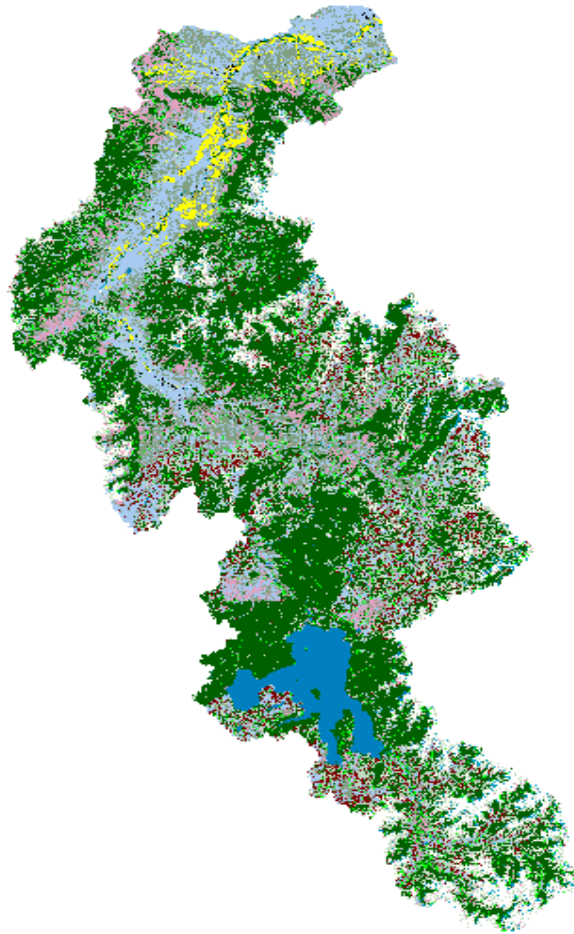


A Satellite-Based Land Cover Map for the Upper Yellowstone River Watershed, Montana and Wyoming

By

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12/01

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Introduction: A satellite-based land classification map describes, with reasonable accuracy, basic land cover types for about 2,474,141 acres in the Upper Yellowstone River watershed, Montana-Wyoming. The foundation data source consists of two Landsat satellite Enhanced Thematic Mapper (ETM+) scenes dated July 13, 1999. This cloud and haze-free imagery provided good spectral band representation with minimal defects.

In April, 2001 the USDA Natural Resources Conservation Service (NRCS) Montana GIS facility received an ETM+ classified data set from the Geographic Information and Analysis Center (GIAC), Montana State University, Bozeman, Montana. Data were provided on CD-ROM and included a classified data set based on a land cover key with accompanying tabular files of accompanying accuracy assessment matrices.

In order to standardized land cover types, the original land cover/use key used for field data gathering was converted to a GAP land cover legend modeled after the Montana Land Cover Atlas (1). [Note: Cover code numbers used for this project follow the same conventions and numbering protocol as those found in the referenced GAP report]. This helped standardized land cover classes resulting in a more meaningful separation of land cover from land use. A calculated accuracy assessment as determined by GIAC was 64.3%. Subsequent field visits were made in order to develop stratification decision rules to reduce land classification confusion and improve the overall accuracy of the map. A final post-stratification accuracy assessment of 72.2% was achieved. Documentation for the assessment may be found in the metadata file (upyell_lcc.met).

Project Area: The project area includes the upper reaches of the Yellowstone River beginning at the Park/Sweet Grass County line east of Livingston, Montana upstream including the headwaters of the Yellowstone River in Wyoming. The area includes the entire 4th code (8-digit) hydrologic unit #10070001 (Yellowstone Headwaters) and the portion of #1007002 (Upper Yellowstone) that describes the watershed upstream from the Park/Sweet Grass County line, excluding the Shields and Boulder river watersheds. (Figure 1). About 1,362,084 acres or 55% of the Upper Yellowstone watershed area lies within the state of Wyoming, of which about 1,203,600 acres or 49% of the project area lies within the boundary of Yellowstone National Park.

