) in the mixed prairie of western North Dakota; Brown (1971) in the badlands of southeastern Montana; Mackie (1970) in the Missouri River Breaks of central Montana; Wright and Wright (1948) in the sagebrush grasslands of south central Montana; Daubenmire (1970) in eastern Washington, and Harniss and West (1973) in southeastern Idaho.

While potential vegetal composition varies continually with one or more environmental factors, gradients *between* areas with dissimilar topoedaphic conditions (ecologic units) are usually relatively abrupt as compared to gradients *within* these ecologic units. Because of the apparent strong relationships between vegetation and topoedaphic conditions, vegetation of the Yellow Water Triangle was treated as a mosaic of associations correlated with site conditions and disturbance factors, i.e., grazing and fire. The classification system presented in this paper is somewhat of a compromise between association

and continuum philosophies wherein data were gathered assuming that vegetal composition varied continuously over space, while final analysis of data involved both objective and subjective attempts to classify the continuum into associations (habitat types).

The concept of habitat type classification, where a climax vegetation association develops in response to climatic and topoedaphic conditions, was first applied to vegetation of eastern Washington and northern Idaho by Daubenmire (1952, 1970). Similar systems have been applied to the forests of Montana by Pfister et al. (1977) and to the mountain grass and shrublands of western Montana by Mueggler and Handl (1974). An attempt has been made here to maintain continuity with these systems. This system is also similar, albeit with different nomenclature, to a vegetation-soil-climate classification system developed by Ross and Hunter (1976) and currently in use by the USDA-SCS. The SCS "range site" seems essentially equivalent to the term "habitat type" as used here. The term "ecologic land unit" (a combination of land type and habitat type), as used by Thompson et al. (1976) of the USDA-Forest Service, Region One, is apparently very similar to the term "habitat type" used in this paper.

This study was initiated during summer 1970. Results were originally intended to assist in the determination of pronghorn antelope and livestock habitat relationships and to aid in evaluation of the ecological effects of chemical and mechanical control of big sagebrush in central and eastern Montana. Just as important, however, the study is seen as the first phase in the development of the philosophies and techniques to be used in a habitat type classification system for the plains area of Montana. Since completion of the triangle habitat type classification system, subjective approximations have been devised for various areas through the plains province (covering approximately 171,000 km^2 [66,023 $mi.^2$] of Montana), with the hope that the entire area can eventually be classified.

While vegetation similar to that of the triangle probably occurs in adjacent areas of central Montana, and possibly other parts of eastern Montana, it must be emphasized that this classification system was not intended for application any place except the area on which sampling was conducted (the triangle). A key for use by personnel in applying the classification system was purposely not devised in order to discourage use of the system in other areas. The only parts of this system meant to be used by workers in other areas, at least without extensive study, are the habitat type concept and the techniques of data gathering and analysis.

DESCRIPTION OF STUDY AREA

Location and Physiography

The triangle lies in east central Montana between U.S. Highway 87, Montana Highway 200 and Route 244, and between the towns of Winnett and Grassrange (Fig. 1). Lewistown, the geographical center of the state, lies 48 km (30 mi.) west of the northwestern corner of the triangle, while Billings is about 113 km (70 mi.) south of its southernmost tip. The triangle encompasses an area of approximately 689.7 km² (266.3 mi.²) of which 62 per cent is in Petroleum County and 38 per cent in Fergus County.

The area is partially bounded by two perennial streams, McDonald and Flatwillow creeks, originating in the Judith and Snowy mountains uplift and flowing into the Musselshell River east of the triangle. McDonald Creek bounds the triangle on the north and Flatwillow Creek flows past the southern and a portion of the eastern borders of the area. Several intermittent streams originate near the western side of the triangle and flow to the east (Fig. 1). Bodies of water are restricted to man-made reservoirs, the largest being Yellow Water Reservoir (85 hectares [211 acres]).

The highest elevations in the triangle occur in that portion of the Snowy Mountains

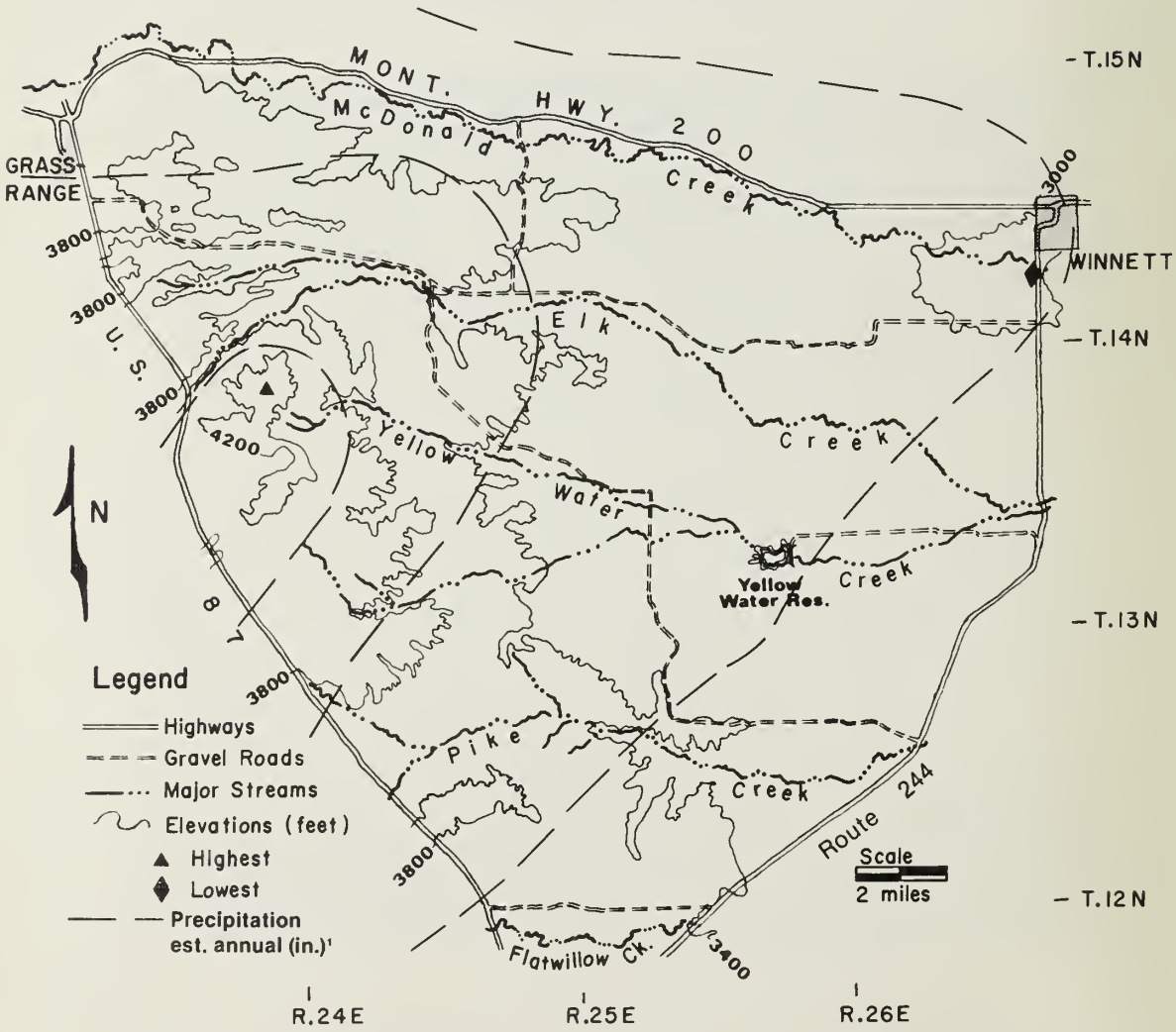


Figure 1. Yellow Water Triangle, Montana.

uplift protruding into the western part of the area (Fig. 1). Button Butte at 1,372 meters (4,500 ft.) is the highest point. The high, gravel-capped bench south of Pike Creek in the southwestern quadrant attains elevations slightly over 1,220 meters (4,000 ft.). The lowest elevation is at the town of Winnett where McDonald Creek crosses Route 244. Elevations along Route 244 increase progressively from McDonald Creek to Flatwillow Creek (Fig. 1).

Geology and Soils

Most of the triangle area (Figs. 3-11) is underlain by Cretaceous strata of the Colorado shale formation (Reeves 1927, Johnson and Smith 1964), lying directly exposed or covered by a relatively thin solum. In many locations, the Colorado shale strata are buried beneath one or more layers of gravel originating from the Judith and Snowy mountains during the Pleistocene ("Ice Age") Epoch. To the west (stratigraphically below) of the outcroppings of Colorado shale is the Kootenai formation surrounding Button Butte (shown as "highest point" in Fig. 1). Numerous igneous intrusions (plugs, dikes, and sills) of apparent Eocene age occur throughout the triangle.

The various geological substrates support distinctive vegetation associations. Each formation comprises several subunits (members); each, upon weathering, produces a different type of soil and, in turn, different plant compositions.

The definite boundaries between geological substrates with their characteristic vegetation facilitated differentiation and mapping of habitat types. The boundary separating habitat types on the upper members of the Colorado shale formation from those on the lowest member of the Colorado shale (and all of the Kootenai formation) is especially distinct due to the abrupt and complete disappearance of *Artemisia tridentata* as one travels from east to west across the area.

Following are descriptions of the geological substrates of the triangle (from Johnson and Smith 1964). Listed under each substrate are the names of soil types. In many cases, these are obsolete names used by Gieseker (1953). Much of the soils nomenclature has been changed since then, and updated information is not available for the bulk of the triangle. However, updated information and nomenclature are available for some parts of the triangle as a result of a soil survey done by the SCS on sagebrush treatment areas of this project. Soil names from this survey are indicated by asterisks.

I. Strata of the Colorado shale formation (from east to west, Cretaceous)

   A. Niobrara member—olive gray shale with limestone and sandstone concretions and some bentonite. Soil—Lismas clay, Thebo clay*(?)

   B. Carlile member—dark gray shale with limestone concretions in upper part and red ironstone concretions in lower part. Soils—Lismas clay, Delpine-Fields silty clay loams*

   C. Calcareous shale member—gray calcareous shale weathering white. Soils—Yawdim and Cabba soils*

   D. Mosby sandstone member—ledge-forming sandstone with a shale layer. Soils—Lismas clay

   E. Belle Fourche member—dark gray shale with bentonite beds and black ironstone concretions in lower part. Soils—Thebo-Lisam clays*, Bercail clay loam*

   F. Mowry member—gray siliceous sandstone weathering white. Soils—?

   G. Unnamed sandy member—gray sandy shale with yellowish gray sandstone. Soils—Thebo clay*, Maginnis clay loam, Martinsdale loam and gravelly loam

   H. Skull Creek member—gray shale with some yellowish gray sandstone in lower part. Soils—Thebo clay*(?), Maginnis clay loam

   I. Lower sandstone member—gray to yellowish brown sandstone. Soils—Castner-Morton loams and stony loams

II. Kootenai formation (Cretaceous, undifferentiated)—ledge-forming metamorphosed sandstone layers interbedded with red shale. Soils—Castner-Morton loams and stony loams, Cushman loam, Darrett loam and stony loam

III. Ellis formation (Jurassic, undifferentiated)—mostly flaggy sandstones. Soils—not known

IV. Quadrant formation (Mississippian, undifferentiated)—limestones and shales. Soils—not known

V. Terraces—gravel-capped tables with gravel layers a few feet to 15 or 20 feet thick. Soils—Phane and Gerdrum soils*, Gerdrum and Tealer clays*, Woodhawk and Verson clay loams*, Marias silty clay*, Verson and Warrick clay loams*, Cargo gravelly loam*, others

VI. Alluvium—material eroded from uplands and redeposited in bottomlands. Soils—Absher and Nobe soils*, Billings-Arvada clay loam, others

VII. Igneous intrusions—hard fractured rock near the surface with shallow soil mantles. Soils—? Since there has been no detailed soils survey made on these geological types, no soil names can be listed.

Climate

The climate of the triangle area is semiarid and cool with great extremes in temperature. Grassrange receives significantly higher annual precipitation than Flatwillow, but mean annual temperatures are similar (Fig. 2). The precipitation difference may be caused by the proximity of Grassrange to the Judith and Snowy mountains uplift. Slightly lower summer temperatures at Grassrange as compared to Flatwillow may be due to the higher elevation of Grassrange—1,061 vs. 956 meters (3,481 vs. 3,136 ft.). Some portions of the area (i.e., Button Butte) in the western part of the triangle are over 300 meters (984 ft.) higher than Grassrange with cooler summer temperatures and greater precipitation than Grassrange (Fig. 2).

Both stations exhibit continental patterns of precipitation with a sharp maximum in early summer (Fig. 2) and a minimum during the winter. On the average, 40 per cent of the total annual precipitation falls during May and June and 75 per cent occurs through the growing season (April-September).

The average freeze-free season ranges from 115-125 days (between 25 May and 17 September) (Caprio 1964).

Land Use

Approximately 16,625 hectares (41,050 acres), or 24.1 per cent of the triangle is administered by the USDI's BLM; the remainder is in private or state ownership. Most of the public land of the triangle is in Petroleum County and is fairly evenly distributed. Some public land is leased to individual landowners and some is under a common use arrangement between several ranchers. An area of public land around Yellow Water Reservoir is designated as the Yellow Water National Wildlife Refuge, administered by the USDI's Fish and Wildlife Service, but it is mainly used for livestock grazing.

Presently, most of the triangle is grazed by cattle with some small areas in cultivation of hay or grain. Total area planted to grain in 1970 (estimated from aerial photographs) was 998 hectares (2,471 acres); approximately 3,400 hectares (8,400 acres) of land was in alfalfa and hayfields.

The intensities and periods of grazing were and are extremely variable across the area; grazing in the past was characterized by greater numbers of livestock, longer periods of use, and more sheep than at present.

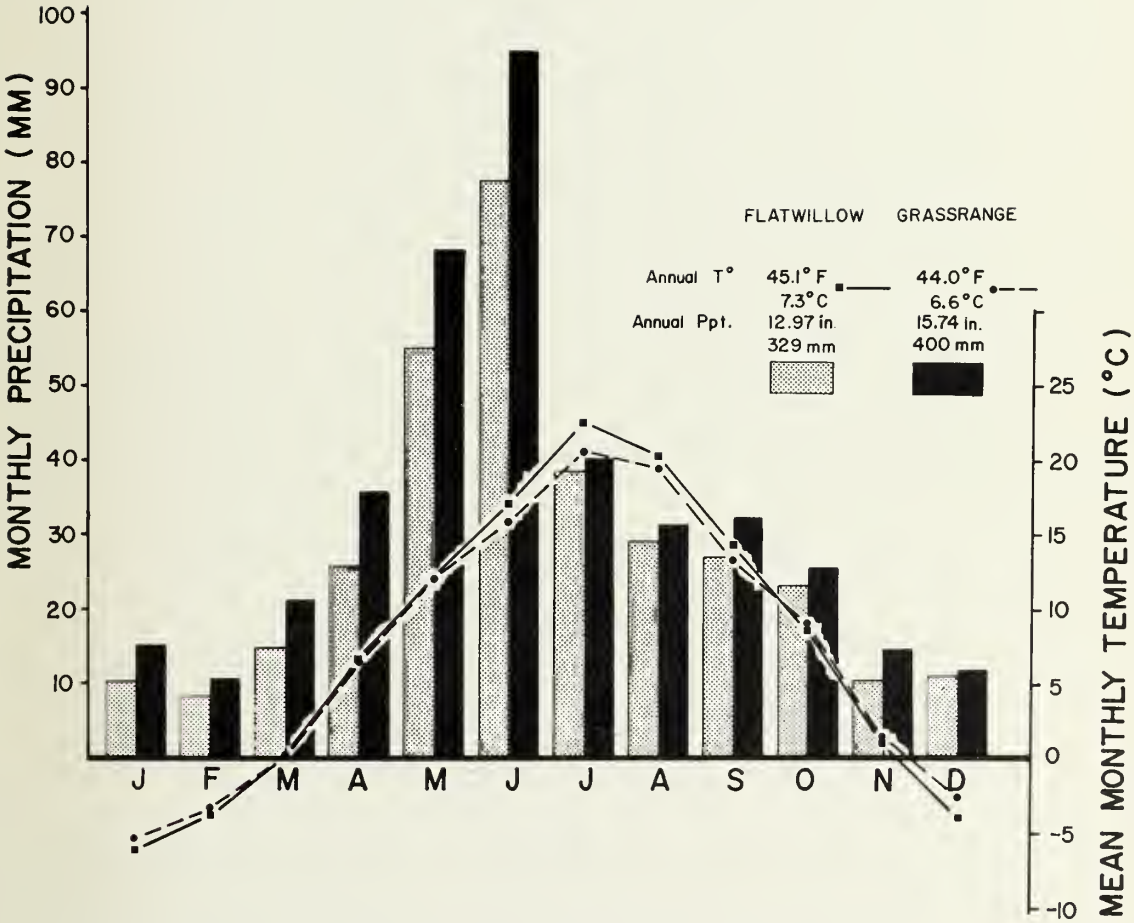


Figure 2. Annual mean temperature and precipitation in the Yellow Water Triangle.

TABLE 1.—Soils Descriptions (Gieseker 1953, SCS unpublished 1966*)

Name	Depth of Solum[1]	Width of A Horiz.[2]	Width of B Horiz.[3]	Color of A Horiz.[4]	Texture of A Horiz.[5]	Texture of B Horiz.[6]	Nature of Parent Material[7]	Salinity	Other Characteristics
Lismas C	6	1-2	4-5	grsh. Brwn.	SiC	C	Clay shale	Low	Non-calcareous
Delpine—Fields CL*	38	3	None	dk. Gr.	SiCL	—	True platy shale	None	Non-calcareous
Yawdim-Cabba soils*	12	3	None	Gr.-lt. Brwnsh. Gr.	L-SiCL	—	Soft shale	None	Moderately calcareous
Thebo-Lisam C*	24-42	5	None	grsh. Brwn.	C	—	Clay shale	Gypsum in[8] C horizon	Clay vertic[9] entisols
Maginnis CL	10-15	6	None	grsh. Brwn.	CL	—	Platy shale	None	Non-calcareous
Martinsdale L & gravelly L	36	5-7	1-13	Brwn.	L	Grav. L	Gravel and sand	None	
Castner-Morton L & stony L	8-30	4-7	0-11	dk. grsh. Brwn.	Stony L	L or CL	Shaly SS	None	Calcareous B horizon
Cushman L	36	5-7	3-13	grsh. Brwn.	L	L or CL	Sandy shale	None	
Darrett L and stony L	24-36	6-10	2-9	rdsh. Brwn.	L or CL	CL	Red shale and SS	None	Calcareous C horizon
Phane*	15-23	1-3	9	grsh. Brwn.	L	C	CL or C alluv.	None	Gravel begins below 20"
Woodhawk*	5 ft.	3-5	8-14	grsh. Brwn.	CL	C	CL or C alluv.	Below 30"	Gravels throughout, gypsum at 55-60" soft vesicular crust on A1[10], lower part of B is calcareous
Gerdrum	5 ft.	A2-2"	27	Brwnsh. Gr.	VF SL	C	C underl. by grav.	Solodic, pH 8-9[11]	Columnar Bt[12] horizon, gypsum at 18-60", no gravel above 40"
Tealer C*	5-6ft.	A2-1"	23	Brwnsh. Gr.	L	C	C alluv.	Solodic B and C horiz. pH 8-9	Gypsum at 11-60", slick spots
Verson CL*	25	1-2	19	grsh. Brwn.	L	C	C alluv. and limestone gravel	None	Lime at 17-42", gravel beginning at 17"
Bercail CL*	34	4	20	grsh. Brwn.	CL	C	C alluv. and C shale	None	Very calcareous B horizon
Cargo gravelly L*	5	5	None	grsh. Brwn.	L	—	Gravel	None	Calcareous throughout, crowns of benches, gravel throughout
Warrick*	26	3	21	Brwnsh. Gr.	L-SiL	C	C or CL on gravel	Gypsum at 26-46"	Gravel below 40"
Marias SiC*	24	4	14	grsh. Brwn.	SiC	SiC	C alluv.	None	On fans and terraces
Absher CL*	9	A2-2"	4	lt. Brwnsh. Gr.	L	C	C and CL alluv.	Very saline below 5" pH 7.8-8.6	Columnar B2t[12] horizon, on low terraces
Nobe C*	4	A1-1"	3	grsh. Brwn.	C	C	C or CL alluv.	Saline below 6" pH 8.5-9	Natric, vesicular crust, on terraces, fans and bottomlands
Billings-Arvada C	8-10	1-2	6-8	Lt. Gr. to Gr.	CL	C	C or CL alluv.	Saline and possibly alkaline	Poor to moderate drainage, on bottomlands

*Soils on treatment areas described in detail by Soil Conservation Service

[1]The depth of the solum is the depth to the parent material (material from which the soil is formed), in inches unless otherwise noted.

