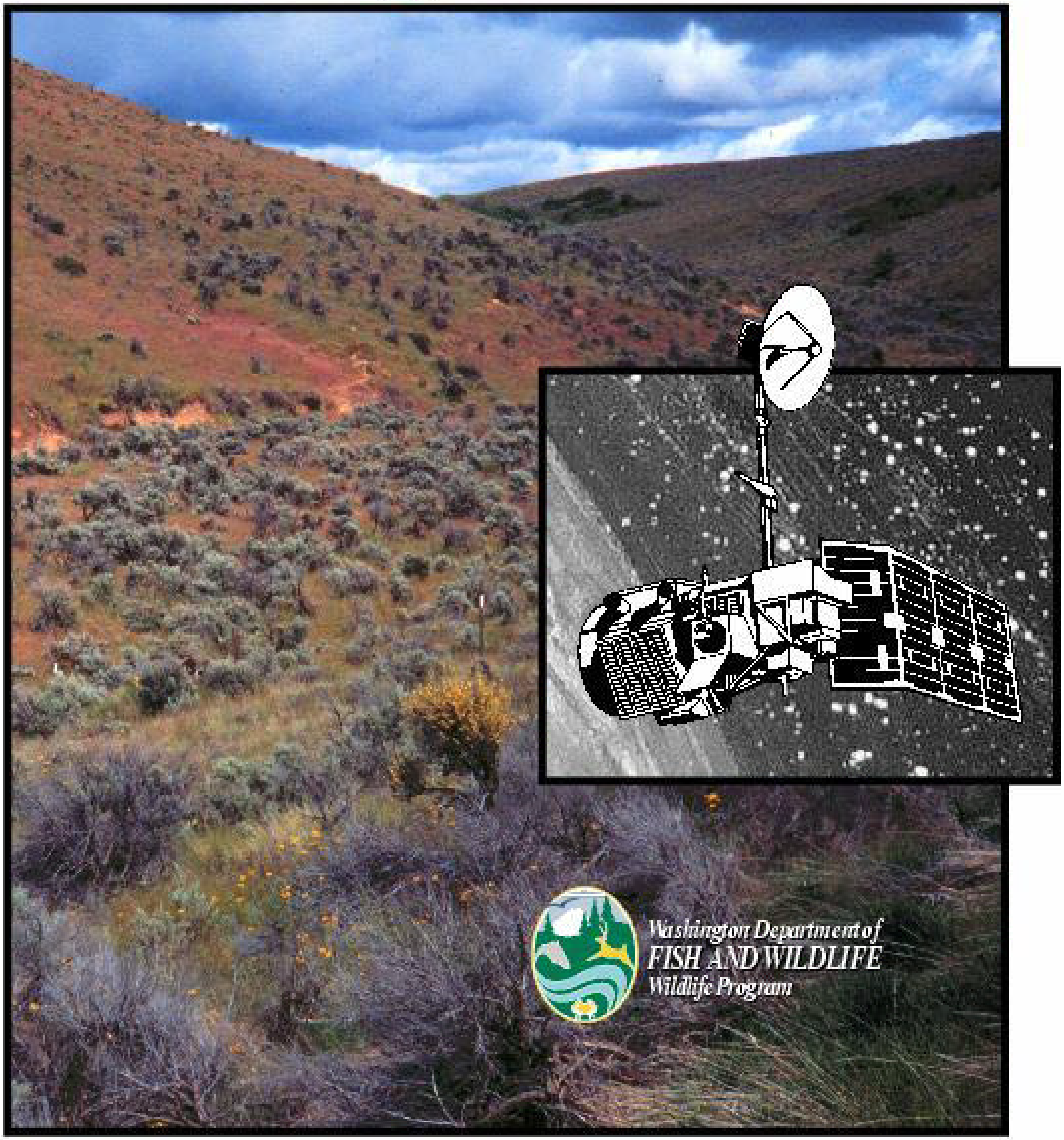
STATE OF WASHINGTON August 2000

Shrubsteppe Mapping of Eastern Washington Using Landsat Satellite Thematic Mapper Data



WDFW 637

SHRUBSTEPPE MAPPING OF EASTERN WASHINGTON USING LANDSAT SATELLITE THEMATIC MAPPER DATA

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August 2000

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ACKNOWLEDGMENTS

The Landcover Mapping Steering Committee consisted of John Pierce, Research Division Manager; research biologists Matt Vander Haegen and Michael Schroeder; Michelle Snyder, Spatial Data Management Manager; and James Eby, Wildlife Resource Data Systems Manager.

The underlying research needs this landcover mapping project addressed were formulated by John Pierce, Matt Vander Haegen, and Michael Schroeder. Assistance in development of image processing techniques was provided by Michelle Snyder and Brian Cosentino, Spatial Data Analyst. Project guidance, communications between principals, and budget management was provided by Michelle Snyder and James Eby.

Field data collection activities were developed and managed with the assistance of Matt Vander Haegen, Michelle Snyder, and Michael Schroeder. Thanks to the many field personnel who collected the invaluable data required to make this landcover mapping effort a success.