(1) Fisher, F.B., J.C. Winne, M.M. Thornton, T.P., Z. Ma, M.M. Hart, and R.L. Redmond. 1998. Montana land cover atlas. Unpublished report. Montana Cooperative Wildlife Research Unit, The University of Montana, Missoula. Viii + 50pp.

Classification and Cover Classes: The 1999 land cover classes were derived by GIAC using appropriate image processing protocol. An unsupervised classification (post processing) process was used. A brief description of the steps used by Dr. Richard Aspinall and staff to derive the land cover classification is provided in Appendix A.

Fifteen dominant cover classes (Table 1) were derived. These classes are the result of post-classification review and field-based stratification rules. The full resolution of the data set was maintained at 0.056 acres per pixel for computation purposes. Table 3 lists total acreage and percent of area for the entire study area. The body of the report includes individual narratives that describe each cover class with a representative image.

Accuracy and Post Classification Stratification: An overall accuracy of 64.3% was achieved for the final unsupervised classification prior to the application of stratification rules. Upon review of the final classification, confusion existed relative to the distribution of some vegetative classes, most notably, those classes having high near infrared reflectance. The principal stratification tool used to reduce confusion was the 30-meter Digital Elevation Model (DEM) data.

Twenty-three 1:24,000 scale check plots were produced for field verification. Extensive field checks were made to determine how well the fifteen cover type clusters fit the landscape. Confusion and inconsistencies were documented from which a series of stratification rules were derived. Table 2 is a summary of the field-derived stratification rules in the order in which they were imposed. Confusion in the near infrared reflectance classes 2020, 3200, 4300, 4500 and 6120 required elevation-based stratification. For example, confusion between irrigated agriculture and upland deciduous shrubs required an elevation "cut-off" above which the irrigated agriculture class was unlikely to occur based on field observations. In some areas, such as the Tom Miner Basin, irrigated agriculture (hayland) was so intermixed with deciduous shrubs and aspen stands, that a clear separation was not possible.

Using the Map: The accompanying color wall map displays dominant land cover classes for the Upper Yellowstone River watershed. It is designed to show general land cover relationships for the entire project area with sufficient cultural feature data for reference, including roads and town sites. The scale of the map is about 1:211,000, or 1 inch equals about 3.33 miles. The projection is UTM, zone 12, datum NAD-83. The complete metadata may be found on the distribution CD-ROM.

Disclaimer: The Upper Yellowstone River watershed land cover classification map is to be used as a primary reference source and is not intended for site specific planning. Not all land cover types are shown and some may not be accurately represented. This is public information and may be interpreted by organizations, agencies, units of government or others based on needs; however they are responsible for the appropriate application.

Table 1. Upper Yellowstone River watershed classification legend based on the Montana GAP analysis legend

I Urban and Agricultural Land

1100 Urban or Developed Lands

2020 Agricultural Lands - Irrigated

II Grasslands

3150 Low / Moderate Cover Grasslands

III Shrublands

3200 Mixed Deciduous Shrub

3350 Sagebrush (>20% canopy)

IV Forest Lands

4000 Low Density Coniferous Forest

4200 High Density Coniferous Forest

4300 Mixed Deciduous / Coniferous Forest

4400 Standing Burnt Forest - Regeneration

V Water

5000 Water (lakes and ponds)

VI Riparian

6120 Broadleaf Riparian

VII Barren Lands

7300 Rock, Rock outcrop

7500 Riverwash / Gravel Pits, Disturbed

VIII Alpine

8100 Alpine Meadows

IX Perennial Snow and Ice

9100 Snowfields

Table 2. Stratification rules as applied to the Upper Yellowstone River watershed area

Applied universally

4300 (Mixed Deciduous / Coniferous Forest) to 4200 (High Density Coniferous Forest)
 4214 (Rocky Mountain Juniper*) to 3150 (Low / Moderate Cover Grasslands)

*this class is not described; it may have been valid if it had been more narrowly defined in the cluster aggregation phase of classification.