[2]If the A horizon is dark, it is called "topsoil."

[3]"Subsoil"

[4]If the horizon is dark (A1) it indicates a non-alkaline, non-saline soil with considerable organic matter in the topsoil.

If the horizon is light (A2), the soil is possibly saline, alkaline, or calcareous (grayish-brown is darker than brownish-gray).

[5]C-Clay, Si-silt, S-sandy, L-loam, Gr.-Gray, grsh.-grayish, Brwn.-brown, Brwnsh.-brownish, lt.-light, SS-sandstone, dk.-dark, VF-very fine, rdsh.-reddish.

[6]Clay "B" horizons signify the presence of subsurface claypans with associated poor water and root penetration.

[7]Soil-forming material.

[8]Gypsum indicates possible salinity but not alkalinity.

[9]Heavily cracked soils subject to heaving and "self-plowing."

[10]A vesicular crust indicates very poor water and air permeability.

[11]Soils with pH below 8.4 may be saline but are not alkaline. Soils with pH above 8.4 are alkaline and may be saline.

[12]A very fine-textured B horizon

METHODS

Any attempt to classify vegetation begins with a subjective approximation. The first step in this approximation was to travel the area, becoming familiar with plant species, vegetal communities, topography, geology, and soils. Although the author was able to identify on sight most of the plants of the region, some use was made of a reference plant collection. Identification of most plants in this collection was verified by Edwin E. Booth, curator of the Montana State University Herbarium at the time. Species identification procedures followed the keys in Booth (1950), and Booth and Wright (1959); nomenclature follows these references or Hitchcock and Cronquist (1973), with the latter given preference. Common names of all sampled species are given in Appendix A Table 2.

The initial approximation was followed by a more intensive reconnaissance. Notes were taken on vegetal composition, relative species dominance, gross soil characteristics, geology, slope, aspect, apparent grazing intensity, and the exact locations of approximately 350 reconnaissance sites throughout the triangle. These sites were chosen subjectively and represented distinct topoedaphic units as seen on 1:15840 black and white aerial photos taken in 1970. At the time of reconnaissance, the vegetation continuum was subjectively broken down into broad types on the basis of gross physiognomy. Some riparian, wetland, and forest types were not analyzed further except to make species lists.

By this time, it was possible to recognize (aided by literature and geological maps of the area) different strata of the Colorado formation, the Kootenai formation, gravel benches, and igneous intrusions. Easily recognizable soil characteristics of importance to plants were: texture and organic matter content of the topsoil, clay content, stoniness, salinity, self-plowing tendencies, permeability, and in some cases, depth of the solum. Other characteristics were judged from information available in literature, soil surveys, and maps. Soils information was derived from a combination of unpublished SCS descriptions, general observations from soil profiles exposed by soil pits or erosion, and observations of the surface characteristics previously mentioned. Detailed soils information is lacking for most of the triangle and gathering detailed and quantitative soils data was beyond the scope of this study. While some gross relationships between soil and vegetation could be deduced, no formal or detailed attempt was made to correlate plant communities with soil characteristics.

The subjective approximate classification was then objectively refined. Seventy-five stands (not included in the original 350 reconnaissance sites) were chosen throughout the area, attempting to choose one or more sampling locations from each topoedaphic entity (except riparian and wetland) as seen on 1:15840 aerial photographs. Once these stands were located on the ground, a macroplot, which appeared to be homogeneous and relatively representative of the stand, was laid out. This macroplot consisted of one or two 30-meter lines, along each of which twenty 2x5 decimeter microplots were evenly spaced. A percentage indicating frequency of occurrence of each species was determined for each stand. Canopy coverage of all plant species, and the area coverage of mulch, rock, and bare ground, were estimated using a slightly modified version of the canopy coverage estimation method used by Daubenmire (1959). An attempt was made to sample stands that seemed relatively less heavily grazed (as judged by apparent vigor of plants, presence of considerable litter and mulch, and a relative lack of grazing-increaser plant species) than the triangle in general. Some heavily grazed, or otherwise disturbed, stands were specifically sampled to try to determine the effects of such disturbance. Each sample site was permanently field marked and recorded on aerial photographs.

Once these data were gathered, initial classifications were refined by arranging the stand vs. species frequency tables in similar groupings (association tables). Frequency rather than canopy coverage data were used for this because it was believed that frequency data were less subject to year-to-year fluctuations resulting from short-term differences in grazing intensity and weather.

Final refinement of the approximation was accomplished by computing indices of similarity between all stands within physiognomic groups, and placing all indices in a matrix with similar stands arranged adjacent to each other (Sneath and Sokal 1962). The index of similarity used was a modification, by Spatz, of Jaccard's community coefficient as reported in Mueller-Dombois and Ellenberg (1974).

In the final classification, the habitat types and phases were grouped within more inclusive categories referred to as series. As mentioned above, these larger categories were chosen subjectively and based on gross physiognomy or life form. Floristic composition of potential vegetation associations (if indeed, associations exist at all) could not be ascertained due to a lack of historical records, a lack of representative relict areas in all ecologic units, and a history of vegetal change over the entire area resulting from heavy grazing. Therefore, descriptions of potential vegetation associations were made using certain assumptions based on known reactions of taxa to various treatments; information from other studies concerning the relationships between plants, edaphic factors, and grazing pressure, and the descriptions of vegetation associations in similar areas by other workers.

A classification system is no better than the quantity and quality of data it is based on, and even the best one must be considered an approximation subject to future change as relationships between plant communities and various influencing factors are better understood. This does not mean, however, that an approximation is not useful or worthwhile. This study, for example, has produced a valuable land management tool in spite of the problems mentioned in the preceding paragraph and certain limitations inherent in the overall objectives and scope of the study. The techniques described here are adequate to turn the concept of the habitat type approach for vegetation classification into a useful system for the vegetation of eastern Montana. Any further attempts at classifying vegetation regionwide on a topoedaphic basis, however, will require a much more rigorous approach including quantitative soil-slope sampling as well as phytosociological studies (i.e., ordination). Because of the importance of *all* habitat types to livestock and wildlife, future work should also include intensive sampling in and the description of all habitat types, including riparian, wetland, and forested.

DISCUSSION

Habitat Types and Phases of the Yellow Water Triangle

The triangle is not a homogeneous area with respect to climate or geology. The precipitation gradient from east to west across the area, and the radically different geology of the east side compared to the west side, causes the triangle to straddle two major biologic zones—the mixed prairies and the foothill grasslands and forests. Because of this, the area represents a kind of transition between the two zones and probably can not be considered as typical of either one.

Triangle vegetation was classified both according to habitat types and existing cover types. Daubenmire (1952) defined "habitat type" as "the collective area which is capable of supporting the same homogeneous plant association." This involves a consideration of the abiotic as well as biotic features of the system, including climate, soil, topography, fire, and native animal influences; effects of man and his animals are not considered. A description of the vegetation of a habitat type is the description of the *potential* vegetation were the site not disturbed; however, such potential vegetation presently exists only on small, isolated relict sites.

The actual vegetation covering a site that has been disturbed is called the cover type. These cover types are the result of heavy grazing pressure by livestock, and/or cultivation, and are susceptible to changes in species composition when management is altered. As will be discussed later, some apparent types may be fire climaxes resulting from events occurring periodically throughout history. A discussion of cover types and successional changes to be expected within the major habitat types is found later in the discussion of habitat types and management. Some areas of the triangle are undergoing primary succession, at least this was the case before man accelerated the rate of soil erosion to the point where it was more rapid than soil development. Many parts of the triangle, with a few decades of overgrazing and poor farming practices, evidently lost topsoil formed over thousands of years (Ellison 1960, Noble 1969, and Hormay 1970). Evidences of past erosion can be seen in extensive raw gully formation, plant pedestalling, and formation of erosion pavements. Since hundreds or thousands of years will elapse before these areas could again support pristine vegetation (if such is desired), the potential vegetation associations for these sites should be considered early stages of primary succession; these associations are stable and highly adapted to the present rather than original (more highly developed) soils.

Vegetation over the area is in all stages of secondary succession due to different degrees of livestock grazing pressure. Areas experiencing light pressure over a number of years, and not severely damaged by past erosion, probably indicate what the potential vegetation should be. Other places have had so much accelerated erosion that, for the most part, a new site potential, different from what it was before the arrival of the white man, has been established.

Overgrazing, by removal of soil-protecting litter (mulch) and vegetation cover, increases water run-off from uplands (Adams 1966, Noble 1969, and Whitman et al. 1964) tending to strip the topsoil from adjoining low-lying areas. Following a long period of such accelerated erosion, some low-lying areas probably bear little resemblance to what they were before livestock grazing began. In this way, extreme livestock grazing pressure on some areas has led to the destruction or complete change of soil and vegetation on locations miles away (Shantz 1935, Jacks and Whyte 1939).

Appendix A Table 3 lists coverage of vegetation types. Area coverage was estimated using the dot grid method on 1:15840 aerial photographs which had the habitat types outlined. Appendix A Table 1 shows canopy coverage of important taxa in each habitat type where data were gathered. The relationships between major habitat types or phases with geology are shown in Figures 3-11. Not all habitat types described are shown.

The habitat and cover types of the triangle occupying the greatest area may be divided into three basic categories according to life form of the dominant plants: (1) shrub-grassland, (2) coniferous forest, and (3) grassland. Another category includes the wetland types. Naming of habitat types and phases was done using both constancy (per cent occurrence of species by stands) and canopy coverage data, with constancy

being given more weight. Further subdivisions provide series and habitat types as follows:

Hierarchy of Yellow Water Triangle Vegetation Classification (species names and symbols) are given in Appendix A Table 2

I. Shrub-grasslands

A. *Artemisia* Series

1. *Artemisia tridentata/Agropyron spicatum* Habitat Type, *Bouteloua gracilis* Phase
2. *Artemisia tridentata/Agropyron spicatum* Habitat Type, *Agropyron smithii* Phase
3. *Artemisia tridentata/Agropyron dasystachyum* Habitat Type, *Agropyron spicatum* Phase
4. *Artemisia tridentata/Agropyron dasystachyum* Habitat Type, *Sarcobatus vermiculatus* Phase
5. *Artemisia tridentata/Koeleria cristata* Habitat Type
6. *Atriplex dioica/Gutierrezia sarothrae* Habitat Type
7. *Artemisia tridentata/Festuca idahoensis* Habitat Type, *Bouteloua gracilis* Phase
8. *Rosa arkansana/Thermopsis rhombifolia* Habitat Type
9. *Artemisia cana/Agropyron smithii* Habitat Type

B. *Sarcobatus* Series

1. *Sarcobatus vermiculatus/Agropyron dasystachyum* Habitat Type

C. *Juniperus* Series

1. *Juniperus horizontalis/Carex parryana* Habitat Type

II. Wetlands (not subdivided into series)

1. *Populus deltoides/Symphoricarpus occidentalis* Habitat Type
2. *Scirpus/Carex* Habitat Type
3. *Suaeda/Salicornia rubra* Habitat Type

III. Grasslands (not subdivided into series)

1. *Agropyron spicatum/Agropyron smithii* Habitat Type
2. *Muhlenbergia cuspidata/Andropogon scoparius* Habitat Type
3. *Poa pratensis/Artemisia ludoviciana* Habitat Type

IV. Coniferous Forest

A. *Pinus* Series

1. *Pinus ponderosa/Artemisia tridentata* Habitat Type
2. *Pinus ponderosa/Agropyron spicatum* Habitat Type

Shrub-Grasslands

Artemisia Series

Artemisia tridentata/Agropyron spicatum Habitat Type *Bouteloua gracilis* Phase

1. Floristic composition

Dominant—*Artemisia tridentata, Agropyron spicatum, Bouteloua gracilis, Poa sandbergii, Stipa comata*

Subordinate—*Koeleria cristata, Agropyron dasystachyum, Artemisia frigida, Selaginella densa, Carex stenophylla, Opuntia polyacantha, Vicia americana, Agropyron smithii*

2. Site—undulating uplands
3. Geology—Niobrara member (M), Carlile M, Mosby M, Belle Fourche M, Mowry M, unnamed sandy M, Skull Creek M, terraces, igneous intrusions (Fig. 3)
4. Soil description—Well developed with mollic epipedon, deep solum, thin topsoil, clay subsoil
5. Soil types—Lismas C, Delpine-Fields SiCl, Thebo-Lisam C, Bercail Cl, Maginnis Cl, Martinsdale I, Phane, Gerdrum, Woodhawk, Verson, Marias, Warrick
6. Parent materials—various
7. Relative productivity—high
8. Management—moderate or light grazing, no cultivation. Heavy grazing results in replacement of *Agropyron spicatum* by *Bouteloua gracilis*. Conversion to grassland is highly destructive to pronghorn and sage grouse habitat.

The *Artemisia tridentata/Agropyron spicatum* habitat type, as originally defined by Daubenmire (1970), exists only in Washington; vegetation associations in central Montana dominated by these two species are considerably different in respect to the floristic composition contributed by subordinate species. Therefore the *Artemisia tridentata/Agropyron spicatum*-dominated plant communities in this area are designated the *Bouteloua* phase of the *Artemisia tridentata/Agropyron spicatum* (Montana) habitat type of Mueggler and Handl (1974).

The *Bouteloua* phase differs from Daubenmire's (1970) habitat type due to the presence of typical mixed prairie species: *Bouteloua gracilis, Koeleria cristata, Opuntia polyacantha, Artemisia frigida, Gutierrezia sarothrae, Vicia americana*, and *Phlox hoodii*. The phase contains *Stipa comata* and *Poa sandbergii* as does Mueggler's and Handl's (1974) habitat type.

The *Artemisia tridentata-Agropyron spicatum* association is found on relatively well-developed soils formed from a variety of parent materials, and has probably had the opportunity to reach a state of dynamic equilibrium under conditions of the prevailing climate. Because of this apparent advanced state of development, the *Artemisia tridentata-Agropyron spicatum* association was considered to be the climatic climax for the areas underlain by the Colorado shale formation. *Agropyron spicatum* usually, but not always, occurs on soils with a dark topsoil. Some stands of *Agropyron spicatum* are situated on entisols (soils lacking horizon differentiation), although these are not considered to be the same phase.

Because of wetter springtime weather to the west, which is closer to the center of origin of the species, *Agropyron spicatum* completes most of its growth in spring and early summer (Blaisdell 1958, Pyrah 1972). The triangle may be a transition area between the mixed prairie just to the east and the *Agropyron spicatum*-dominated grasslands of the Judith Basin and other areas to the west. *Agropyron spicatum* becomes increasingly restricted to rocky hilltops as one travels east in Montana, finally disappearing in the western Dakotas, whereas typical mixed prairie associations increase to the east. The upland soils of the triangle appear to be more favorable for *Agropyron spicatum* (presumably migrating in from the west) than for any other grass. *Artemisia* seems to be better adapted to soils of the triangle and nearby areas underlain by the Colorado formation than it is to the soils of both the areas just to the west (underlain by the Kootenai formation) and the east (underlain by the Eagle formation). Soils derived from both these formations support little *Artemisia tridentata*, even when heavily grazed. The sandy soils of the Eagle formation are highly favorable for *Stipa comata;* the vigor of this species on sandy soils is far greater than on the generally clay or clay loam soils of the triangle.

Numerous areas without *Artemisia tridentata* may be found on the gravel terraces, usually as a result of past and present fires occurring throughout the region during hot,

dry periods in late summer. Once burned, a stand of *Artemisia tridentata* in this region does not re-establish for many years, leaving a perennial grass-dominated site. Most of these burned areas are within the *Artemisia tridentata-Bouteloua gracilis* cover type and are considered to be a variation of this type.

Artemisia tridentata/Agropyron spicatum Habitat Type *Agropyron smithii* Phase

1. Floristic composition

   Dominant—*Agropyron smithii, Artemisia ludoviciana, Stipa viridula*

   Subordinate—*Artemisia tridentata, Taraxacum officinale, Tragopogon dubius*

2. Site—swales and footslopes
3. Geology—terraces and tables, Lower Sandstone M
4. Soil description—Well developed with relatively thick dark topsoil, loam texture, deep solum
5. Soil type—Syblon
6. Parent materials—alluvium
7. Relative productivity—very high
8. Management—moderate grazing, cultivation will result in gully formation. Conversion to grassland is highly destructive of pronghorn and sage grouse habitat. Contour-furrowing may temporarily reduce run-off and erosion.

Moisture collecting sites associated with the gravel-capped tables support a more mesophytic vegetation composition than those receiving only the macroclimatic amount of moisture. These sites include swales and footslopes of bluffs and hillsides. The soils are deep with good moisture penetration, supporting dense swards of *Agropyron smithii* and *Stipa viridula*, and numerous forbs such as *Artemisia ludoviciana, Taraxacum officinale* and others. *Artemisia tridentata* is often absent in the middle of swales, possibly because of severe competition from the dense grass cover.

Artemisia tridentata/Agropyron dasystachyum Habitat Type *Agropyron spicatum* Phase

1. Floristic composition

   Dominant—*Artemisia tridentata, Agropyron dasystachyum, Agropyron smithii*

   Subordinate—*Agropyron spicatum, Poa sandbergii, Koeleria cristata, Stipa viridula, Vicia americana*

2. Site—undulating uplands and gentle slopes
3. Geology—Niobrara M, Carlile M, Belle Fourche M, unnamed sandy M, Skull Creek M, terraces (Fig. 4)
4. Soil description—poorly developed, shallow solums, little or no topsoil, clay texture throughout, alkaline and possibly saline, self-mulching
5. Soil types—Lismas C, Thebo-Lisam C, Tealer
6. Parent materials—clay shale
7. Relative productivity—moderate
8. Management—little or no grazing, no cultivation.