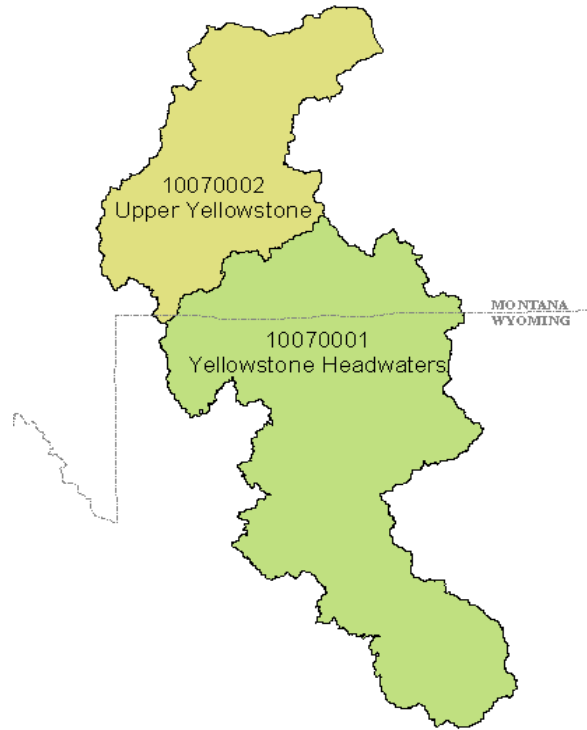
Applied based on elevation

6120 (Broadleaf Riparian) to 4300 (Mixed Deciduous / Coniferous Forest) > 5000'
 1100 (Urban or Developed Land) to 7300 (Rock, Rock outcrop > 5800'
 3150 (Low / Moderate Cover Grasslands) to 8100 (Alpine Meadows) > 9,200'
 2020 (Agricultural Lands - Irrigated) + 4300 (Mixed Deciduous / Coniferous Forest) +
 6400 (Mixed Riparian) to 3200 (Mixed Deciduous Shrub) > 5500'
 4300 (Mixed Deciduous / Coniferous Forest) + 6400 (Mixed Riparian) to 2020
 (Agricultural Lands - Irrigated) < 5500'
 4400 (Standing Burnt Forest - Regeneration) to 3200 (Mixed Deciduous Shrub) < 6000'

Table 3. Upper Yellowstone River watershed land cover classification

Class #	Name	Pixel Count	Acres	%
1100	Urban or Developed Lands	43,642	2,426	0.10
2020	Agricultural Lands - Irrigated	680,547	37,832	1.53
3150	Low/Moderate Cover Grasslands	6,272,786	348,704	14.09
3200	Mixed Deciduous Shrubs	2,425,867	134,854	5.45
3350	Sagebrush (>20% canopy)	5,263,899	292,620	11.83
4000	Low Density Coniferous Forest	3,537,432	196,646	7.90
4200	High Density Coniferous Forest	16,287,696	905,433	36.65
4300	Mixed Deciduous/Coniferous Forest	1,374,070	76,385	3.09
4400	Standing Burnt Forest - Regen	1,775,639	98,708	3.99
5000	Water (lakes and ponds)	1,706,371	94,857	3.83
6120	Broadleaf Riparian	40,584	2,256	0.09
7300	Rock, Rock outcrop	1,545,439	85,911	3.47
7500	Riverwash/Gravel Pits, Disturbed	495,179	27,527	1.11
8100	Alpine Meadows	1,612,520	89,640	3.62
9100	Snowfields	1,444,966	80,326	3.25
0000	Unclassified Area	296	16	0.00
Totals		44,506,933	2,474,141	100.00

Figure 1. Upper Yellowstone River watershed by 4th code (8-digit) hydrologic units



Cover Class Code	10070001		10070002	
	Acres	%	Acres	%
1100	364	0.02	2,062	0.25
2020	85	0.01	37,746	4.62
3150	169,825	10.24	178,816	21.90
3200	75,732	4.57	59,065	7.23
3350	155,484	9.38	137,084	16.79
4000	161,646	9.75	34,958	4.28
4200	617,936	37.27	287,335	35.19
4300	51,996	3.14	24,375	2.98
4400	94,876	5.72	3,802	0.47
5000	93,627	5.65	1,225	0.15
6120	-----	-----	2,256	0.28
7300	66,484	4.01	19,360	2.37
7500	22,185	1.34	5,324	0.65
8100	72,050	4.35	17,478	2.14
9100	74,837	4.51	5,418	0.66

1100 - Urban or Developed Lands



Land Cover
Distribution

This cover type consists of high density residential and commercial development. This type includes the cities of Livingston and Gardiner and small rural town sites. Confusion may exist with areas of bare rock and pavement or shadows from steep hillsides or cliffs.

Total Area: 2,426 acres

Percent of Area: 0.10

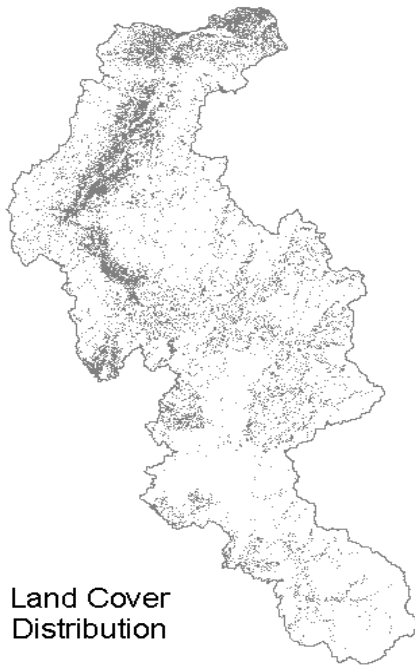
2020 - Agricultural Lands, Irrigated



This cover type consists of irrigated agricultural lands used primarily for crop or hay production. Principle crops include winter wheat, barley, grass hay and alfalfa hay. Areas of irrigated pasture are included. Some areas that were not actively irrigated at the time of imagery acquisition are included in cover type Low/Moderate Cover Grasslands (3150). Confusion may exist with areas of Mixed Deciduous Shrubs (3200) at higher elevations.

Total Area: 37,832 acres
Percent of Area: 1.5

3150 - Low / Moderate Cover Grasslands



Land Cover
Distribution

This cover type consists of low to moderate cover grasslands with total grass cover from 25 to 60% and shrub cover generally less than 15%. This type includes areas of native rangeland, non-irrigated pasture and miscellaneous disturbed sites, including idle cropland and burn areas. Representative species include bluebunch wheatgrass, needle and thread, western wheatgrass, crested wheatgrass, Idaho fescue and sandberg bluegrass. Some areas having less than 15% Rocky Mountain juniper, limber pine and Douglas fir cover are included.