This is called the *Agropyron smithii* phase of the *Artemisia tridentata/Agropyron dasystachyum* habitat type to distinguish it from a habitat type of the same name but with somewhat different composition in southern Idaho (R. Daubenmire 1977, personal communication). Soils formed directly over shale outcrops of the Colorado formation are usually high in clay content and soluble salts. The salts normally include an excess of sodium ions, adversely affecting soil physical properties (unless large amounts of calcium

ions are also present).

Clay soils forming over shales often lack horizon differentiation (where it is impossible to separate out a topsoil layer and a subsoil layer in the profile). There are two reasons for this: First, the soils are newly formed (young) and haven't had a chance to develop horizons; second, these soils possess vertic tendencies (self-mixing), but not to the extreme of being true "vertisols," caused by expansion and contraction, upon wetting and drying, of bentonite clay. A soil with vertic tendencies is restrictive to the types of plants able to grow in it. Ordinarily *Agropyron spicatum* is not abundant on vertic soils in the triangle, possibly as a result of overgrazing rather than the inability of the plants to grow in that type of soil. Heavy clay soils support an association dominated by *Artemisia tridentata, Agropyron dasystachyum, Agropyron smithii,* and *Agropyron spicatum* plus considerable *Koeleria cristata, Stipa viridula,* and *Poa sandbergii.* Coverage of *Agropyron spicatum* is usually less than in the *Artemisia tridentata/Agropyron spicatum* habitat type, *Bouteloua* phase, whereas coverage of rhizomatous forms of *Agropyron* is greater. *Agropyron spicatum* is the dominant grass on some sites, possibly depending on the degree of soil development. It appears that this habitat type could be an intermediate stage of primary succession between the undeveloped soils of shale slopes and the well-developed soils of the *Artemisia tridentata/Agropyron spicatum* habitat type, *Bouteloua* phase. Forb coverage is reduced and composition is different on this type of soil as compared to soils of other *Artemisia* habitat types. *Vicia americana* occurs with somewhat greater constancy than it does in the *Artemisia tridentata/Agropyron spicatum* habitat type, *Bouteloua* phase.

White and Lewis (1969) found the roots of *Agropyron smithii* and *Stipa viridula* are constructed so that the outer layers (cortex) of the roots strip off when vertic soils crack, leaving the roots unbroken. Many other species of plants do not survive in these soils because the cracking movements break the roots.

Due to the dense clay surface, *Bouteloua gracilis* and *Stipa comata* are almost absent from this habitat type even with heavy grazing. *Selaginella densa* is also nearly absent.

The *Artemisia tridentata/Agropyron dasystachyum* habitat type, *Agropyron spicatum* phase usually occurs on soils derived from shales of certain members of the Colorado formation. Soils from various parts of these members also support the *Artemisia tridentata/Agropyron spicatum* habitat type, *Bouteloua* phase, possibly due to a greater degree of development.

Because a considerable amount of clay material was mixed with the gravel on gravel-capped terraces or deposited over it, some sites on the terraces support vegetation more adapted to a clay soil than normally expected. In some spots, the original parent material apparently contained considerable sodium salts. Sodium ions disperse the very fine soil particles, drastically slowing water penetration, thereby influencing the vegetation composition. Water stands in these spots (called "slick spots"), eventually evaporating rather than soaking in. The vegetation on slick spots appears to be an *Artemisia tridentata-Agropyron dasystachyum* association (possibly similar to the *Schedonnardetum paniculati* association of Looman 1963) but with less *Artemisia* than in other areas.

Artemisia tridentata/Agropyron dasystachyum Habitat Type *Sarcobatus vermiculatus* Phase

1. Floristic composition

   Dominant—*Artemisia tridentata, Agropyron dasystachyum, Sarcobatus vermiculatus, Distichlis stricta*

   Subordinate—*Iva axillaris, Gutierrezia sarothrae, Bahia oppositifolia*

2. Site—rolling uplands and relatively steep hillsides

3. Geology—Niobrara M, Carlile M, Mosby M, Belle Fourche M, unnamed sandy M, Skull Creek M (Fig. 4)

4. Soil description—usually clay or clay loam, alkaline and saline, often vertic, weak development, ground water relatively near surface

5. Soil types—Thebo-Lisam C, Lismas C, others (?)

6. Parent materials—marine shales
7. Relative productivity—low
8. Management—Anything more than light grazing pressure will result in severe erosion. Cannot be cultivated.

This phase occupies clay or clay loam soils usually where a ground water supply is available to the *Sarcobatus* (Rickard 1965a, Branson et al. 1970). The ground water in these locations is saline and usually alkaline (high in sodium and carbonate ions) with the salts and water being translocated from the roots to the leaves of the *Sarcobatus* plants. When the leaves fall from the shrubs, the salts contained therein are added to the surface of the soil. Presumably in this way a non-saline, non-alkaline soil surface with *Sarcobatus* bushes and overlying saline-alkaline ground water can become saline-alkaline. A soil with a surface layer that is at least non-saline (not necessarily non-alkaline) is apparently necessary for the survival of *Artemisia tridentata* (Daubenmire 1970), and if something causes this condition to change, the *Artemisia* may be killed. (For a discussion of the problems of salinity and alkalinity in soils and their differences, see the staff publication of the U. S. Salinity Laboratory 1954.) Rickard (1964) compared pH (measure of alkalinity), conductivity (measure of salinity), and exchangeable sodium percentage in the surface soil beneath *Artemisia* and *Sarcobatus* bushes and found that all measurements were higher under the *Sarcobatus* than the *Artemisia*. He concluded that salts were being added to the soil by the *Sarcobatus* bushes and that these salts were killing adjacent *Artemisia* bushes, since many of these plants were dead or dying.

The addition of sodium ions to the topsoil by *Sarcobatus*, in addition to accelerated erosion resulting from overgrazing, has a detrimental effect on the physical properties of the soil, reducing moisture penetration and thereby influencing the vegetation composition (Rickard 1965b). Possibly in all areas where both *Sarcobatus* and *Artemisia* exist, and where the *Sarcobatus* is maintaining itself and reproducing, all of the *Artemisia* (and other plants intolerant of saline-alkaline conditions in the surface soil) will eventually be eliminated.

If the surface soil between *Sarcobatus* shrubs is not saline-alkaline, *Artemisia tridentata*, *Agropyron dasystachyum*, *Iva axillaris*, and *Gutierrezia sarothrae* will be found. Where the canopy coverage of *Sarcobatus* is high, and the soil very saline-alkaline, the dominant grass is *Distichlis stricta* and where saline-alkaline ground water approaches or reaches the surface, thick stands of this grass are present. Daubenmire (1970) reports that *Sarcobatus* and *Distichlis* are very tolerant of salinity in soils, *Artemisia tridentata* much less so, and *Agropyron* even less than *Artemisia*. *Artemisia* is more tolerant of high alkalinity than of high salinity.

Artemisia tridentata/Koeleria cristata Habitat Type

1. Floristic composition

   Dominant—*Artemisia tridentata*, *Koeleria cristata*, *Agropyron dasystachyum*

   Subordinate—*Gutierrezia sarothrae*, *Phlox hoodii*, *Arenaria hookeri*, *Eriogonum pauciflorum*, *Eriogonum flavum*, *Carex filifolia*, *Agropyron spicatum*, *Vicia americana*, *Petalostemon purpureum*
2. Site—gentle upland slopes, crowns, and sides of gravel-capped terraces
3. Geology—calcareous shale M, edges of terraces
4. Soil description—weakly developed, shallow solum, Si or SiC texture may be gravelly, calcareous
5. Soil types—Yawdim-Cabba, Cargo
6. Parent materials—calcareous silty shale, gravel
7. Relative productivity—very low
8. Management—Even very light grazing pressure will cause erosion. Cultivation will result in severe erosion.

Immature soils derived from the calcareous shale member of the Colorado formation support a distinctive vegetation type consisting solely of the *Agropyron dasystachyum-Carex filifolia* association (apparently similar to Looman's 1963 *Eriogonum flavi* alliance). In addition to the dominant species, *Gutierrezia sarothrae, Phlox hoodii, Machaeranthera grindeloides, Eriogonum pauciflorum,* and *Eriogonum flavum* are common. Coverage of bare ground is high and that of litter is low. Erosion potential appears high. The immature nature of the soil and the types of plants present indicate that this habitat type is probably in an early state of primary succession. In observing the habitat type from a distance, the very low canopy coverage of *Artemisia* is striking when contrasted to sites on either side of it; apparently *Artemisia tridentata* in this area does not thrive on silty, calcareous soils.

The crowns of gravel-capped terraces constitute a variation within this habitat type. Although some notable differences in vegetation composition are evident, they are not great enough to warrant creation of a different habitat type. The canopy coverage of all species of plants is low, and that of bare ground and rock is high. In addition to *Artemisia tridentata* and *Agropyron spicatum,* there are *Muhlenbergia cuspidata, Carex filifolia,* and a large number of caespitose forb species (i.e., *Arenaria hookeri, Phlox hoodii,* and *Paronychia sessiliflora*). This might be considered a *Muhlenbergia cuspidata* phase of the *Artemisia tridentata/Agropyron spicatum* habitat type.

Atriplex dioica/Gutierrezia sarothrae Habitat Type

1. Floristic composition

   Dominant—*Atriplex dioica, Gutierrezia sarothrae, Agropyron dasystachyum*

   Subordinate—*Sitanion hystrix, Iva axillaris, Artemisia tridentata*

2. Site—badlands, uplands, fans
3. Geology—Belle Fourche M, unnamed sandy M, Skull Creek M, alluvium from various shale members
4. Soil description—very weakly developed, clay (bentonite), alkaline
5. Soil type—not known
6. Parent material—montmorillonite clay (bentonite) or clay alluvium
7. Relative productivity—nearly zero
8. Management—provides virtually no usable forage for livestock. Cannot be cultivated.

The *Atriplex dioica-Gutierrezia sarothrae* association comprises mostly *Atriplex dioica* and little else. The soil varies from slightly altered bentonite to almost pure bentonite, is often saline-alkaline, and subjects all plants growing in it to extremely high moisture stress (Branson et al. 1970). Areas with pure bentonite are so restrictive to plant growth that nothing can become established. Even after heavy rains, most of the water runs off, wetting only the top few centimeters of clay. Those areas with some plant growth apparently have some organic material and silt incorporated with the bentonite or wind-deposited from other places. As with the *Artemisia tridentata/Koeleria cristata* habitat type, this type is in an early stage of primary succession, the condition persisting due to the inherent resistance of the material to modification. Sometimes the *Atriplex-Gutierrezia* association occurs on clay outwash soils originating from raw shale slopes of the Carlile member. These soils also are very impervious to water penetration, supporting only relatively xerophytic vegetation. These sites are often adjacent to *Sarcobatus* bottomlands, intergrading with the *Sarcobatus vermiculatus/Agropyron dasystachyum* habitat type and habitat types containing *Artemisia.*

Artemisia tridentata/Festuca idahoensis Habitat Type *Bouteloua gracilis* Phase

1. Floristic composition

   Dominant—*Agropyron spicatum, Festuca idahoensis*

Subordinate—*Artemisia tridentata, Stipa comata, Koeleria cristata, Artemisia frigida, Bouteloua gracilis, Balsamorrhiza sagittata*

2. Site—high elevation uplands receiving over 16 inches annual precipitation
3. Geology—Kootenai formation
4. Soil description—stony; well developed; thick, dark topsoil; loam texture; non-saline; non-alkaline
5. Soil type—not known
6. Parent material—sandstone
7. Relative productivity—high
8. Management—withstands moderate to high grazing pressure. Highly productive under cultivation.

Some relicts of an *Artemisia tridentata-Festuca idahoensis* association on the tops of small, steep-sided buttes inaccessible to livestock are separated from the rest of the *Artemisia* shrub-grasslands by approximately two miles of continuous grassland *(Agropyron spicatum/Bouteloua gracilis* habitat type). *Artemisia tridentata* is the dominant shrub along with some *Artemisia cana* and *Juniperus horizontalis* shrubs. *Agropyron spicatum* generally has a higher canopy coverage than *Festuca idahoensis*, although both are dominant grasses. On these sites are some of the few occurrences of *Balsamorrhiza sagittata* east of the main chain of the Rocky Mountains, although it occurs in a few other places in the Judith Basin. This forb is an indicator of the *Artemisia tridentata-Festuca idahoensis* association in Montana and Idaho. The phase is distinguished from Daubenmire's (1970) *Artemisia tridentata/Festuca idahoensis* habitat type in that the latter contains no *Artemisia frigida, Koeleria cristata*, or *Bouteloua gracilis*. The presence of *Bouteloua gracilis* in this phase also distinguishes it from Mueggler's and Handl's (1974) *Artemisia tridentata/Festuca idahoensis* (Montana) habitat type. This association resembles Wright's and Wright's (1948) *Festuca idahoensis* type near Bozeman.

Rosa arkansana/Thermopsis rhombifolia Habitat Type

1. Floristic composition

   Dominant—*Chrysothamnus nauseosus, Artemisia tridentata, Artemisia longifolia, Agropyron dasystachyum*

   Subordinate—*Thermopsis rhombifolia, Arenaria hookeri, Carex parryana*
2. Site—broken uplands
3. Geology—Carlile M, Belle Fourche M, Mowry M, Skull Creek M, Niobrara M (Fig. 4)
4. Soil description—thin or nonexistent, raw shale slopes, texture similar to sand, may be saline
5. Soil type—not known
6. Parent material—marine clay shales
7. Relative productivity—low
8. Management—no particular management considerations. Cannot be cultivated.

This habitat type (found on raw, weathered clay shale) is undergoing primary succession culminating in an *Artemisia tridentata/Agropyron dasystachyum* habitat type, *Agropyron spicatum* phase as soil is formed.

The edaphic characteristics of raw, weathered shale apparently are similar to a coarse-grained sandy soil since the shale particles are similar in size to sand grains. With continued weathering, these will eventually be reduced to clay-sized particles, forming a clay soil. Because of this sand-like characteristic, the floristic composition found on these raw shale slopes resembles that occurring on sandy soils with a shrub stratum containing *Rosa arkansana, Artemisia longifolia, Artemisia tridentata*, and *Chrysothamnus nauseosus*.

These shrubs are usually widely scattered, the canopy coverage of any one species rarely exceeding 10 per cent. Canopy coverages of other taxa also are low, exposing large amounts of bare ground. The dominant grasses (or grass-like plants) are *Calamogrostis montanensis, Agropyron dasystachyum, Carex parryana,* and *Calamovilfa longifolia;* but *Stipa comata,* well adapted to some deep, sandy soils in this region, is absent in this habitat type. A conspicuous and ubiquitous forb throughout the habitat type is *Thermopsis rhombifolia.* An occasional patch of *Juniperus horizontalis* and a few scattered *Pinus ponderosa* trees occur on these shale slopes.

Since herbaceous plants on shale slopes in this area remain green longer during the summer than similar plants on other upland habitat types, the suggestion is that they are drawing on sources of moisture available to them for longer periods than is generally the case elsewhere in the triangle. The presence of both *Calamovilfa longifolia* and *Rosa arkansana* signifies that moisture stress in soil of this habitat type is very low (Branson et al. 1970). Cracks in the shale may allow deep penetration of both roots and water, enabling plants to maintain themselves during long periods of drought. Since this would concentrate the moisture falling over a general area into a relatively few spots (the cracks), as opposed to a soil where moisture falling over an area soaks in evenly throughout the area, the number of plants drawing on this moisture supply and their canopy coverage would be restricted.

In spots where the shale is weathered enough to produce a relatively deep layer of sand-sized particles, the canopy coverage of *Calamovilfa longifolia, Agropyron dasystachyum, Thermopsis rhombifolia,* and *Carex parryana* is greater than on less weathered spots. Exposed and weathered shale-like sandstones of the Mowry member support *Calamogrostis montanensis* and *Carex parryana* in equal proportions (canopy coverage) and half as much *Artemisia longifolia* as either of the other two taxa.

A phase of this habitat type occurs on igneous intrusions and rocky outcrops such as sandstone ledges of certain members of the Colorado formation. These outcrops support *Rhus trilobata* plus a mixture of shrubs similar to that of the shale slopes. The dominant grasses are often *Agropyron spicatum* or *Agropyron dasystachyum.* Had these sites covered a greater area within the triangle, they may have been put into a *Rhus trilobata/Agropyron spicatum* habitat type similar to the one tentatively recognized by Mueggler and Handl (1974). Such a habitat type would be dominated by *Rhus trilobata* and *Agropyron spicatum.*

Artemisia cana/Agropyron smithii Habitat Type

1. Floristic composition

   Dominant—*Artemisia cana.* One or the other of the grasses, *Agropyron smithii* or *Poa pratensis,* may be dominant depending on the microhabitat.

   Subordinate—*Stipa viridula, Rosa* ssp., *Chrysothamnus viscidiflorus*

2. Site—bottomlands
3. Geology—alluvium from meandering streams (Fig. 5)
4. Soil description—moderately developed. Clay loam or loam, non-saline, non-alkaline, high water table, well drained
5. Soil type—not known
6. Parent materials—alluvial silt
7. Relative productivity—high
8. Management—heavy winter grazing pressure is destructive of pronghorn winter habitat.

Although a few scattered bushes of *Artemisia cana* grow on some of the uplands (usually on the Kootenai formation) of the triangle, the species is normally restricted to apparent high water deposits and old stream channels along major streams (Hanson and Whitman 1938, Beetle 1960) where soil is coarser (Branson et al. 1970).

The perennial grass layer usually comprises one or more of the following species:

Agropyron smithii, Stipa viridula, or *Poa pratensis. Poa pratensis* is an invader species establishing in certain moist areas, probably as a result of some trigger factor or factors such as overgrazing or flooding. Forb species number and cover are generally small with various taxa scattered throughout the type.

The distribution of *Artemisia cana* in the triangle resembles what Thatcher (1959) observed in southeastern Wyoming. He determined that the shrub is usually found on lowlands with the water table often within the root zone, and on moderately deep, slightly to moderately alkaline soils that are permeable in all horizons. Whenever the shrub occurs on uplands in southeastern Wyoming and in the triangle, the soil parent materials are sandstone or gravel.

Sarcobatus Series

Sarcobatus vermiculatus/Agropyron dasystachyum Habitat Type

1. Floristic composition

   Dominant—*Sarcobatus vermiculatus, Poa sandbergii, Agropyron dasystachyum.* The following may be dominant dependent on microhabitat: *Artemisia tridentata, Bouteloua gracilis, Distichlis stricta*

   Subordinate—*Agropyron smithii, Koeleria cristata, Artemisia frigida, Carex stenophylla, Opuntia polyacantha*

2. Site—bottomlands
3. Geology—alluvium from marine shales (Fig. 6)
4. Soil description—silty or clay loam, well developed where not eroded, alkaline ground water near surface, poorly drained, saline and alkaline, light colored
5. Soil types—Absher, Nobe, Billings-Arvada
6. Parent materials—alluvium
7. Relative productivity—low to moderate
8. Management—will withstand moderate grazing. Conversion to hayfields is successful with irrigation.