Total Area: 348,704 acres
Percent of Area: 14.09

3200 - Mixed Deciduous Shrub

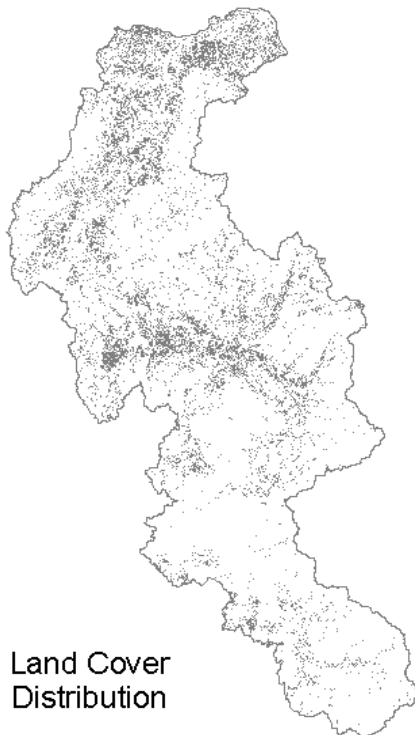


This cover type consists of mixed deciduous shrubs having canopy cover of about 30 to 90%. It occurs at elevations generally above 5500' in transitional zones from grassland to forestland. This type is associated with Mixed Deciduous / Coniferous Forest (4300). It may also be confused with small areas of non-irrigated hayland at higher elevations. Primary species include, but are not limited to, common snowberry, ninebark, Douglas hawthorn, western serviceberry and chokecherry.

Total Area: 134,854 acres

Percent of Area: 5.4

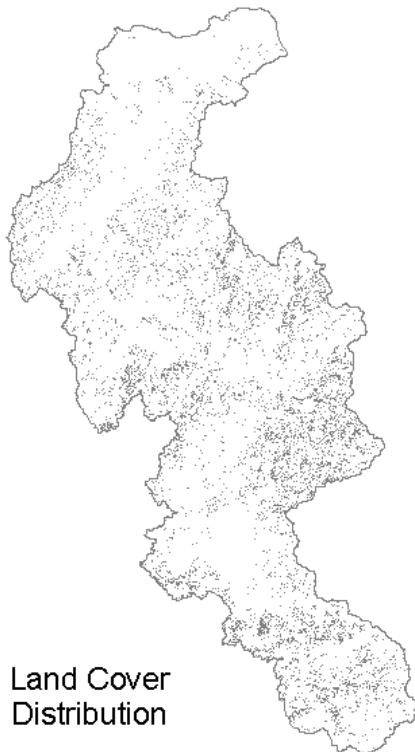
3350 - Sagebrush (> 20% canopy)



This cover type consists of shrubland dominated by sagebrush (*Artemisia* spp) having about 20 to 50% canopy. Dominant species include mountain big sagebrush, basin big sagebrush and silver sagebrush. It occurs on river terraces, alluvial fans, uplands and mountainsides. While evenly distributed over the project area, one of the largest concentrations is located in the northern areas of Yellowstone National Park on lands adjacent to the Yellowstone, Gardner and Lamar Rivers. These areas are associated with Low / Cover Grasslands (3150), when sagebrush canopy cover is less than about 15%.

Total Area: 292,620 acres
Percent of Area: 11.83

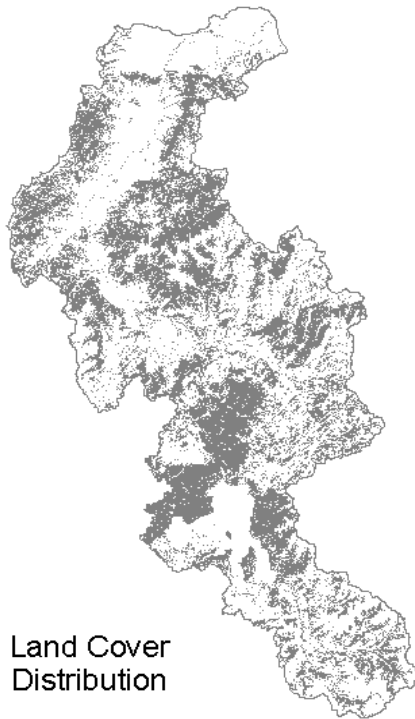
4000 - Low Density Coniferous Forest



This cover type consists of open forest land having canopy cover of about 20% to 40%. These areas are characterized by Douglas fir, Rocky Mountain juniper and limber pine with intermixed areas of grass and/or deciduous shrub cover. This type generally occupy drier sites (south and west aspects) on hillsides and mountain slopes. This cover type includes adjacent areas of Low / Moderate Cover Grasslands (3150) and/or Mixed Deciduous Shrubs (3200).

Total Area: 196,646 acres
Percent of Area: 7.95

4200 - High Density Coniferous Forest



Land Cover
Distribution

This cover type consists of forest land having canopy cover from about 40% to over 90%. These areas generally occupy north and east aspects on mountainsides, all aspects above about 7500' and in cool mountain drainageways. Douglas fir and lodgepole pine represent the dominant forest species within this cover type. Areas of subalpine fir, Englemann spruce and whitebark pine are included.

Total Area: 905,433 acres
Percent of Area: 36.60

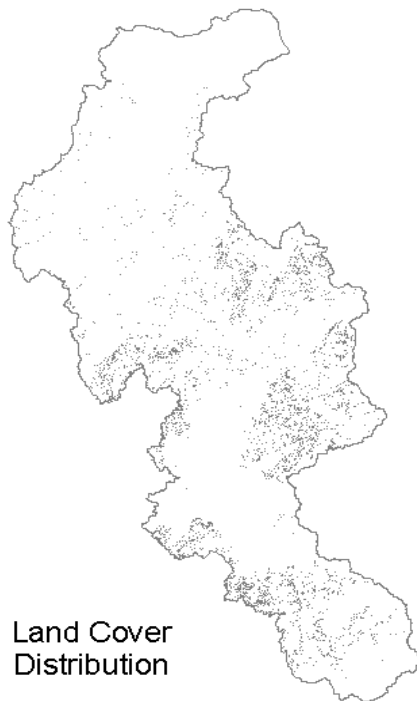
4300 - Mixed Deciduous and Coniferous Forest



This cover type consists of a mixture of deciduous and coniferous forest. Aspen is the dominant deciduous component and Douglas fir is the dominant coniferous component. This type occupies moist sites throughout the project area in drainage ways and depressions and on mountainsides having a north or east aspect. Tree canopy cover is about 30 to 80%. Areas of Mixed Deciduous Shrub (4300) and High Density Forest (4200) are associated with this cover type.

Total Area: 76,385 acres
Percent of Area: 3.09

4400 - Standing Burnt Forest - Regeneration



Land Cover
Distribution

This cover type consists of regenerating forest land primarily associated with recent forest fires. It is characterized by very dense stands of lodgepole pine saplings among standing and down snags and occurs nearly exclusively in and adjacent to Yellowstone National Park. Adjacent areas of Low / Moderate cover Grasslands (3150) and Mixed Deciduous Shrub (4300) are found in areas lacking regeneration of lodgepole pine.

Total Area: 98,708 acres
Percent of Area: 3.99

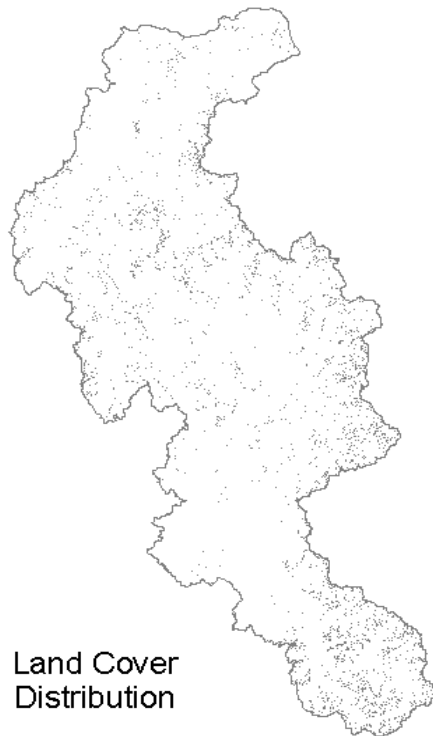
6120 - Broadleaf Riparian



This cover type consists of broadleaf deciduous trees, primarily plains cottonwood and willow (spp) along the lower portions of the Yellowstone River corridor including Mission Creek. This type represents the commonly used term "Cottonwood Galleries" on primary floodplains. It is associated with Agricultural Lands - Irrigated (2020).