The purest stands of *Sarcobatus* are in bottomland areas of the triangle where alluvium derived from Colorado formation shales has been deposited. However, pure stands of *Sarcobatus* are not common; usually some *Artemisia* is present. As one travels away from a stream, bordered mainly by shrubs such as *Symphoricarpus* and *Rosa*, a band of *Artemisia cana* is usually encountered and then a band of pure *Sarcobatus* or *Sarcobatus* and *Chrysothamnus nauseosus* mixed. Traveling still farther from the stream, *Artemisia tridentata* bushes are seen, the coverage increasing progressively until pure *Artemisia*-grass stands are reached. The grass layer in the *Sarcobatus vermiculatus/Agropyron dasystachyum* habitat type is a mosaic with different sites dominated by *Agropyron dasystachyum* or *Agropyron smithii* and *Poa sandbergii* or by *Distichlis stricta.* Various intergradations are involved. This is similar to Mueggler's and Handl's (1974) *Sarcobatus vermiculatus/Agropyron smithii* habitat type except that their grass layer has large amounts of *Agropyron smithii* rather than *Agropyron dasystachyum* as is the case in most areas here.

Hanson and Whitman (1938) do not report a *Sarcobatus* type in western North Dakota although the species does occur there in very minor amounts. They do report *Distichlis-Agropyron smithii* and *Artemisia cana* types; *Sarcobatus* apparently has not become extensively established in those areas, although the habitat seems favorable.

Juniperus Series

Juniperus horizontalis/Carex parryana Habitat Type

1. Floristic composition

Dominant—*Carex parryana, Juniperus horizontalis, Calamogrostis montanensis*

Subordinate—*Thermopsis rhombifolia, Eriogonum pauciflorum, Carex stenophylla*

2. Site—hilly uplands
3. Geology—restricted to the unnamed sandy M (Fig. 7)
4. Soil description—same as for *Artemisia/Chrysothamnus nauseosus* habitat type
5. Soil type—not known
6. Parent material—sandy shale
7. Relative productivity—low
8. Management—no particular management considerations. Cannot be cultivated.

This habitat type is visually conspicuous and distinctive in appearance. As primary succession advances, this becomes an *Artemisia/Agropyron* habitat type as judged from data gathered on shale where soil had formed. Also found on this outcrop is a stand of *Pinus ponderosa* with *Juniperus horizontalis* and *Agropyron spicatum* in the understory. It is unclear whether this is another stage of primary succession or if there is some inherent edaphic difference causing the establishment of *Pinus*.

Wetlands

Riparian Series

Populus deltoides/Symphoricarpus occidentalis Habitat Type

1. Floristic composition

   Dominant—(depending on microhabitat) *Populus deltoides, Symphoricarpus occidentalis, Rosa woodsii, Prunus virginiana, Salix amydaloides, Salix rigida, Acer negundo*

   Subordinate—*Ribes* ssp., *Shepherdia argentea, Poa pratensis, Agropyron smithii,* numerous forbs
2. Site—riparian
3. Geology—next to streams (Fig. 8)
4. Soil description—silty, high water table, non-saline, non-alkaline, subject to flooding
5. Soil type—not known
6. Parent material—alluvium
7. Relative productivity—very high
8. Management—heavy livestock use is destructive of mule deer and white-tailed deer habitat.

This type occurs along streams which flow during a considerable portion of the growing season. Taxa of the habitat type require large amounts of moisture, obtained from water migrating out from the stream. Two phases are recognized within the habitat type depending upon whether or not trees are present.

The *Populus deltoides-Symphoricarpus occidentalis* association comprises a variable mixture of *Populus deltoides, Acer negundo, Salix amygdaloides, Prunus virginiana, Crataegus douglasii* (mostly on the west side of the triangle), *Symphoricarpus occidentalis, Rosa woodsii,* plus some *Ribes* ssp., *Salix rigida,* and *Shepherdia argentea.* The *Symphoricarpus occidentalis-Rosa woodsii* association is similar except for an absence of trees. A quantitative sampling of this habitat type was not attempted because the distribution of various species was extremely variable and appeared largely due to chance. Some basic differences may exist in the habitat type as it occurs on the west or the east side of the triangle, possibly due to greater and more dependable water supply in the streams farther

west. *Salix rigida* and *interior* primarily grow next to continuously running streams such as Flatwillow Creek. Many species of mesomorphic forbs, including *Arctium lappa, Asclepias speciosa, Bidens vulgata, Cicuta douglasii, Glycyrrhiza lepidota, Helianthella uniflora, Rumex* ssp., *Solidago gigantea, Urtica dioica*, and others, occur throughout the habitat type.

Scirpus/Carex Habitat Type

1. Floristic composition

   Dominant—*Scirpus americanus, Schedonnardus paniculatus, Scirpus validus, Carex rostrata, Carex nebraskensis*

   Subordinate—*Juncus balticus, Beckmannia syzigachne, Spartina gracilis*

2. Site—streamsides, alongside reservoirs
3. Geology—alluvium
4. Soil description—constantly wet, anaerobic, high organic matter content, non-saline, non-alkaline
5. Soil type—not known
6. Parent material—alluvial silt
7. Relative productivity—very high
8. Management—Livestock grazing of these areas is highly destructive to waterfowl habitat.

This habitat type occurs on only a few acres of the triangle, usually in marshy areas along some slow-moving streams and around reservoirs. Dominant vegetation comprises *Scirpus americanus, S. paludosus, S. validus, Juncus balticus, Typha latifolia, Carex rostrata, C. nebraskensis*, plus smaller amounts of *Beckmannia syzigachne* and *Spartina gracilis*. Water movement and exchange is rapid enough to prevent a build-up of salts.

Suaeda/Salicornia rubra Habitat Type

1. Floristic composition

   Dominant—*Suaeda fruticosa, Suaeda occidentalis, Salicornia rubra, Puccinellia nuttalliana*

2. Site—swales, bottomlands, saline seeps
3. Geology—Niobrara M, Belle Fourche M, unnamed sandy M, Skull Creek M, alluvial terraces and bottomlands
4. Soil description—wet, extremely saline and alkaline, clay texture, anaerobic
5. Soil type—not known
6. Parent material—marine shales, alluvium
7. Relative productivity—low
8. Management—Management considerations may involve only the prevention of the increase of such areas.

This very minor habitat type occurs where extremely saline and alkaline water seeps continuously and slowly at the surface. Water movement is slow enough that it evaporates and becomes saturated with salts (usually sodium and magnesium sulfates), forming white crusts on the ground surface and on objects protruding out of the water. A few extreme halophytes (plants adapted to saline conditions) can exist, but even though water is always present, non-halophytes are subjected to severe physiological drought and cannot become established. The vegetation association is dominated by *Suaeda fruticosa, S. occidentalis, Salicornia rubra*, and sometimes *Puccinellia nuttalliana*.

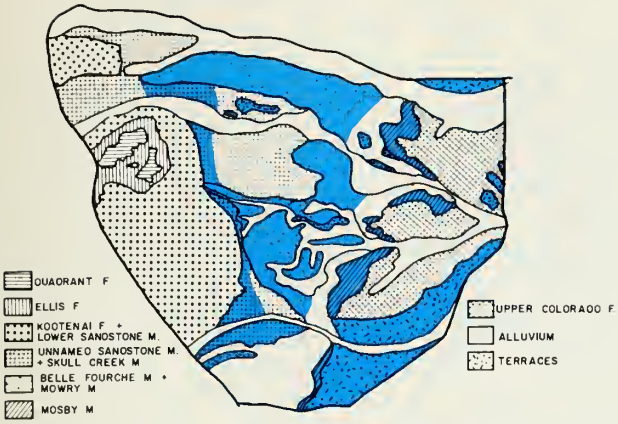


Figure 3. Distribution of the *Artemisia tridentata/Agropyron spicatun* Habitat Type, *Bouteloua* Phase.

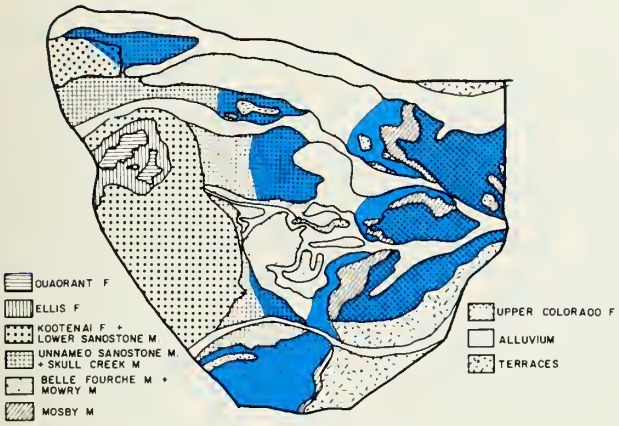


Figure 4. Distribution of the *Artemisia tridentata/Agropyron dasystachyum* Habitat Type, *Agropyron spicatum* and *Sarcobatus vermiculatus* Phases and the *Rosa arkansana/Thermopsis rhombifolia* Habitat Type.

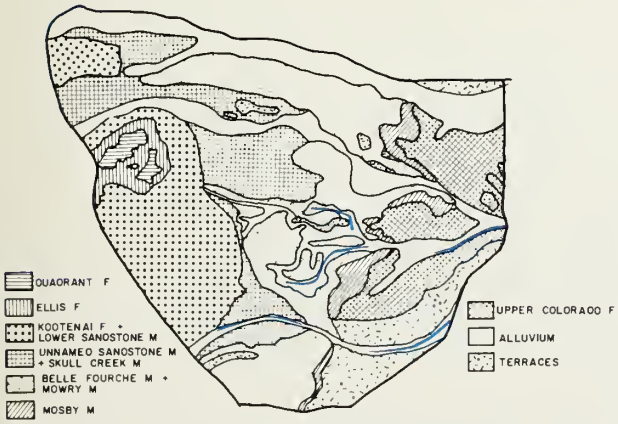


Figure 5. Distribution of the *Artemisia cana/Agropyron smithii* Habitat Type.

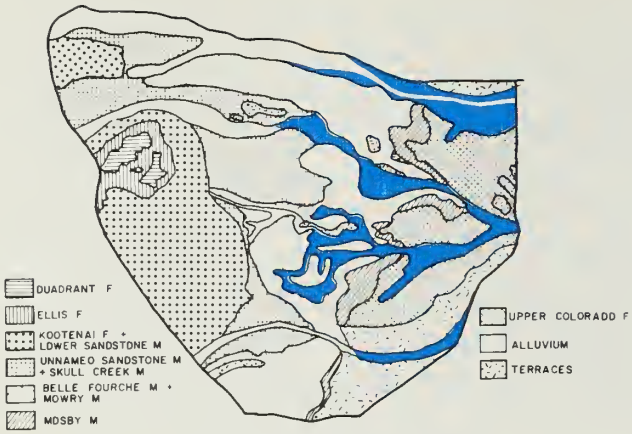


Figure 6. Distribution of the *Sarcobatus vermiculatus/Agropyron dasystachyum* Habitat Type.

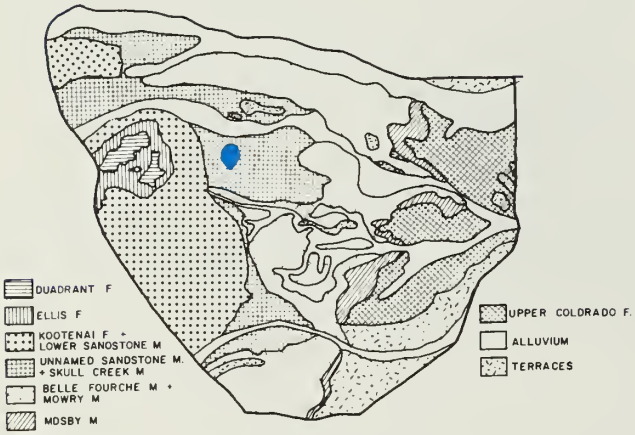


Figure 7. Distribution of the *Juniperus horizontalis/Carex parryana* Habitat Type.

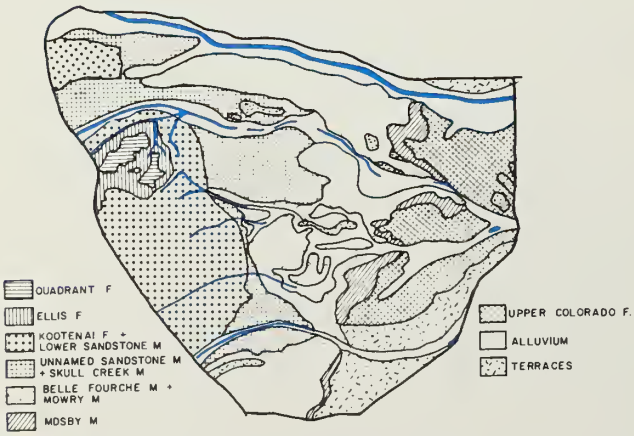


Figure 8. Distribution of the *Populus deltoides/Symphoricarpus occidentalis* Habitat Type.

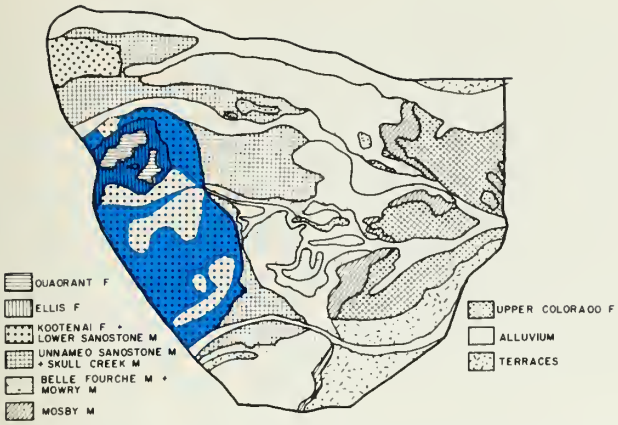


Figure 9. Distribution of the *Agropyron spicatum/Agropyron smithii* Habitat Type and the *Muhlenbergia cuspidata/Andropogon scoparius* Habitat Type.

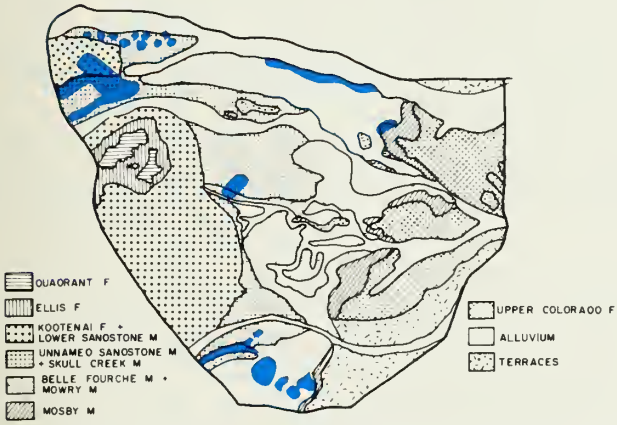


Figure 10. Distribution of the *Pinus ponderosa/Artemisia tridentata* Habitat Type.

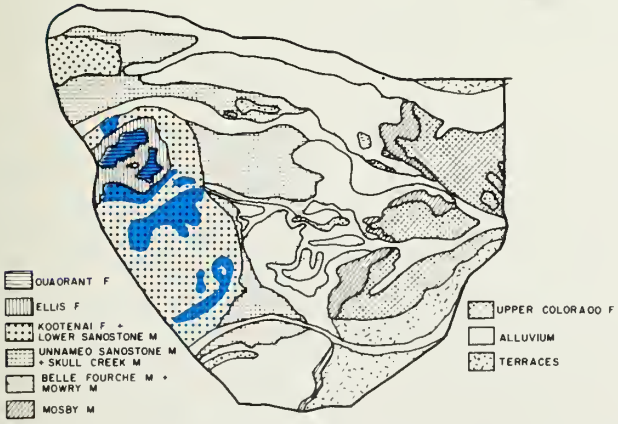


Figure 11. Distribution of the *Pinus ponderosa/Agropyron spicatum* Habitat Type.

Artemisia tridentata/Agropyron spicatu
Habitat Type
Bouteloua gracilis Phase

Artemisia tridentata/Agropyron spicatum
Habitat Type
Agropyron smithii Phase

Artemisia tridentata/Agropyron dasystach
Habitat Type,
Agropyron spicatum Phase

Artemisia tridentata/Koeleria cristata
Habitat Type

Atriplex dioica/Gutierrezia sarothrae Habitat Type

Artemisia tridentata/Festuca idahoensis Habitat Type
Bouteloua gracilis Phase

Artemisia tridentata/Agropyron dasystachyum Habitat Type, *Sarcobatus vermiculatus* Phase

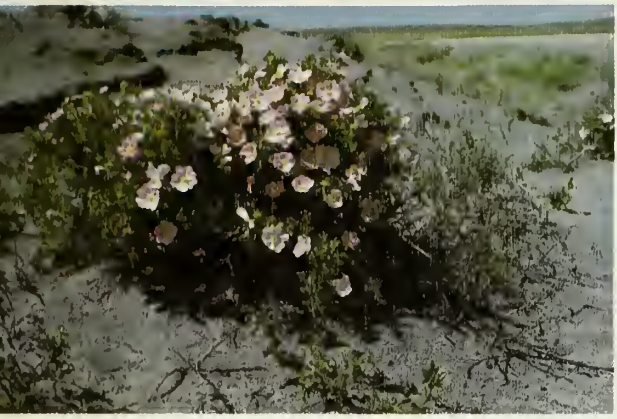
Sarcobatus vermiculatus/Agropyron dasystachyum Habitat Type

Artemisia cana/Agropyron smithii Habitat Type

Populus deltoides/Symphoricarpus occidentalis Habitat Type

Scirpus/Carex Habitat Type

Suaeda/Salicornia rubra Habitat Type



Rosa arkansana/Thermopsis rhombifolia Habitat Type

Juniperus horizontalis/Carex parryana Habitat Type

Agropyron spicatum/Agropyron smithii Habitat Type

Poa pratensis/Artemisia ludoviciana Habitat Type

Muhlenbergia cuspidata/Andropogon scoparius Habitat Type

Pinus ponderosa/Artemisia tridentata Habitat Type

Pinus ponderosa/Agropyron spicatum Habitat Type

Grasslands

On the Lower Sandstone member of the Colorado shale formation, the Kootenai formation and the Ellis formation are vegetation associations consisting of grasslands virtually devoid of shrubs. One sample plot contained some *Chrysothamnus viscidiflorus* and was the only one with any shrub cover. Noted in various areas, but not occurring in any sample plots, were scattered bushes of *Artemisia tridentata*, *Artemisia cana*, *Juniperus horizontalis*, and *Rosa woodsii*. A possible explanation for this paucity of shrubs is a shallow solum above impermeable bedrock. Shrubs are more common on strike slopes (the steep, broken part of a rock outcrop) (*Rhus trilobata-Agropyron spicatum* phase), and in low spots where soil has been washed in from adjacent areas and deposited. Apparently, areas of the Kootenai formation receiving over approximately 17 inches in annual precipitation support *Pinus ponderosa* forests rather than grasslands as climax. Comparisons between photographs made in 1917 by H. L. Shantz, and of exactly the same sites in 1959 by Philips (Philips 1963), show substantial increases in *Pinus* cover on the Kootenai formation at the expense of the open grassland. *Pinus* may advance into the grassland during favorable seedling establishment years as a result of disturbances ("Trigger factors," Billings 1952) such as overgrazing, or it may be that grasslands were at one time maintained by fire and with the advent of fire protection, the *Pinus* is advancing (Griggs 1938).