Total Area: 2,256 acres
Percent of Area: 0.09

7300 - Rock, Rock outcrop

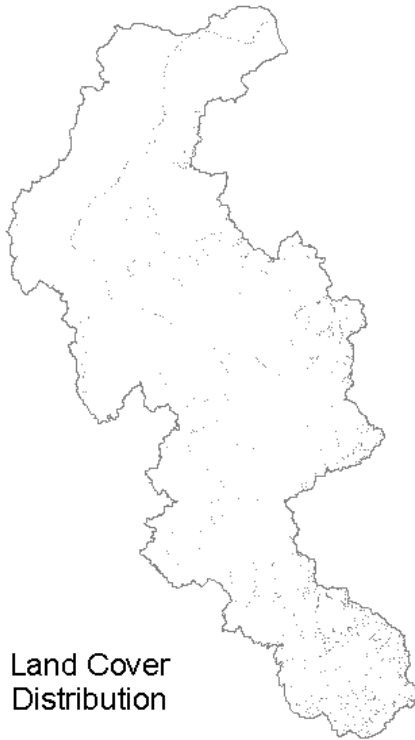


Land Cover
Distribution

This cover type consists of bare rock land and rock outcrop. While scattered areas of this type may occur throughout the project area, most areas are restricted to elevations greater than 9000' (alpine) and is associated with the Alpine Meadows (8100) and Snowfields (9100) cover types.

Total Area: 85,911 acres
Percent of Area: 3.47

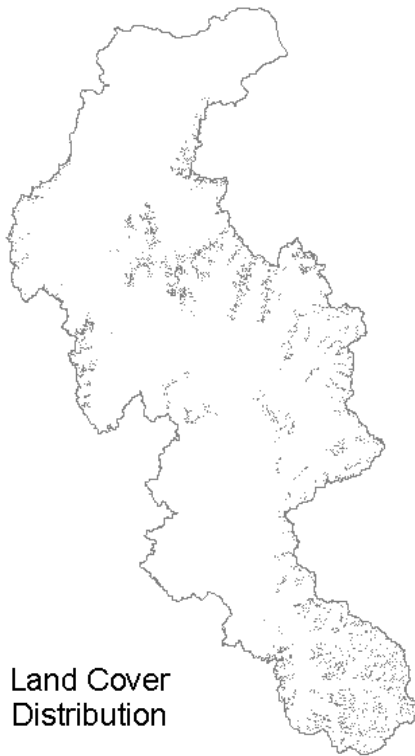
7500 - Riverwash / Gravel Pits, Disturbed



This cover type consists of areas of bare river bed gravel exposed along the Yellowstone and Lamar rivers, open gravel pits and miscellaneous disturbed areas (mines) and alpine talus. Included are water areas associated with the Yellowstone River channel not included in Water (lakes and ponds) 5000, due to imaging and/or classification anomalies.

Total Area: 27,527 acres
Percent of Area: 1.11

8100 - Alpine Meadows

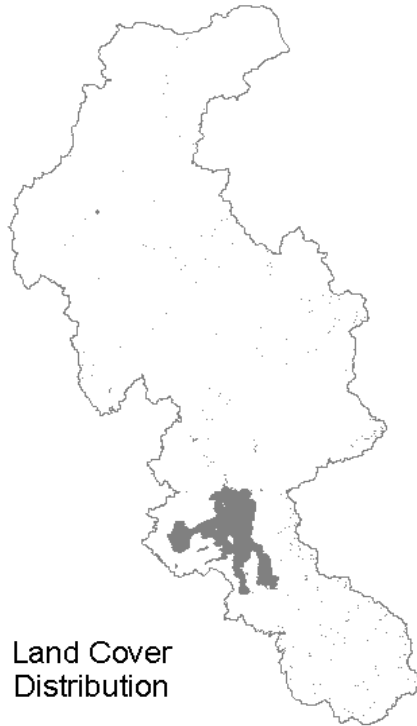


Land Cover
Distribution

This cover type consists of open alpine areas above treeline on mountain tops at elevations above 9200'. Vegetation includes low growing forbs, sedges and cushion plants. This cover type is associated with Snowfields (9100) and Rock, Rock outcrop (7300).

Total Area: 89,640 acres
Percent of Area: 3.62

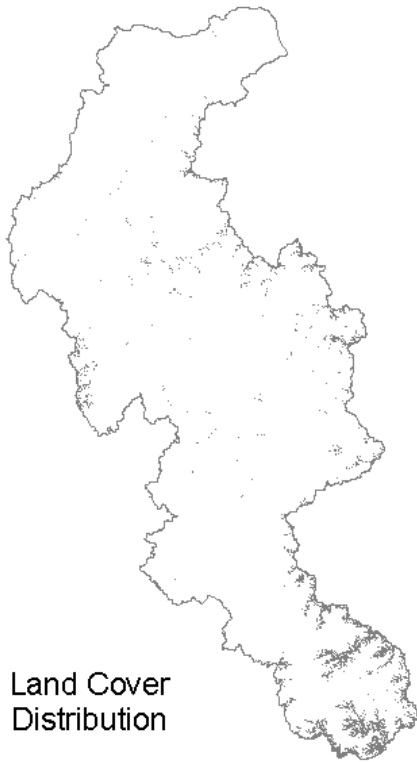
5000 - Water / Lakes, Ponds



This cover type consists of open water bodies (lakes and ponds), the largest of which is Yellowstone Lake in Yellowstone National Park.

Total Area: 94,857 acres
Percent of Area: 3.83

9100 - Snowfields



This cover type consists of areas of seasonal or permanent snow. This cover type is associated with Alpine Meadows (8100) at high elevations. This type may be confused with other highly reflective areas throughout the project area, such as rock outcrop.

Total Area: 80,326 acres
Percent of Area: 3.25

Appendix A. Summary of procedures used to prepare the 1999 land cover classification as provided by the Geographic Information and Analysis Center (GIAC), Montana State University, Bozeman, Montana; Dr. Richard Aspinall, Director.

Land Cover Mapping

1. Georeference two 1999 LANDSAT 7 ETM+ scenes to UTM NAD83 Zone 12 projection.
2. Pan sharpen ETM+ imagery for 1999 to 15m pixel resolution. Uses a Principal Component method. This calculates principal components, re-maps the high resolution image into the data range of PC-1 and substitutes it for PC-1, then applies an inverse principal components transformation. The method is used in applications that require the original scene radiometry (color balance) of the input multispectral image to be maintained as closely as possible in the output file. As this method scales the high resolution data set to the same data range as Principal Component 1, before the inverse Principal Component calculation is applied, the band histograms of the current output file closely resemble those of the input multispectral image. This radiometric accuracy comes at the price of large computational overhead. The Principal Component method is consequently the slowest of the methods available and requires the most system resources. Another result of this methodology is that the output file tends to have the same data range as the input multispectral file.
3. Classify ETM+ into a maximum of 150 classes using Iterative Self-organizing Clustering. This is iterative in repeatedly performing an entire classification (outputting a thematic raster layer) and recalculating statistics. Self-organizing refers to the way in which the method locates clusters that are inherent in the data. It used the minimum spectral distance formula to form clusters. This begins with either arbitrary cluster means and, each time the clustering repeats, the means of the clusters are shifted. The new cluster means are used for the next iteration. This repeated until a maximum percentage of unchanged pixels has been reached between two iterations.
4. Organize key from field data collection.
5. Random sample of 2000 vegetation classes in YNP from Don Despain dataset - re-code types to match land cover key.
6. Examine spectral classes and label. YNP data are used to guide the labeling for classes that occur extensively inside the Park. Two classes identified for each spectral class (first, second). Irrigation and burned areas also identified as binary types superimposed on other land cover classes.
7. Use field data for validation.