Agropyron spicatum/Agropyron smithii Habitat Type

1. Floristic composition

   Dominant—*Agropyron spicatum*, *Stipa comata*, *Artemisia frigida*

   Subordinate—*Agropyron smithii*, *Bouteloua gracilis*, *Calamovilfa longifolia*, *Koeleria cristata*, *Poa sandbergii*, *Cerastium beeringianum*, *Vicia americana*, *Carex parryana*

2. Site—undulating uplands
3. Geology—Kootenai formation, Lower Sandstone M, Ellis formation (Fig. 9)
4. Soil description—well developed, brown or red topsoils, loam texture, non-saline, non-alkaline, well drained, subsoil non-clayey, stony, often shallow solums
5. Soil types—Castner-Morton loams and stony loams, Cushman loam, Darrett loam and stony loam
6. Parent material—sandstone
7. Relative productivity—high
8. Management—withstands moderate grazing, highly suitable for cultivation.

This habitat type appears virtually identical to the one described by Mueggler and Handl (1974) and will be given the same name as theirs to maintain synonymy. Of the grassland types, the *Agropyron spicatum/Agropyron smithii* habitat type covers the greatest area, although a considerable amount of it has been planted to grain and crested wheatgrass. The bedrock is partly weathered, metamorphosed sandstone, relatively impervious to roots or water. Because of the shallow solum and impermeability of the bedrock, the soils are considered to have low water-holding capacity (Gieseker 1953). A lithosolic phase of this habitat type where *Stipa comata* has greater coverage than *Agropyron spicatum* because of edaphic rather than grazing reasons is recognized. Depending on characteristics of individual microhabitats, plus differences in grazing pressure, either *Agropyron smithii*, *Stipa comata*, or *Calamovilfa longifolia* is the dominant grass. Considering the habitat type as a whole (in its current grazed condition), *Stipa comata* has the greatest canopy coverage, followed by *Agropyron spicatum*. Another important mid-grass is *Agropyron smithii*. The short grasses, *Koeleria cristata* and *Poa sandbergii*, are about equal in abundance.

Total canopy coverage and number of forb species are much higher on grassland habitat types than on any of the other habitat types in the triangle. *Artemisia frigida* and *Cerastium beeringianum* are the most common forbs, although numerous others are abundant. Some forbs common in this association, but completely absent in the shrub-

dominated associations, are *Heuchera parviflora, Artemisia biennis, Helianthus petiolaris, Cerastium beeringianum, Hymenopappus filifolius,* and *Phlox kelseyi.*

Muhlenbergia cuspidata/Andropogon scoparius Habitat Type

1. Floristic composition

   Dominant—*Muhlenbergia cuspidata, Andropogon scoparius*

   Subordinate—*Agropyron spicatum, Agropyron dasystachyum, Koeleria cristata, Stipa comata, Stipa viridula, Gutierrezia sarothrae, Phlox hoodii, Linum perenne, Aristida longiseta*

2. Site—moderately steep slopes in uplands
3. Geology—Kootenai formation (Fig. 9)
4. Soil description—weak development, red color, loam texture, non-saline, non-alkaline, well drained, eroded
5. Soil types—Darrett loam and stony loam
6. Parent material—red shale
7. Relative productivity—moderate
8. Management—Light grazing, not suitable for cultivation.

The *Muhlenbergia cuspidata-Andropogon scoparius* association is apparently restricted to a particular stratum of shaly or silty parent material in the Kootenai formation. This is the only place in the triangle where either of these grasses occurs as dominants. *Andropogon* is an important component of true prairie grasslands in the Midwest (Weaver and Fitzpatrick 1934) and gradually increases in abundance when approaching that region. In south central South Dakota, White (1971) determined that both *Andropogon scoparius* and *Muhlenbergia cuspidata* were most abundant on weakly developed soils subject to rapid erosion. Observations indicate that this is also the case in the triangle and in other parts of eastern Montana. The Judith Basin to the west of the triangle probably represents the westernmost occurrence of this species at this latitude. If one follows Dix's (1958) moisture ordination with *Bouteloua gracilis* and *Agropyron smithii* on the dry end, and *Andropogon* and *Muhlenbergia* on the wet end, it might be concluded that this vegetation association occurs on a more moist site than most of the other upland associations. Other important grasses are *Agropyron spicatum* and *Aristida longiseta.* Although stands of *Pinus* often occupy similar sites, it is unclear whether the presence of these trees represents different environmental conditions or merely vagaries of distribution. *Juniperus horizontalis* is important locally but not over the general area of the habitat type. There is a relatively large number of forb species present (more than any other habitat type in the triangle) but none of them is important in terms of canopy coverage except *Gutierrezia sarothrae* (also considered a half-shrub). Plant and litter coverage are much less in this habitat type than in the other grassland habitat types.

Poa pratensis/Artemisia ludoviciana Habitat Type

1. Floristic composition

   Dominant—*Poa pratensis, Agropyron smithii, Artemisia ludoviciana*

   Subordinate—*Melilotus officinale, Cirsium undulatum, Juncus balticus, Carex rostrata, Carex foenea, Achillea millefolium*

2. Site—swales
3. Geology—Kootenai formation
4. Soil description—deep topsoil with abundant organic matter, loam texture, non-saline, non-alkaline
5. Soil type—not known

6. Parent material—sandstone and alluvium
7. Relative productivity—very high
8. Management—can withstand moderate grazing pressure. Cannot be cultivated.

Swales in the grassland habitat types support a more mesophytic vegetation association than the swales in the eastern part of the triangle. The *Poa pratensis-Artemisia ludoviciana* association contains the second greatest number of species and the most complete plant cover of any in the triangle. Canopy coverage of both grasses and forbs is much higher than in any of the other habitat types. Other important grasses are *Agropyron smithii* and *Agropyron repens*. Since two out of three of the dominant grasses are invaders, there is a question as to the dominant grass composition before the onset of disturbance by overgrazing. It is expected that dominance of this plant community by non-native grasses will continue regardless of any changes in management, justifying the consideration of this as a habitat type. Other forbs occurring in considerable quantities are *Achillea millefolium* (invader), *Melilotus officinale* (invader), and *Cirsium undulatum*. Sedges and rushes include *Carex foenea*, *C. rostrata*, and *Juncus balticus*. These swales are surrounded by very large, flat, sloping tables covered with soils of low moisture-holding capacity releasing considerable quantities of water to migrate gradually into the swales during much of the growing season. This favors the establishment of some hydrophytes (i.e., *Typha latifolia*, *Juncus balticus*).

Coniferous Forest

Pinus Series

Pinus ponderosa/Artemisia tridentata Habitat Type

1. Floristic composition

   Dominant—*Pinus ponderosa*, *Artemisia tridentata*

   Subordinate—*Juniperus horizontalis*, *Agropyron spicatum*, *Aristida longiseta*, *Poa sandbergii*
2. Site—steep shale slopes
3. Geology—Mosby M, unnamed sandy M (Fig. 10)
4. Soil description—thin or undeveloped, raw shale slopes, texture similar to sand
5. Soil type—not known
6. Parent material—sandy shales, soft sandstone
7. Relative productivity—low
8. Management—Leave as is for mule deer cover. Timber not commercially important.

This habitat type occurs on various exposed strata of the Colorado shale formation because of some unknown favorable combination of edaphic and topographic factors. While reproduction of pine is evident, indicating that the populations are probably maintaining themselves, it is difficult to determine whether or not they are increasing in area. The density of the stands ranged from about 20-28 trees per acre, with all sizes represented. The diameter breast height (dbh) of mature trees is generally less than 10 inches. The understory of the association comprises mainly the shrubs *Artemisia tridentata* and *Juniperus horizontalis* and the grass *Agropyron dasystachyum*; *Agropyron spicatum* is locally important. Bare ground (disregarding the canopy coverage of the trees) occupies a relatively great area, although not as much as in some other habitat types.

Pinus ponderosa/Agropyron spicatum Habitat Type

1. Floristic composition

   Dominant—*Pinus ponderosa*, *Agropyron spicatum*

   Subordinate—*Balsamorrhiza sagittata*

2. Site—high elevation uplands, estimated annual precipitation 17 inches
3. Geology—Kootenai formation, Ellis formation, Quadrant formation (Fig. 11)
4. Soil description—well developed, brown or red topsoils, loam or sandy loam texture, non-saline, non-alkaline, well drained, subsoil not clayey, stony, often shallow solums
5. Soil types—Castner-Morton loams, Cushman loam, Darrett loam and stony loam
6. Parent material—sandstone
7. Relative productivity—high
8. Management—not suitable for commercial timber production. Provides habitat for mule deer if not overgrazed.

Pine stands of this type generally have an understory of similar floristic composition and less canopy coverage than adjoining grasslands. There are about 15-20 trees per acre in mature stands and up to three times this many in stands of young trees. Apparently, two important age classes (as judged from aerial photographs) are represented, indicating that seedlings become established only during certain periods (lasting probably two or more consecutive years) when favorable conditions exist for heavy seed production, seed germination, seedling survival, and development of seedlings into young, relatively drought-resistant trees. This probably applies also to some other seed-reproducing species such as *Artemisia tridentata* and *Agropyron spicatum,* which in this region appear to be near the edge of their range. A large increase in the density of *Pinus* stands in this general area (western triangle and west) occurred between 1917 and 1959, as shown by photographs of Shantz and Philips (1963).

This type is considered synonymous to the *Pinus ponderosa/Agropyron spicatum* habitat type of Pfister, Arno et al. (1977) and so is given the same name. A few small stands of *Pinus ponderosa* with *Symphoricarpus occidentalis* in the understory were noted, indicating the presence of a *Pinus ponderosa/Symphoricarpus occidentalis* habitat type (Pfister, Arno et al. 1977) within the triangle, although in very minimal amounts. Some *Pseudotsuga menziesii* trees were also seen on a steep, north-facing slope in the western part of the triangle, but were not considered abundant enough to constitute a stand of *Pseudotsuga menziesii* habitat type.

Distribution of Important Taxa

Artemisia tridentata

Beetle (1960) considers central Montana to be at the northeastern edge of *Artemisia tridentata* distribution. The *A. tridentata* in the triangle fits the characteristics of subspecies *wyomingensis* as described by Beetle and Young (1966). Some *A. tridentata* occurs in eastern Montana, but farther east it apparently becomes increasingly confined to areas of moisture collection, deep soil, and good drainage (i.e., swales).

Artemisia covers a greater percentage of the land in the triangle (Appendix A Table 1) than any other shrub; considerations of its distribution are very important when analyzing the vegetation of the area.

The distribution pattern of *Artemisia* apparently results from a combination of natural and man-caused factors. Numerous workers have reported that *Artemisia* increases both in density and range following heavy livestock grazing (Wright and Wright 1948, Pickford 1932, Cottam and Stewart 1940, Shantz and Piemeisel 1940, Tisdale 1947, Thatcher 1959, Johnson 1966, and Pearson 1965). In undisturbed plant communities containing *Artemisia*, the *Artemisia* is in a state of dynamic equilibrium with dominant grasses (usually tall bunchgrasses) in the community. Neither of these has a complete competitive advantage over the other and so the importance of the *Artemisia* remains the same. However, when a disturbing factor is inserted, one dominant increases in importance. Heavy livestock use increases the competitive advantage of *Artemisia* over most tall grasses, often resulting in greater cover, density, and range of the shrub. Reconstructing the relative importance of *Artemisia* before the arrival of domestic livestock is very difficult since there are no his-

torical records of this sort, and completely relict areas on *Artemisia* habitat types are rare. Other land treatment practices, such as plowing and seeding, are also important in changing the density and distribution of *Artemisia*. After certain land treatment practices cease (as they have in many cases), the density and distribution of *Artemisia* may remain unchanged for many years.

Natural soil factors also affect the distribution and vigor of *Artemisia*. Evidence presented in the literature concerning the effects of soil on *Artemisia* apparently is somewhat conflicting. However, it must be considered that the various studies were conducted in widely differing climatic and geographical areas with different subspecies and ecotypes of the species. It is generally agreed that *Artemisia* grows best on deep soils (Beetle 1960, Fautin 1946, and Thatcher 1959). Fautin (1946) found that *Artemisia* in western Utah was most abundant on relatively non-saline, permeable soils with high water-holding capacity. According to Patten (1963), *Artemisia* in southwestern Montana grows best on sandy loam soils, and Robertson et al. (1966) found that soils with sandy loam to loam topsoils were best. However, Houston (1961) determined that *Artemisia* in the northern Great Plains was most abundant in clayey soils. Thatcher (1959) and Gates (1956) agreed with Fautin (1946) that *Artemisia* is favored by soils of low salt content. Smith (1966) found pH ranges of 6.5 to 7.5 (very slightly acid to very slightly alkaline) in the topsoil and 7.5 to 8.5 (very slightly alkaline to alkaline) in the subsoil to be favorable for *Artemisia* in North Park, Colorado. Thatcher (1959) found that *Artemisia* in southeastern Wyoming grew on soils derived from almost every conceivable type of parent material, but that it could not tolerate high water tables or fine-textured subsoils. Data from Brown (1971) indicated that *Artemisia* in southwestern Montana is most abundant on clay loam and silt loam soils with relatively low salinity and sodium content and relatively high calcium to sodium ratios. In considering what appear to be conflicting results as reported above, it must be kept in mind that all three different subspecies (and different ecotypes within those subspecies) were involved in those studies. For example, observations indicate that *A. tridentata* ssp. *tridentata* is better able to tolerate sandy soils (or the competition of other plants thereon) than is *A. tridentata* spp. *wyomingensis*.

Observations in the triangle indicate that *A. tridentata* ssp. *wyomingensis* is most vigorous on soils with a clay loam topsoil. It is less vigorous on gravelly soils and calcareous silty soils and it is virtually nonexistent on soils derived from Kootenai sandstones. Low-lying areas with poor drainage and high salt content support little or no *Artemisia*. *Artemisia* is a minor constituent of the vegetation communities on raw shale slopes and rocky areas. Very sandy soils derived from the Eagle sandstone just east of the triangle are totally devoid of *A. tridentata*, but support some *A. cana*. Because of fire, some sites in the eastern part of the triangle are devoid of *Artemisia;* after 30 or 40 years, *Artemisia* has not re-established itself in these areas.

For reasons discussed above, no attempt will be made to describe the relative abundance of *Artemisia* in various habitat types except in some cases where edaphic conditions definitely appear to be a factor. While not supported by data, all areas in the triangle which now have *Artemisia* were probably historically occupied by the shrub, although possibly in greater quantity now. A large upland area in the western part of the triangle surrounding Button Butte is virtually free of *Artemisia*, apparently due to edaphic conditions.

Agropyron spicatum

Ecologically, *Agropyron spicatum* appears to be the most important grass in the triangle. It is usually found on soils exhibiting considerable profile development, including the presence of a well-defined mollic epipedon (a friable topsoil containing considerable dark-colored organic matter), plus a distinct subsoil horizon. Such soils generally range in texture from clay loam to loam, although the species is not entirely restricted to these. Good soil drainage and root penetration are necessary. *A. spicatum* is found on slightly vertic soils in some parts of the triangle. General observations indicate that this may be an unusual situation and that some compensating factor must be present, because *A. spicatum* roots are not resistant to breakage produced by cracking and heaving in such soils. Possibly, although it was not determined, the vertic soils with good stands of *A. spicatum* are very shallow with some sort of permeable material beneath, such

as heavily fractured weathered shale. All sites where *A. spicatum* occurred on vertic soils were found on shale strata of the unnamed sandy member in the Colorado shale formation and on the Bearpaw shale formation north of the triangle. More study is needed in other locations to determine the relationship of *A. spicatum* to vertic soils.

A. spicatum is not found on most soils lacking a distinct topsoil, on saline or alkaline soils, on poorly drained soils, on bentonitic soils, or on calcareous silty soils. Small amounts occur on stony, shallow soils with fractured bedrock and on raw shale slopes. Daubenmire (1970) notes that within the climatic zone where *A. spicatum* is a major dominant, very thin soil over fractured basalt supports vigorous stands of this species. Brown (1971) noted that *A. spicatum* is most abundant (with *Artemisia tridentata*) on soils possessing moderate characteristics. Salinity and alkalinity were low, slope was moderate, texture was a clay loam, and horizon development was evident. In southwestern North Dakota, Dodd (1970) found *A. spicatum* to be restricted to extremely rocky infertile soils on the tops of hills.

A. spicatum occurs with various different dominant or subdominant species depending on the habitat type. On Colorado shale areas, it is co-dominant with *Artemisia tridentata; Bouteloua gracilis, Koeleria cristata*, and *Stipa comata* are other important grasses in the association. On the Kootenai formation, it is co-dominant with *Stipa comata, Agropyron smithii*, and *Artemisia frigida*, all of which, with the possible exception of *Stipa*, are increasers with grazing and may not be as abundant in the habitat type as the data indicate. *A. spicatum* is also co-dominant with *Artemisia tridentata* and *Festuca idahoensis* in the *Artemisia tridentata/Festuca idahoensis* habitat type. In other parts of Montana, and in Idaho and Washington, such an association may represent a transition between the *Artemisia tridentata/Agropyron spicatum* habitat type (*Festuca* absent) and the *Artemisia tridentata/Festuca idahoensis* habitat type (*Agropyron spicatum* absent) (Wright and Wright 1948, Daubenmire 1970).

Agropyron smithii

This grass has very wide ecologic amplitude, tolerating a wide range of soil moisture stress situations (Branson et al. 1970); it is found in at least small amounts in most habitat types of the triangle. It apparently is most abundant in moist swales (Holscher 1945) and bottomlands where drainage is good. It often is also an important constituent of the *Artemisia tridentata/Agropyron dasystachyum* habitat type, *Agropyron spicatum* phase (Ross et al. 1973). Although *A. smithii* appears capable of withstanding considerable levels of soil salinity, it is usually not dominant in highly saline areas. *Agropyron* can survive in some soils with extremely high clay content but it is more vigorous and abundant on medium (loam or clay loam) textured soils such as those found in swales, presumably because of better root penetration (Jorgensen 1970). Soil conditions on many other sites are probably favorable for *A. smithii*, but it is not found in great abundance on these sites due to competition from other grasses. Soil disturbances of such sites, detrimental to many of the species normally dominant there, allow establishment of *A. smithii* with its aggressive colonization capabilities (Judd 1937). Data from Ross et al. (1973) show *A. smithii* to be dominant on silty range sites in northern and northeastern Montana, on clayey range sites throughout the state, and occurring in only minor amounts on most other range sites. White (1971) determined that *Agropyron* in south central South Dakota was most common on well developed soils, but was also important on some poorly developed soils if they were fine-textured.

Stipa comata

In the triangle, *Stipa comata* has the greatest canopy coverage and frequency in habitat types dominated by *Artemisia tridentata* and/or *Agropyron spicatum*. Generally, it occurs where *Agropyron spicatum* would be dominant under undisturbed conditions, even though this dominance may not exist now.

Stipa is a habitat type dominant where soils are sandy (White 1971). Soils derived from Eagle sandstone (east of the triangle across Route 244) are very sandy and support much more vigorous stands of *Stipa* than any within the triangle. Ross et al. (1973) present data supporting this conclusion. *S. comata* does not occur in the triangle (or other areas, Coupland 1961) on soils of finer texture than clay loams, increasing in importance with

increasing coarseness of soil texture (from clay loam to loam). Data of Ross et al. (1973) indicate that *S. comata* is absent on clayey range sites and is a dominant on silty range sites. Data from the triangle do not seem to agree with Ross et al. that *S. comata* is a dominant on silty range sites although this may result from the fact that their silty range sites are somewhat different climatically and are not as calcareous as those in the triangle.

Stipa viridula

Stipa viridula occasionally occurs as a dominant in association with rhizomatous wheatgrasses and *Artemisia cana*. Very rarely do heavy stands of this grass occur in the triangle, although it is found in small quantities in numerous areas. Coupland (1961) found that *S. viridula* was important in communities dominated by *Agropyron dasystachyum* and *Koeleria cristata*.

Site characteristics favorable for the species seem to be similar to those for *Agropyron smithii* because of its strong association with *Agropyron smithii*. Because it is most abundant in swales and *Artemisia cana* bottomlands, the most favorable site apparently is one with deep moisture penetration and a medium-textured soil. Although it is most abundant on medium-textured soils, it is also well-adapted to very fine-textured, vertic clay soils (White 1971). Data from Ross et al. (1973) agree with those from the triangle showing that *Stipa* may be more of a dominant in clayey triangle habitat types than data seem to show since there is evidence that *Stipa* is a decreaser under grazing (Ross et al. 1973, Hanson et al. 1931) and most of these areas have experienced heavy grazing pressure.

Habitat types with clay loam or gravelly clay loam topsoils and clay subsoils (gravel-capped tables) do not support significant amounts of *S. viridula* but it has often been noted that where sites within these habitat types were plowed and abandoned, *S. viridula* increased in abundance. This may result from possible increased clay content of the upper soil due to mixing of the A and B horizons, or a possible aggressiveness of the grass in establishing on disturbed areas. Thatcher (1966) has a different explanation for this. He concluded that disc-plowing of shortgrass prairies (a disclimax dominated by *Bouteloua gracilis*, *Buchloe dactyloides*, and *Carex stenophylla*) causes a return to a more climax situation where midgrasses dominate. These midgrasses include *Agropyron smithii* and *S. viridula* and possibly *S. comata*. *S. viridula* is also abundant in other disturbed areas such as abandoned irrigation ditches, roadsides, and crested wheatgrass seedings.

Bouteloua gracilis

Bouteloua is an important grass in the *Artemisia tridentata/Agropyron spicatum* habitat type (*Bouteloua* phase) and the *Sarcobatus vermiculatus/Agropyron dasystachyum* habitat type in the triangle. Data from Brown (1971) show that *Bouteloua* is most important in his *Sarcobatus* and *Artemisia tridentata-Agropyron spicatum* communities. Most studies indicate that it increases with grazing pressure and can therefore be considered to be more abundant at the present time than before the arrival of livestock. It is most abundant on the gravel-capped tables and *Sarcobatus*-dominated bottomlands where topsoil is remaining. *Bouteloua* is usually found as a subordinate grass in *Agropyron spicatum*-dominated habitat types, and may or may not be found with *Artemisia tridentata*.

Bouteloua is most highly adapted to well-developed, medium-textured soils (clay loams to loams) although one study indicated that it was more vigorous on sandy soil than on loam (Mueller 1941). The root system is shallow, allowing it to make maximum use of moisture from light showers (Weaver 1958). In the triangle, summer showers frequently wet only the topsoil (if present), giving *Bouteloua* a competitive advantage over many other plants since it is highly adapted to use this moisture. *Bouteloua* is not found on weakly developed soils with clay at the surface, presumably because such soils are dry at shallow depths for too long (Coupland 1961). Plowing a soil with a clay subsoil virtually eliminates *Bouteloua* from the site for many years, possibly due to the increase in clay at the surface. *Bouteloua* has a narrow range of moisture stress tolerance, being unable to withstand either extremely high moisture stress (as in heavy clay soils) or extremely low moisture stress (as in poorly drained situations) (Branson et al. 1970). This may offer additional explanation as to why *Bouteloua* is not found on heavy clay soils. *Bouteloua* may occur on well-developed solonetzic soils such as on certain bottomlands occupied by *Sarcobatus* (Coupland 1961).

Koeleria cristata

Koeleria is most abundant in the *Artemisia tridentata/Agropyron spicatum* (*Bouteloua* phase), *Agropyron spicatum/Bouteloua gracilis, Sarcobatus vermiculatus/Agropyron dasystachyum,* and *Artemisia tridentata/Koeleria cristata* habitat types. In only the latter can it be considered a dominant constituent of the plant community, possibly because it is favored by the silty, calcareous soil of that habitat type. The canopy coverages of *Koeleria* in the habitat types where it is abundant are almost identical, so the degree of its importance in different habitat types results from the variability of abundance of other taxa in the plant communities.

Wright and Wright (1948) found that *Koeleria* was most abundant in their vegetation type with the most *Agropyron spicatum,* and was a co-dominant with *Stipa comata* and *Bouteloua gracilis* in another vegetation type. *Koeleria* always occurred in communities with more than trace amounts of *Agropyron spicatum.*

Others working in mixed prairie grasslands (Ellison 1960, Hanson and Whitman 1938, Coupland 1961, Mackie 1970, and Smith 1969) agree that *Koeleria* is strongly associated, and is often a co-dominant, with rhizomatous wheatgrasses such as *Agropyron dasystachyum* and *Agropyron smithii. Koeleria* occasionally co-dominates with *Bouteloua gracilis* but more often it seems to be a subordinate grass in associations dominated by this species. Although this species possesses a high ecologic amplitude, it is absent in the triangle in extremely heavy clay soils, moist swales, saline and/or alkaline soils, *Pinus ponderosa* stands, and on raw shale slopes.

Poa sandbergii

The associations where *Poa sandbergii* is a dominant (at least in some stands) are the *Sarcobatus vermiculatus-Agropyron dasystachyum, Artemisia tridentata-Agropyron spicatum, Agropyron spicatum-Bouteloua gracilis,* and *Artemisia tridentata-Agropyron dasystachyum* associations. It is never more than a subordinate grass in the *Artemisia tridentata-Bouteloua gracilis* disclimax, and it occurs only rarely in other associations.

Smith (1969) determined that *Poa* was important in all of his vegetation groups, but it was apparently most important on sites dominated by *Artemisia* and rhizomatous species of *Agropyron.* Mackie (1970) also found *Poa* to be highly associated with rhizomatous species of *Agropyron* and *Sarcobatus.* Others (Coupland 1950, Wright and Wright 1948) reported that *Poa* was a minor constituent of associations dominated by *Stipa comata* and *Bouteloua gracilis* and occurred only rarely in *Agropyron spicatum*-dominated associations. It is difficult to conclude with which major grass species *Poa* is most strongly associated, although there are indications that rhizomatous species of *Agropyron* are very important associates. Grazing apparently influences the importance of *Poa* in a plant community (Daubenmire and Colwell 1942, Daubenmire 1970). Data from southeastern Washington show a reduction in coverage resulting from heavy cattle grazing and an increase as a result of heavy sheep grazing (in areas where *Bromus tectorum* is important). Some variations in coverage of *Poa* in the triangle may be due to grazing patterns rather than site differences; general observations indicate this species is most abundant on clay or clay loam soils.

Agropyron dasystachyum

On the basis of canopy coverage, this species is the second most important mid-grass (behind *Agropyron spicatum*) in the triangle. It possesses a wide ecologic amplitude, resulting in a wider range of importance in triangle habitat types than any other plant. The only associations where it was not found were the *Juniperus horizontalis-Carex parryana* and *Poa pratensis-Artemisia ludoviciana* associations, although coverage was low in the *Artemisia cana* habitat type.

Compared to its very similar relative, *Agropyron smithii, Agropyron dasystachyum* seems to be more adapted to upland sites with fine-textured (silty or clayey) and often saline-alkaline soils; *Agropyron smithii* is most common in moist, low-lying areas such as swales, footslopes, and floodplains (Holscher 1945). Both species often occur together in about equal quantities and frequently *Agropyron smithii,* instead of *Agropyron dasystachyum,* is found on upland clay sites in *Artemisia tridentata/Bouteloua gracilis* cover types. Coupland (1961) states that *A. dasystachyum* tends to be more abundant on fine-

textured soils than *A. smithii* and that *A. smithii* is more abundant on disturbed soils and sites where *Bouteloua gracilis* is a dominant. These observations agree with general observations in the triangle. *A. dasystachyum* constitutes about 80 per cent of the rhizomatous *Agropyron* on fine-textured lacustrine soils of Canadian mixed prairie (Coupland 1961).

Per cent frequency data from Smith (1969) show that *A. smithii* was more abundant in more vegetation groups than *A. dasystachyum* and that the relationship with fine and coarse-textured soils was not the same as those discussed above. His lack of distinction between heavily and lightly grazed sites, and the fact that he was working in a large area east and north of the triangle in addition to the triangle, possibly caused him to report results different from those observed by this researcher.

Artemisia frigida

Artemisia frigida is very abundant in the triangle, although some of this abundance results directly from man's activities. Two sites where it is a dominant taxon were plowed and seeded to *Agropyron desertorum*. It is also one of the dominant taxa in the unplowed (but grazed) areas of the *Agropyron spicatum/Agropyron smithii* habitat type. While the coverage of *A. frigida* seems to be negatively correlated with the coverage of bare ground, it would not be a valid conclusion that bare ground prevents its growth. Other factors responsible for the absence of plant and litter cover probably are also responsible for the absence of *Artemisia*. Sites where *Artemisia* is least abundant usually have poorly developed soils with greater than 20 per cent coverage of bare ground, and occur in the *Pinus ponderosa/Artemisia tridentata, Rosa arkansana/Thermopsis rhombifolia, Juniperus horizontalis/Carex parryana, Artemisia tridentata/Koeleria cristata, Atriplex dioica/Gutierrezia sarothrae*, and *Artemisia tridentata/Agropyron dasystachyum* habitat types. The factors (not all found in each site) responsible for the high coverage of bare ground on these sites, and possibly the low canopy coverage of *A. frigida*, are presence of raw, partially weathered shale with poor water-holding capacity near the surface; silty, calcareous, unstable soil; extremely dense impermeable clay "soil," and self-mulching clay soils which destroy the roots of many plants.

Weaver (1919, 1920) states that *A. frigida* has a deep, extensive root system. *A. frigida* is better adapted to sites with an abundance of *Agropyron spicatum* than to those with mostly *Bouteloua gracilis*, either because of inherent differences in site potential or because of grazing pressure differences. Wright and Wright (1948) found that *A. frigida* was important in three vegetation types where *Agropyron spicatum* was at least a major grass, if not a dominant; in three vegetation types where *Bouteloua gracilis* was a major grass (in two of these, *Agropyron spicatum* was a dominant), and in two types where *Koeleria* was a dominant. Quinnild and Cosby (1958) noted that *Artemisia* was the most common forb on their relict mesas, and Coupland (1961) stated that it occurred more frequently on medium-textured than fine-textured soils, and was the major forb in all mixed prairie communities.

Evidence suggests that *Artemisia* increases in abundance due to various grazing practices. Lewis et al. (1956) reported that the species increased with grazing in western South Dakota; Ellison (1960) concurred, basing his conclusions on studies of the area around Mandan, North Dakota. Others agreeing that *Artemisia* increases with grazing were Beetle 1950, Sarvis 1920, Johnson 1956, and Lodge 1954. Measurements of dry matter production of *A. frigida* in the *Artemisia tridentata-Agropyron spicatum* association of the triangle (unpublished data), both inside an exclosure (standing for three years up to the time of clipping) and outside (subjected to heavy spring and early summer grazing), strongly indicate a direct relationship between grazing intensity and productivity of *A. frigida*. Because of this, the abundance of *Artemisia* in the triangle is probably higher now than it was before livestock were introduced into the area.

Vicia americana

Little mention of this species exists in the literature of the region. Mackie (1970) lists *Vicia* as being important only in his *Artemisia tridentata-Agropyron smithii* association. Data of Smith (1969) indicate it as being most abundant in his *Artemisia-Agropyron* and *Artemisia-Koeleria-Bouteloua* groups.

Although *Vicia* is widespread in the triangle, it rarely occurs on habitat types in early stages of primary succession. These include the *Atriplex dioica/Gutierrezia sarothrae*, *Artemisia tridentata/Koeleria cristata*, *Rosa arkansana/Thermopsis rhombifolia*, and *Juniperus horizontalis/Carex parryana* habitat types. It also does not occur on sites where the vegetation canopy coverage is extremely high, as in the *Poa pratensis/Artemisia ludoviciana* habitat type. Its greatest occurrence is in the *Agropyron spicatum-Agropyron smithii* and *Artemisia tridentata-Agropyron dasystachyum* associations. Because bare ground coverage is low in the former and high in the latter, it cannot be concluded that low abundance of *Vicia* is directly related to bare ground coverage, although many sites where the species is absent have low plant coverage.

Taraxacum officinale

This invader (Davis 1952), important as wildlife food, has become established to a small extent in the triangle as it has over most of the country. This taxon was present in few sample plots and no definite statement can be made as to frequency and abundance by habitat types. Sample plots with the greatest coverage of *Taraxacum* were in the *Agropyron spicatum/Agropyron smithii* habitat type. *Taraxacum* is usually observed in moist swales and footslopes of the gravel-capped benches and moist disturbed areas, such as roadside ditches, where the soil is not saline-alkaline.

Tragopogon dubius

The distribution of *Tragopogon* in the triangle was very similar to that of *Taraxacum*. It occurred mostly in moist disturbed areas such as roadside ditches. It was never abundant enough to be considered a dominant.

Selaginella densa

Although this short, non-flowering species (related to the ferns) apparently is not important as food for animals, it is a good indicator of habitat types and possibly of range condition. It may also be important in helping prevent soil erosion when other cover is removed.

Van Dyne and Vogel (1967) found that *Selaginella* was most abundant in places where *Bouteloua* and *Stipa comata* were dominant. It was also associated with the *Stipa comata-Agropyron smithii*, *Agropyron smithii-Muhlenbergia cuspidata*, and *Agropyron spicatum* types. They determined that Selaginella coverage was least on relatively deep soils and greatest on soils of medium texture. Grazing was shown by that study to decrease coverage of the species. Smoliak (1965) found that compared to control areas, coverage in southeastern Alberta was higher on areas subjected to rotation grazing and less on continuously grazed areas.

Coupland (1950) states that *Selaginella* is least abundant on clay soils and most abundant on soils of medium texture. He concurred with Van Dyne and Vogel that heavy livestock use decreased coverage of *Selaginella*, probably as a result of trampling effects.

In the triangle, *Selaginella* is most abundant in the *Artemisia tridentata-Agropyron spicatum* and *Agropyron spicatum-Agropyron smithii* associations. When considering only canopy coverage, it appeared to be a dominant in these associations, but due to its very low stature and moisture requirements, this probably was not the case (Clark et al. 1943). *Selaginella* is a minor associate of the *Artemisia tridentata/Bouteloua gracilis* cover type and is absent in habitat types with clay soils, silty soils, and raw shale substrates. The presence or absence of this species on untilled sites is a very strong indicator of whether a site supports the *Artemisia tridentata-Agropyron spicatum* association or the *Artemisia tridentata-Agropyron dasystachyum* association. Comparisons of abandoned plowed sites and unplowed sites within the *Artemisia tridentata/Agropyron spicatum* and *Agropyron spicatum/Agropyron smithii* habitat types show that treatments of this sort virtually eliminate *Selaginella* from the plant community for many years. Thus, within these habitat types, the degree of *Selaginella* coverage is a good indicator of whether or not a site has been plowed and abandoned, even if most other indicator species have disappeared.

The effects of grazing on coverage of *Selaginella* in the triangle are unclear, and more intensive studies would be needed to determine this.

Habitat Types and Management

Effects of Grazing on the *Artemisia tridentata/Agropyron spicatum* Habitat Type, *Bouteloua gracilis* Phase, and the *Artemisia tridentata/Bouteloua gracilis* Cover Type

The heavily grazed, gravel-capped terraces throughout the triangle support stands of *Artemisia* and shortgrasses such as *Bouteloua*, *Stipa comata*, *Poa sandbergii*, and *Koeleria*. Scattered patches of *Agropyron spicatum* exist throughout these areas, increasing toward the edges of the terraces. Since heavy grazing has been the rule on these terraces, certainly much heavier than the pressure exerted by wild ungulates, certain components of the original vegetation community probably have decreased and others have increased.

On the basis of known effects of heavy grazing on various species of plants, it can be assumed that what once may have been an *Artemisia tridentata-Agropyron spicatum* association is now an *Artemisia tridentata-Bouteloua gracilis* disclimax. Evidence is abundant that *Bouteloua* increases in abundance with heavy grazing and that *Agropyron spicatum* is strongly decreased or even eliminated (Coupland 1961, Daubenmire 1970, Tisdale 1947, Stoddart 1946, McIlvanie 1942, Heady 1950, Blaisdell and Pechanec 1949, and Cooper 1953). Good stands of *Agropyron spicatum* occur on what appear to be moderately grazed areas of the triangle. While evidence is strong that overgrazing may have virtually eliminated *Agropyron spicatum* from the gravel terraces, it possibly may not have existed there in much greater quantities before livestock grazing than it does now. These areas, at best, seem to be only slightly better than marginal habitat for the species. However, *Agropyron spicatum* bunches persisting only beneath *Artemisia tridentata* bushes, where they are inaccessible to cattle, seem to indicate otherwise. One site in the extreme southeastern part of the triangle, subjected to very light grazing at most, supports a vigorous stand of *Agropyron spicatum* and *Artemisia;* outside the fence, where grazing is heavy, the only *Agropyron spicatum* plants to be found are under the protection of sagebrush bushes.

Grazing causes changes in vegetation because of its direct, often detrimental, effects on plants and its effects on soil and microclimate. Selectivity by livestock for certain types of plants causes some species to be grazed more heavily than others. A general presumption is that shortgrasses are harder for cattle to eat and therefore would tend to increase at the expense of more exposed taller grasses. However, other complicating factors such as differences in palatability, elevation of growing point above the ground, and ratio of fertile to vegetative stems influence the susceptibility of a grass to grazing damage (Branson 1953). Elevated growing points, high ratios of fertile to vegetative stems, and high palatability are characteristics contributing to detrimental effects if a grass is grazed heavily.

In this habitat type, Ellison (1960) reported that under moderate continuous grazing, *Agropyron smithii*, *Stipa comata*, *Koeleria cristata*, and *Psoralea argophylla* are considered as decreasers, whereas *Bouteloua* and *Artemisia frigida* are increasers. Branson (1953) also reports that *Agropyron smithii* and *Koeleria cristata* are decreasers. Other reports on *Koeleria cristata* are somewhat conflicting. Beetle (1950) and Clark (1930) report it as a decreaser; Vogel and Van Dyne (1966) report it as an increaser. Tueller and Blackburn (1974), Vogel and Van Dyne (1966), Smoliak (1974), Clark (1930), Craddock and Forsling (1938), Larson and Whitman (1942), Smoliak (1965), and Lodge (1954), state that *Stipa comata* is a decreaser and Smoliak (1974) states that heavy sheep grazing increases basal area of *Bouteloua* and decreases basal area of *Stipa comata* and *Agropyron smithii*. Data from sample plots, comparing spring-summer grazed stands in this habitat type with light to moderately grazed stands (Table 2), definitely show a large increase in *Bouteloua* canopy coverage with increased grazing pressure. Changes in dominance of other species are less definite, although *Stipa comata* appears to be slightly more abundant on heavily grazed sites than on lightly grazed ones; but, as noted above, results of others are different (Ellison 1960, Smoliak 1965, and Sarvis 1941). The differences, however, may result from the fact that their work was done in areas more favorable climatically and edaphically for *Stipa comata* and involving different ecotypes of the species. Cooper (1953) reported that *Agropyron smithii* and *Agropyron spicatum* decreased with heavy grazing on certain *Artemisia* ranges near Tensleep, Wyoming, whereas *Artemisia tridentata* was an increaser.

TABLE 2.—Percent Canopy Coverage Comparisons Between Adjacent Grazed and Ungrazed Stands

	Habitat Type					
	Sarcobatus-Agropyron		*Artemisia-Agropyron*			
	Stand No.		Stand No.			
	14	15	57	56	73	74
	−*	+*	−	+	−	+
Bare ground	14	25	2	11	8	13
Grass	44	23	52	46	55	43
Forbs	12	10	9	6	16	9
Selaginella densa		1				
Lichens	8	3		1	2	6
Flat litter (mulch)	57	35	75	57	69	46
Standing litter	18	5	30	10	34	6
Artemisia tridentata	7	3	2		19	24
Sarcobatus vermiculatus	5	< 1				
Agropyron spicatum			25	1	46	19
A. dasystachyum	11	10		5		
A. smithii	2			< 1	< 1	< 1
Bouteloua gracilis	< 1	7		2	4	14
Koeleria cristata	8	< 1	3	2	2	2
Poa sandbergii	11	2	14	5	1	1
Stipa comata					4	5
Distichlis stricta	< 1	< 1				
Carex eleocharis	3	< 1		5	< 1	< 1
Bromus japonicus	3		4	9		
Gutierrezia sarothrae	< 1	< 1	< 1	3		
Opuntia polyacantha	4	6			< 1	< 1
Artemisia frigida	4	3	< 1	< 1	< 1	< 1
Taraxacum officinale					1	< 1
Tragopogon dubius				< 1	< 1	
Achillea millefolium	2			< 1		< 1

*— = no grazing
+ = grazing

Of the grazed stands, 15 and 56 were spring, summer pastures; 74 was a spring through fall pasture.

Data of Ross et al. (1973), from stands in an *Artemisia tridentata/Agropyron spicatum* habitat type, generally show decreases in per cent composition by weight of *Agropyron spicatum* and *Stipa comata*, little change in *Agropyron smithii* and *Koeleria cristata*, and increases in *Artemisia tridentata* with grazing, although results are somewhat conflicting due to insufficient data.

As noted above, microclimatic changes resulting from grazing may shift vegetation composition on a site. Removal of leaves by livestock prevents the formation of litter (mulch); Reed and Peterson (1961) determined that heavy grazing on the Ft. Keough Experimental Range near Miles City reduced litter cover by 50 per cent. Presence of litter helps prevent the sun from baking the soil surface, provides a source of organic material for incorporation into the soil surface (Hopkins 1954), and reduces the force of raindrops striking the ground. The force of livestock hooves on the ground compacts the surface and destroys the surface structure, resulting in a greater bulk density and lower permeability and water-holding capacity (Rauzi and Hanson 1966). Removal of plant material decreases shading of the soil surface with subsequent higher surface temperatures (Daubenmire and Colwell 1942) and evaporation of soil moisture. All of these factors result in a more xeric site with more xerophytic vegetation composition than existed previously. One of the best examples of this is the increase of *Bouteloua gracilis* in areas which have become more xeric (Coupland et al. 1960, Ellison 1960).

From the evidence discussed above, and the data in Table 2, a relatively undisturbed *Artemisia tridentata-Agropyron spicatum* association, containing moderate amounts of *Bouteloua gracilis, Stipa comata, Agropyron smithii, Artemisia frigida, Koeleria cristata, Poa sandbergii,* and *Agropyron dasystachyum,* upon the advent of heavy grazing, would tend to become an *Artemisia tridentata-Bouteloua gracilis* disclimax with slightly decreased amounts of *Stipa comata,* strongly decreased amounts of *Agropyron spicatum,* and only slightly different amounts of *Agropyron smithii, Agropyron dasystachyum, Koeleria cristata,* and *Poa sandbergii. Artemisia tridentata* would increase moderately.

Because other authors (Coupland 1961, Wright and Wright 1948, Hanson and Whitman 1938, Dix 1958, and Quinnild and Cosby 1958), working in regions surrounding central Montana, recognized climax vegetation associations dominated by *Bouteloua gracilis* and *Stipa comata,* it is possible a climax habitat type dominated by these two species may occur within the triangle. However, soils in the triangle are generally fine-textured, limiting abundance and vigor of *Stipa comata* (Coupland 1961). *Stipa comata* does not appear to be a dominant in any *Artemisia* stand within the triangle, regardless of the grazing treatment. Although *Bouteloua* is a dominant grass in many overgrazed situations, it does not seem to be a dominant in any lightly or moderately grazed area.

Effects of Cultivation on the *Artemisia tridentata/Agropyron spicatum* Habitat Type, *Bouteloua gracilis* Phase, and the *Artemisia tridentata/Bouteloua gracilis* Cover Type

Many gravel-capped terraces in the triangle were plowed and seeded to wheat and other grains during the homestead era, followed by abandonment during the Depression. Some fields were later plowed and seeded to crested wheatgrass *(Agropyron desertorum).* Following the abandonment of these fields, the vegetation continues to undergo secondary succession. A long-lasting effect of plowing these soils is to bring the clay "B" horizon to the surface and mix it with the coarser-textured and more friable topsoil, in effect changing the soil to one that is denser and less permeable at the surface. Hundreds, and perhaps thousands, of years will be necessary for the soil to regain the same profile as in adjacent, undisturbed areas. At least some vegetation differences may persist for as long as the soil differences exist. In actuality, the seeding of crested wheatgrass has created a new habitat type, but one on which the climax vegetation association for the new site has not yet developed.

Presently, the vegetation composition on previously plowed sites resembles the composition on "immature" (and usually fine-textured) soils in the triangle derived from shale. Because of the higher clay content, *Bouteloua gracilis* and *Selaginella densa* are almost absent, whereas *Stipa viridula, Agropyron smithii,* and *Agropyron dasystachyum* are more abundant than on nearby similar, but untilled, sites. If *Agropyron desertorum* was seeded, it persists in varying amounts. The effect seems to be to partially convert an

Artemisia tridentata-Bouteloua gracilis disclimax (or *Artemisia tridentata-Agropyron spicatum* association) to an *Artemisia tridentata-Agropyron dasystachyum* disclimax. The effects of plowing on *Agropyron spicatum* in this habitat type are unclear.

Effects of Grazing on the *Artemisia tridentata/Agropyron dasystachyum* Habitat Type, *Agropyron smithii* Phase

Little can be said concerning livestock grazing effects in this habitat type due to a lack of information. Soils are unstable and normally undergo substantial geological erosion. Placing livestock on such sites would increase erosion rates, with subsequent detrimental effects on vegetation.

As previously noted, *Agropyron spicatum* and *Agropyron smithii* are usually decreasers, so presumably they would decrease in this habitat type. Another important constituent of this type, *Stipa viridula*, may also be a decreaser (Ross et al. 1973), although data to support this are thin. Effects of grazing on *Agropyron dasystachyum*, the major dominant grass of the type, are unknown. *Artemisia tridentata* apparently increases. *Bouteloua*, *Stipa comata*, *Artemisia frigida*, and *Selaginella densa* do not exist in this habitat type, and apparently do not invade as grazing pressure is applied. Two important forbs of this habitat type, *Vicia americana* and *Bahia oppositifolia*, were found to have been decreased three to five times by heavy grazing on the Ft. Keough Experimental Range (Reed and Peterson 1961).

Effects of Grazing and Cultivation on the *Sarcobatus vermiculatus/Agropyron dasystachyum* Habitat Type

On some areas of this habitat type, where a topsoil developed and was able to remain, *Bouteloua* is the dominant grass species, possibly because of grazing effects. It is difficult to imagine what grass(es) may have decreased at the expense of the *Bouteloua* on these sites, but a rhizomatous species of *Agropyron* was probably one of them. Judging from evidence of severe soil erosion, the areas with a topsoil, and dominated by *Sarcobatus*, were probably more extensive in the past than they are now. Where severe erosion has occurred, very little except bare ground can be found between *Sarcobatus* bushes. These bushes, in some very heavily grazed areas (during the summer), are severely hedged and probably less abundant than they would be without grazing. A common observation in the triangle (apparently different from some other areas, Daubenmire 1970) is the heavy use of *Sarcobatus* by cattle to the extent that it has been almost eliminated from sites where apparently it should be a dominant plant. This was deduced from observations comparing adjacent heavily grazed and lightly grazed *Sarcobatus* stands separated by fences. The original coverage of *Sarcobatus* in the triangle is almost as difficult to assess as that for *Artemisia*.

Sarcobatus bottomlands are often converted to alfalfa *(Medicago sativa)* or to hayfields planted with tame grasses. While alfalfa and hayfields have also been established in other habitat types, such as those dominated by *Artemisia tridentata* and *Artemisia cana*, they are almost always found on bottomlands.

Effects of Grazing and Cultivation on the *Agropyron spicatum/Agropyron smithii* Habitat Type

Little is known of the effects of grazing on vegetation of this habitat type. Considering known reactions of individual species to grazing in other areas as discussed previously, grazing presumably would decrease *Agropyron spicatum*, *Agropyron smithii*, *Koeleria cristata*, and *Stipa comata*, and increase *Bouteloua gracilis* and *Artemisia frigida*. Moderate grazing of this habitat type has not resulted in the establishment of *Artemisia tridentata*. When soil of this habitat type is planted with *Agropyron desertorum*, few native grasses remain except *Koeleria cristata* and *Poa sandbergii*. Canopy coverage of forbs is reduced by more than half, and the number of species is sharply reduced. *Artemisia frigida* remains as the most common forb.

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APPENDIX A, TABLE 1.—Percent Constancy and Percent Canopy

Habitat Type	ARTR/ AGSP		SAVE/ POSA		ARTR/ AGDA		ARTR/ AGDA		ARTR/ KOCR		ROAR/ THRH	
	c[1]	cc[2]	c	cc	c	cc	c	cc	c	cc	c	cc
Phase	BOGR				AGSP		SAVE					
No. Stands Sampled	20		7		12		2		7		4	
Conifer Trees												
Pinus ponderosa												
Shrubs												
Artemisia tridentata	90	11.6	87	3.5	92	14.0	100	14.6	86	9.8	50	5.5
Opuntia polyacantha	80	1.7	87	2.2	42	.5			57	.4	25	.5
Sarcobatus vermiculatus			75	1.4			100	1.2				
Yucca glauca	5	P										
Rosa arkansana											100	1.0
Artemisia longifolia											75	3.8
Chrysothamnus nauseosus			12	P							25	4.6
Juniperus horizontalis												
Chrysothamnus viscidiflorus												
Artemisia cana												
Perennial Graminoids												
Agropyron spicatum	65	10.5	12	.5	83	9.6			57	6.2	50	.3
A. dasystachyum	55	3.3	100	8.5	75	5.2	100	14.4	100	7.7	50	4.7
Bouteloua gracilis	90	7.5	75	12.1	33	.4			71	2.6	25	.1
Stipa comata	100	4.2			33	.2			86	3.0	25	.4
Koeleria cristata	90	4.4	100	3.0	83	5.0			86	4.7	25	.5
Agropyron smithii	90	1.4	37	1.7	67	3.2	50	.9	71	.6	75	.4
Poa sandbergii	95	1.4	100	5.6	100	4.1			71	1.5	50	.9
Carex stenophylla	85	1.3	87	2.3	42	.6			57	.2	75	1.2
Calamovilfa longifolia											50	1.1
Calamogrostis montanensis	25	.4							28	.3	50	5.3
Carex parryana					8	.3					50	5.2
Oryzopsis hymenoides									28	.1		
Carex filifolia	5	.1							86	4.3		
Muhlenbergia cuspidata	5	.2			8	.1			14	.2		
Andropogon scoparius												
Aristida longiseta												
Festuca idahoensis												
Stipa viridula	15	P	12	P	67	1.6	50	1.9	50	1.9	71	1.3
Poa pratensis												
Phleum pratense												
Agropyron repens												
Juncus balticus												
Luzula multiflora												
Typha latifolia												
Distichlis stricta			75	1.4								
Carex rostrata												
C. foenea												
Sitanion hystrix												
Annual Graminoids												
Schedonnardus paniculatus	10	P	87	.4	33	.1	50	.5			25	P
Vulpia octoflora	15	P	37	.3								
Bromus japonicus	40	P	25	.4	25	1.2			14	.1		
B. tectorum	20	.3										
Sub Shrubs												
Eriogonum pauciflorum					8	P			28	.9	25	.9
E. flavum												
Gutierrezia sarothrae	45	.4	62	.3	67	1.0	50	6.6	100	2.4	50	.3
Atriplex dioica												
Artemisia frigida	90	5.9	87	2.9	67	1.4	50	1.0	71	.9	25	P
Forbs												
Astragalus bisulcatus	10	.5										
Vicia americana	70	1.6	87	.2	92	.6	50	.4	71	.9		
Alyssum alyssoides	10	2.6										
Penstemon nitidus									14	P		
Oxytropis sericea	5	P										

Coverage of all Sampled Species by Habitat Types and Phases

JUHO/ CAHA	PIPO/ ARTR	ATDI/ ARTR	POPR/ ARLU	ARCA/ AGSM	AGSP/ AGSM	ARTR/ FEID	MUCU/ ANSC
c³ cc	c cc	c³ cc	c³ cc	c cc	c cc	c cc	c³ cc
1	2	1	1	2	7	3	1
						67 3.5	
	100 25*			50 P	43 .4	100 .6	
							7 1.1
	100 4.8	7 1.3		50 2.8	15 .6		
	50 .3						
						33 .2	5 .7
					14 .2		
				100 27.8		33 .1	
				50 .9	86 8.2	100 7.7	40 7.3
				50 1.6	57 1.2	33 1.7	35 2.7
5 4.2	50 19.2				71 1.3	67 .1	7 .5
				50 P	100 9.5	100 3.6	12 2.2
				50 P	86 4.3	100 3.0	60 2.4
				100 10.3	86 6.1	100 1.1	7 1.4
				50 .2	86 3.0	67 P	
					57 .2	67 .2	
					14 3.5		
					29 P		
	100 2.9	82 4.0			14 1.9	33 1.9	42 1.6
			2 .4				
						33 P	10 .3
	100 .5	2 P			14 P	67 .7	87 13.7
		2 P	67 19.6				65 9.6
	100 1.0	12 .1					35 5.0
65 5.2	50 P	7 P				100 5.4	
15 .3						33 .7	15 2.5
85 6.6	50 .5						
90 12.7					14 1.9	33 1.9	42 1.6
						33 P	10 .3
					14 P	67 .7	87 13.7
							65 9.6
							35 5.0
						100 5.4	
			7 2.2	100 5.9		33 .7	15 2.5
			92 68.1	50 13.1			
			12 1.6				
			17 6.7				
			7 4.6				
			10 .9				
			5 2.2				
			5 4.0		14 P		
			22 5.0				
		40 1.7					
		2 P		50 .1			
		5 1					
				50 .1	71 .4	67 .7	
				50 3.9	14 1.7		
30 1.4							
					14 .1		
25 .4		52 6.8		50 P	43 .4	67 .9	5 P
							77 9.9
		40 6.1					
5 P	100 .2		2 .4	50 .8	100 9.0	100 4.4	22 .4
					14 .1		
					71 1.3	100 .2	
	50 P	5 P		50 .9	14 P		

APPENDIX A, TABLE 1 (continued)

Habitat Type	ARTR/ AGSP		SAVE/ POSA		ARTR/ AGDA		ARTR/ AGDA		ARTR/ KOCR		ROAR/ THRH	
	c[1]	cc[2]	c	cc	c	cc	c	cc	c	cc	c	cc
Phase	BOGR		AGSP		SAVE							
No. Stands Sampled	20		7		12		2		7		4	
Erysimum asperum	5	P							28	P		
Aster canescens			12	P			50	2.2				
Iva axillaris			12	.8			100	4.2				
Draba brachycarpa	10	P	25	P					14	P		
Lepidium densiflorum	40	P	87	P					14	P	25	P
Allium textile	40	P	25	P	25	P			28	P		
Plantago spinulosa	35	.2	75	.5	33	P					25	P
Bahia oppositifolia					8	P	50	2.1	14	P		
Sphaeralcea cooccinea	55	.1	12	P	67	.2	50	.8	71	P		
Thlaspi arvense					8	P						
Phacelia linearis	5	P			8	P						
Rorippa islandica					17	P						
Collomia linearis					8	P						
Gaura coccinea							50	.7				
Lomatium orientale									14	P		
Plantago patagonica	45	P	25	P	8	P			28	P		
Arenaria hookeri	30	.2			33	.7			100	1.9	50	1.1
Machaeranthera grindeloides									43	1.3		
Aster falcatus									14	1.3		
Lesquerella alpina	5	P	12	P					14	P		
Astragalus gilviflorus	15	P							28	1.3		
Townsendia hookeri									14	P		
Phlox hoodii	65	.5			33	.4	50	1.3	57	3.3		
Astragalus spatulatus									14	P		
Senecio canus									14	P		
Psoralea tenuiflora	5	P							14	P		
Thermopsis rhombifolia											100	2.7
Potentilla pennsylvanica	10	P										
Melilotus officinale	10	.2	12	P	17	.3						
Artemisia ludoviciana	5	P										
Aster chilensis												
Polygonum douglasii												
Madia glomerata												
Cirsium undulatum												
Ratibida columnifera												
Ambrosia artemisifolia												
Achillea millefolium	25	P	12	.3	25	.2					25	.2
Epilobium paniculatum												
Grindelia squarrosa											25	P
Sonchus arvensis												
Comandra umbellata	15	.1			8	P			28	.6	50	.2
Erigeron pumilis	45	.1	25	P	8	P			71	.2		
Psoralea argophylla	10	P							14	P		
Heuchera parviflora												
Tragopogon dubius	40	.1			8	P						
Astragalus miser												
Orobanche fasciculata												
Taraxacum officinale	20	.3			17	P						
Erigeron caespitosus												
Helianthus petiolaris												
Zygadenus paniculatus									14	P		
Artemisia biennis												
Androsace septentrionalis	50	.1	50	P	8	P					25	P
Aster pansus												
Cirsium flodmani												
Sisymbrium altissimum												
Liatris punctata												
Balsamorrhiza sagittata												
Thelasperma subnudum									14	.1		
Antennaria rosea	5	P	12	P	8	.1						
Petalostemon purpureum									28	.3		
Linum perenne									14	P		
Cerastium berringianum												
Paronychia sessiliflora												
Petalostemon candidum							50	.4	14	P		
Solidago missouriensis	5	P										
Hymenoxys acaulis									28	P		
Hymenopappus filifolius												
Orobanche ludoviciana												
Collomia tinctoria	10	P							14	P		
Musineon divaricatum	10	P										
Nostoc	15	.1	25	.8	17	.4	50	1.1	43	.3		
Selaginella densa			62	5.2	8	P						
Moss									28	P		
Lichens	89	5.6	100	5.4	92	3.2			86	1.6	75	1.3
Bare Ground		9.5		16.4		27.8		23.9		30.6		23.2
Mulch		48.6		41.1		60.9		40.4		25.6		26.9

[1]Constancy percent
[2]Canopy coverage percent
[3]Frequency percent
P-present, but less than .1% canopy coverage

JUHO/ CAHA	PIPO/ ARTR	ATDI/ ARTR	POPR/ ARLU	ARCA/ AGSM	AGSP/ AGSM	ARTR/ FEID	MUCU/ ANSC
c³ cc	c cc	c³ cc	c³ cc	c cc	c cc	c cc	c³ cc
1	2	1	1	2	7	3	1
		15 .1					
		40 1.4					
	100 P						
		2 P			14 P		
		2 P			14 P	33 P	
						67 P	7 P
				50 P			
					43 .2	33 P	
	50 P				14 P		
5 .7						67 1.2	20 .3
						33 .3	
						33 .1	17 3.2
					29 P		5 P
20 .5					57 .3	67 P	
		10 1.5			43 .2		
			12 6.3	50 P			
15 .3			52 18.0		14 .3		
			7 1.2				
			5 1.6				
			5 P				
			20 4.9				
			5 P				
			5 .1				
	100 .6		67 16.9	50 P	57 1.8	67 .2	
			5 .9				
			2 P				
				50 .4			
				50 .3			
		20 .2			29 1.4	33 P	
					43 .8	67 .6	
					29 1.1	33 .3	
					14 .3		
			5 .15		86 .7	67 P	2 P
					29 .4	33 P	
					29 P		
			20 .2		43 .6		2 P
					14 T		
					14 P		
					14 P		
					14 .7	33 .1	
	7 P			50 P	57 .4	33 P	
			42 .9		25 1.6		20 .4
					29 .1		
					14 P		
					43 .3		7 .2
						33 .7	
					14 P		40 .6
					43 .1		5 .4
					14 P	33 P	2 .4
					14 .2	33 P	20 5.8
					71 3.8		65 4.5
							15 .1
							2 .7
					14 P		10 .5
							62 1.7
							5 P
							2 P
	50 .9				71 26.7	100 9.0	2 P
	50 P						
100 4.4	100 1.4	87 4.9		50 P	71 .6	100 5.9	90 7.6
24.9	25.0	62.6	.2	5.4	2.1	2.9	15.0
29.8	3.7	96.0	96.0	76.3	74.2	55.3	50.0

ACMI	*Achillea millefolium*	Western yarrow
ACNE	*Acer negundo*	Box-elder
AGDA	*Agropyron dasystachyum*	Thickspike wheatgrass
AGDE	*A. desertorum*	Crested wheatgrass
AGRE	*A. repens*	Quackgrass
AGSM	*A. smithii*	Western wheatgrass
AGSP	*A. spicatum*	Bluebunch wheatgrass
ALAL	*Alyssum alyssoides*	Pale alyssum
ALTE	*Allium textile*	Textile onion
AMAR	*Ambrosia artemisifolia*	Annual ragweed
ANRO	*Antennaria rosea*	Rose pussytoes
ANSC	*Andropogon scoparius*	Little bluestem
ANSE	*Androsace septentrionalis*	Northern rockjasmine
ARBI	*Artemisia biennis*	Biennial wormwood
ARCA	*A. cana*	Silver sagebrush
ARFR	*A. frigida*	Fringed sagewort
ARLA	*Arctium lappa*	Great burdock
ARLO	*Aristida longiseta*	Red threeawn
ARLO2	*Artemisia longifolia*	Longleaf sage
ARHO	*Arenaria hookeri*	Hooker's sandwort
ARLU	*Artemisia ludoviciana*	Cudweed sagewort
ARTR	*A. tridentata* ssp. *wyomingensis*	Wyoming big sagebrush
ASBI	*Astragalus bisulcatus*	Two-grooved milkvetch
ASCH	*Aster chilensis*	Creeping aster
ASFA	*A. falcatus*	Creeping white prairie aster
ASGI	*Astragalus gilviflorus*	Three-leaved milkvetch
ASMI	*A. miser*	Weedy milkvetch
ASPA	*Aster pansus*	Tufted white prairie aster
ASSP	*Astragalus spatulatus*	Draba milkvetch
ATDI	*Atriplex dioica*	Rillscale saltbush
BAOP	*Bahia oppositifolia*	Opposite leaf bahia
BASA	*Balsamorrhiza sagittata*	Arrow-leaved balsamroot
BESY	*Beckmannia syzigachne*	Sloughgrass
BIVU	*Bidens vulgata*	Beggarticks
BOGR	*Bouteloua gracilis*	Blue grama
BRJA	*Bromus japonicus*	Japanese brome
BRTE	*B. tectorum*	Cheatgrass, downy brome
CAEL	*Carex stenophylla (eleocharis)*	Narrow-leaved sedge
CAFI	*C. filifolia*	Thread-leaved sedge
CAFO	*C. foenea*	Dryland sedge
CAHA	*C. parryana (hallii)*	Parry sedge
CALO	*Calamovilfa longifolia*	Prairie sandreed
CAMO	*Calamogrostis montanensis*	Plains reedgrass
CANE	*Carex nebrascensis*	Nebraska sedge
CAREX	*C.* ssp.	Sedge
CARO	*C. rostrata*	Beaked sedge
CEBE	*Cerastium berringianum*	Alpine chickweed
CHNA	*Chrysothamnus nauseosus*	Rubber rabbitbrush
CHVI	*C. viscidiflorus*	Green rabbitbrush
CIDO	*Cicuta douglasii*	Western water-hemlock
CIFL	*Cirsium flodmani*	Flodman's thistle
CIUN	*C. undulatum*	Wavy-leaved thistle
COLI	*Collomia linearis*	Narrow-leaved collomia
COTI	*C. tinctoria*	Yellow-staining collomia
COUM	*Comandra umbellata*	Bastard toadflax
CRDO	*Crataegus douglasii*	Black hawthorn
DIST	*Distichlis stricta*	Alkali saltgrass
DRBR	*Draba brachycarpa*	Shortpod draba
EPPA	*Epilobium paniculatum*	Tall annual willow-herb
ERAS	*Erysimum asperum*	Rough wallflower
ERCA	*Erigeron caespitosus*	Tufted fleabane
ERFL	*Eriogonum flavum*	Yellow buckwheat
ERMU	*E. pauciflorum (multiceps)*	Few-flowered buckwheat
ERPU	*Erigeron pumilis*	Shaggy fleabane
FEID	*Festuca idahoensis*	Idaho fescue
GACO	*Gaura coccinea*	Butterfly weed
GLLE	*Glycyrrhiza lepidota*	Wild licorice
GRSQ	*Grindelia squarrosa*	Curlcup gumweed
GUSA	*Gutierrezia sarothrae*	Broom snakeweed
HEUN	*Helianthella uniflora*	Little sunflower
HEPA	*Heuchera parviflora*	Small-leaved allumroot
HEPE	*Helianthus petiolaris*	Prairie sunflower
HYAC	*Hymenoxys acaulis*	Stemless hymenoxys
HYFI	*Hymenopappus filifolius*	Hymenopappus
IVAX	*Iva axillaris*	Povertyweed
JUBA	*Juncus balticus*	Baltic rush
JUHO	*Juniperus horizontalis*	Creeping juniper, horizontal juniper
KOCR	*Koeleria cristata*	Prairie junegrass
LEAL	*Lesquerella alpina*	Alpine bladderpod
LEDE	*Lepidium densiflorum*	Prairie pepperweed

LIPE	*Linum perenne*	Blue flax
LIPU	*Liatris punctata*	Blazing star
LIRI	*Linum rigidum*	Yellow flax
LOOR	*Lomatium orientale*	Eastern biscuitroot
LUMU	*Luzula multiflora*	Sweep's brush
MACA	*Machaeranthera canescens (Aster canescens)*	Hoary aster
MAGL	*Madia glomerata*	Mountain tarweed
MAGR	*Machaeranthera grindeloides (Haplopappus nuttallii)*	Nuttall goldenweed
MEOF	*Melilotus officinale*	Yellow sweetclover
MUCU	*Muhlenbergia cuspidata*	Mountain muhly
MUDI	*Musineon divaricatum*	Leafy musineon
OPPO	*Opuntia polyacantha*	Yellow prickly pear cactus
ORFA	*Orobanche fasciculata*	Clustered broomrape
ORHY	*Oryzopsis hymenoides*	Indian ricegrass
ORLU	*Orobanche ludoviciana*	Suksdorf's broomrape
OXSE	*Oxytropis sericea*	Pendant pod crazyweed
PASE	*Paronychia sessiliflora*	Whitlow wort
PECA	*Petalostemon candidum*	White prairie-clover
PENI	*Penstemon nitidus*	Waxleaf penstemon
PEPU	*Petalostemon purpureum*	Purple prairie-clover
PHHO	*Phlox hoodii*	Hood's phlox
PHKE	*P. kelseyi*	Kelsey phlox
PHLI	*Phacelia linearis*	Threadleaf phacelia
PHPR	*Phleum pratense*	Timothy
PIPO	*Pinus ponderosa*	Ponderosa pine, yellow pine
PLPU	*Plantago patagonica (purshii)*	Indian wheat
PLSP	*P. spinulosa*	Indian wheat
PODE	*Populus deltoides*	Great Plains cottonwood
PODO	*Polygonum douglasii*	Douglas' knotweed
POPE	*Potentifla pennsylvanica*	Prairie cinquefoil
POPR	*Poa pratensis*	Kentucky bluegrass
POSA	*P. sandbergii*	Sandberg's bluegrass
PRVI	*Prunus virginiana*	Chokecherry
PSAR	*Psoralea argophylla*	Silver-leaved scurfpea
PSME	*Pseudotsuga menziessii*	Douglas fir
PSTE	*Psoralea tenuiflora*	Slender-flowered scurfpea
PUAI	*Puccinellia nuttalliana (airoides)*	Nuttall alkaligrass
RACO	*Ratibida columnifera*	Prairie coneflower
RHTR	*Rhus trilobata*	Skunkbush
RIBES	*Ribes ssp.*	Currant, gooseberry
ROAR	*Rosa arkansana*	Arkansas rose
ROIS	*Rorippa islandica*	Marsh yellowcress
ROSA	*Rosa ssp.*	Rose
ROWO	*Rosa woodsii*	Wood's rose
RUMEX	*Rumex ssp.*	Dock
SAAM	*Salix amygdaloides*	Peach-leaf willow
SAIN	*S. interior*	Sandbar willow
SARI	*S. rigida var. watsonii*	Watson willow
SARU	*Salicornia rubra*	Glasswort, pickleweed
SAVE	*Sarcobatus vermiculatus*	Black greasewood
SCAM	*Scirpus americanus*	American bulrush
SCIRP	*S. ssp.*	Bulrush
SCPA	*Schedonnardus paniculatus*	Tumblegrass
SCVA	*Scirpus validus*	Tule, American great bulrush
SECA	*Senecio canus*	Woolly groundsel
SEDE	*Selaginella densa*	Small clubmoss
SHAR	*Shepherdia argentea*	Silver buffaloberry
SIAL	*Sisymbrium altissimum*	Jim Hill mustard
SIHY	*Sitanion hystrix*	Squirreltail bottlebrush
SOAR	*Sonchus arvensis*	Perennial sow-thistle
SOGI	*Solidago gigantea*	Smooth goldenrod
SOMI	*S. missouriensis*	Missouri goldenrod
SPCO	*Sphaeralcea coccinea*	Scarlet globemallow
SPGR	*Spartina gracilis*	Alkali cordgrass
STCO	*Stipa comata*	Needle-and-thread grass
STVI	*S. viridula*	Green needlegrass
SUFR	*Suaeda fruticosa*	Shrubby seepweed
SUOL	*S. occidentalis*	Slender seepweed
SYOC	*Symphoricarpus occidentalis*	Western snowberry
TAOF	*Taraxacum officinale*	Dandelion
THAR	*Thlaspi arvense*	Fanweed
THMA	*Thelasperma subnudum (marginata)*	Thelasperma
THRH	*Thermopsis rhombifolia*	Round-leaved thermopsis
TOHO	*Townsendia hookeri*	Hooker's townsendia
TRDU	*Tragopogon dubius*	Salsify, goatsbeard, oyster plant
TYLA	*Typha latifolia*	Cattail
URDI	*Urtica dioica*	Stinging nettle
VIAM	*Vicia americana*	American vetch
VUOC	*Vulpia octoflora (Festuca octoflora)*	Six-weeks fescue
YUGL	*Yucca glauca*	Yucca, soapweed
ZYPA	*Zygadenus paniculatus*	Panicled deathcamas

APPENDIX A, TABLE 3
Vegetation Type Areas of the Yellow Water Triangle

Differentiated mapping units habitat type, cover type, or phase		No. of acres	No. of hectares	Percent of total
1.	ARTR/AGSP H.T. BOGR Phase	29,589	11,983	17.34
1A.	ARTR-BOGR C.T.	7,775	3,149	4.70
2.	ARTR/AGDA H.T. AGSP Phase	7,440	3,013	4.36
3.	ARTR/AGDA H.T. SAVE Phase	487	197	.28
4.	ARTR/AGSP H.T. AGSM Phase	*3,268	1,323	1.92
5.	ARTR/KOCR H.T.	373	151	.22
6.	ATDI/GUSA H.T.	12	5	.01
7.	ARTR/FEID H.T. BOGR Phase	181	73	.11
8.	ROAR/THRH H.T.	9,568	3,875	5.61
9.	ARCA/AGSM H.T.	1,744	706	1.02
10.	SAVE/AGDA H.T.	15,122	6,124	8.86
11.	JUHO/CAHA H.T.	1,592	645	.93
12.	PODE/SYOC H.T.	6,258	2,534	3.67
13.	Scirpus/Carex H.T.	27	11	.02
14.	Suaeda/SARU H.T.	3	1	<.01
15.	AGSP/AGSM H.T.	18,228	7,382	10.68
16.	MUCU/ANSC H.T.	789	319	.46
17.	POPR/ARLU H.T.	*3,268	1,323	1.92
18.	PIPO/ARTR H.T.	7,440	3,013	4.36
19.	PIPO/AGSP H.T.	7,065	2,861	4.14

*In calculating areas, the ARTR/AGSP H.T., AGSM Phase, was combined with the POPR/ARLU H. T. because of difficulties in differentiating on aerial photos.

Grain in sagebrush areas	928	376	.54
Grain not in sagebrush areas	1,543	625	.90
Crested wheatgrass in sagebrush areas	3,183	1,289	1.86
Crested wheatgrass not in sagebrush areas	1,572	637	.92
Unvegetated bentonite	31	13	.02
Dry lake beds	24	10	.01
Gravel pits	18	7	.01
Alfalfa	7,715	3,125	4.52

Undifferentiated mapping units, combinations of habitat types, cover types, and/or phases	No. of acres	No. of hectares	Percent of total
1, 1A	1,288	522	.75
2, 1A	4,617	1,870	2.71
1,2	3,938	1,595	2.31
1,3	18	7	.01
1, 10	55	22	.03
1, 9	29	12	.02
1, 12	103	42	.06
1, 8	6,244	2,529	3.66
2, 3	3,129	1,267	1.83

2, 6	224	91	.13
2, 10	3,084	1,249	1.81
1A, 3	139	56	.08
1A, 10	362	147	.21
1A, 12	1,071	434	.64
1A, 8	538	218	.31
crested wheatgrass, 2	483	196	.28
crested wheatgrass, 10	20	8	.01
5, 3	334	135	.20
6, 3	120	49	.07
10, 9	395	160	.23
10,12	1,075	435	.63
10, 8	88	36	.05
9, 12	473	192	.28
12, 4	157	64	.09
12, 8	594	241	.35
12. 15	179	72	.10
12, 16	94	38	.05
13, 4	15	6	.01
8, 2	514	208	.30
8, 4	114	46	.07
8, 11	3,241	1,313	1.90
8, 15	304	123	.18
8, 18	1,034	419	.61
15, 16	228	92	.13
15, 19	31	13	.02
1, 1A, 12	861	349	.50
1A, 12, crested wheatgrass	316	128	.18
1A, 2, 12	461	187	.27
1, 2, 3	120	49	.07
crested wheatgrass, 3, 2	422	179	.26
2, 4, 17	75	30	.04
2, 8, 11	56	23	.03
5, 8, 11	64	26	.04
8, 11, 15	734	297	.43
2, grain	30	12	.02
10, alfalfa	143	58	.09
12, alfalfa	541	219	.32
12, crested wheatgrass	292	118	.17
Totals	**170,442**	**68,975**	**100**

total acreage of land containing at least some:	No. of acres	No. of hectares	Percent of total
Sagebrush	80,174	32,470	47.00
Raw shale	24,685	9,997	14.47
Greasewood	23,704	9,600	13.89
Pine	6,885	2,788	4.03
Agropyron spicatum	66,170	26,799	38.79

APPENDIX B

Glossary

Habitat type: A collective area comprising characteristics of soil, climate and topography capable of supporting a certain potential (relatively homogeneous) assembly of plants. Ordinarily, the name of the h.t. is derived from the dominant vegetation only, and not the other parts of the ecosystem.

Cover type: A disclimax vegetation association different from the potential vegetation occupying an undisturbed h.t. The cover type possesses the same non-vegetal ecological features as the h.t. from which it is derived.

Association: A particular grouping of plants. It may be climax or disclimax. Ordinarily, a h.t. contains one association with the name of this association also being the name of the h.t.

Dominant plant: A plant contributing a major proportion of the biomass of an ecosystem and exerting an ecological influence large enough to significantly affect the success of establishment of other plants.

Primary succession: A natural development of both vegetation and soil on primitive sites potentially leading to the formation of a h.t. The primitive condition of the site may be a natural situation, such as exposed rock which has not had a chance to weather, or an anthropogenic situation where man's activities have caused removal and/or alteration of already existing soil.

Secondary succession: A natural development of vegetation potentially leading to the formation of a habitat type. It is assumed that a climax vegetation association once occupied the site but was caused to revert to a seral stage by forces strong enough to change the vegetation but not the soil.

Series: A broad vegetation category based on life form or physiography and species of dominant plants. These are further subdivided into habitat types.

Climax: A vegetation association that is fully adapted to a set of site conditions. The term climax in this paper is assumed to mean topoedaphic climax.

Disclimax: A vegetation association that is not developed to its fullest potential under natural environmental conditions—as a result of some man-related disturbance. Vegetation in equilibrium with prehistoric fire and wild ungulate grazing conditions is not considered as disclimax.