The compilation and digitization of the Conservation Reserve Program data was accomplished through the efforts of Wildlife Program intern Jeff Colburn.

Editorial assistance was provided by Matt Vander Haegen, Michael Schroeder, Brian Cosentino, and Rebecca Ritter, Spatial Data Analyst with the Department of Natural Resources.

Financial support for this project was provided in part by Federal Aid to Wildlife Restoration funds under the Pittman-Robertson Projects.

Front cover graphic design by Darrell Pruett, Washington Department of Fish and Wildlife, Olympia, WA.

Front cover photograph by John Jacobson, Washington Department of Fish and Wildlife, Olympia, WA.

EXECUTIVE SUMMARY

Shrubsteppe provides important habitat for many wildlife species in Washington State, such as the sage grouse (*Centrocerus urophasianus*), sharp-tailed grouse (*Tympanuchus phasiannellus*), and pygmy rabbit (*Brachylagus idahoensis*) which are currently listed as threatened or endangered with extinction. Shrubsteppe once extended over nearly all of the non-forested land in Washington east of the Cascade Mountain Range, but now only occupies about 50% of its historical range. The continuous loss of this important habitat makes it imperative the spatial distribution and characteristics of shrubsteppe be mapped for the effective conservation and management of obligate wildlife species. The wide distribution of shrubsteppe landcover throughout eastern Washington made the data obtained from the Thematic Mapper (TM) sensor onboard the Landsat 5 satellite platform a logical and cost-effective choice for this mapping project.

An exhaustive literature review and research effort was conducted to determine an image processing methodology which would optimally discriminate between numerous shrubsteppe habitat conditions, and other landcover in eastern Washington. TM *channels* 3,4,5, and 7 representing the red visible, near-infrared, and two mid-infrared wavelengths, respectively, were selected because they consistently provided the most effective discrimination among shrubsteppe landcover conditions. Furthermore, the research efforts using these TM channels demonstrated multitemporal TM data provided optimal discriminatory capability over the processing of single date TM data.

An unsupervised clustering technique was applied to each Landsat TM *scene* to group the enormous amount of variability in the spectral TM data into a set of 175 unique *spectral classes*. Each of these classes represents subtle landcover variations from components such as vegetative biomass and exposed soil**.** Field data were collected on the landcover composition of nearly 1300 *ground-truth* sites which spatially corresponded with the spectral classes. Based on this ground-truth information, the image analyst assigned a spectral class to *landcover class* of either open water, sand dune, shrubsteppe with less than 10% shrub cover, shrubsteppe with greater than or equal to 10% shrub cover, cropland, forest/shrub, barren, or snow. Additional classes which were not derived from the TM data included palustrine wetland areas obtained from the US Fish and Wildlife Service's National Wetland Inventory digital database, and Conservation Reserve Program (CRP) land obtained from the Natural Resources Conservation Service (NRCS).

Numerous wildlife species such as sage grouse use CRP land established with grass cover for nesting and other important habitat functions. Therefore, it is important for wildlife managers to know the distribution of CRP land over time, especially in context with the diminishing shrubsteppe habitat. CRP areas were mapped for Okanogan, Douglas, Lincoln, Grant, Adams, Franklin, Benton, Klickitat, Walla Walla, and Yakima counties by compiling and digitizing CRP field boundaries from aerial photographs. Although budget and time constraints prevented CRP

mapping of the other eastern Washington counties, the nine mapped counties contained about 80% of the CRP land in eastern Washington.

Substantial *spectral confusion* between different landcover classes often occurs when processing TM data to obtain landcover information. This spectral confusion results when two different landcover classes have similar spectral characteristics due to similar amounts of live and dead biomass, and exposed soil conditions. Substantially less of this spectral confusion occurred when multitemporal data sets were processed using both an early spring and mid to late summer Landsat scene. Therefore, multitemporal data sets were used to develop landcover information as allowed by budget and availability of scene pairs for the same area.

Considerable effort was required by the image analyst to reduce the spectral confusion by using interpretation experience and ancillary data such as aerial photos. This editing procedure consisted of systematically checking the landcover data as viewed on a computer monitor to determine potential confusion areas. Once the correct landcover was determined for the confusion areas displayed on the screen, the image processing software was used to digitally draw polygons around these areas. Within these polygons, the data elements constituting the confusion areas were edited to a value which would represent the correct landcover class in the final geographic information system (GIS) data file.

The mapping accuracy of the TM-derived landcover classes was determined by an accuracy assessment procedure using data from the NRCS's National Resources Inventory (NRI). Some of the significant advantages to using the NRI data for the accuracy assessment included resource savings realized by the WDFW, data collection by an independent agency, fairly even distribution of randomly selected sites throughout the study area, and information collected for sites which would have been logistically very difficult to ground reconnaissance.

Overall accuracy based on the TM-derived landcover classes used in the accuracy assessment was nearly 93%. The shrubsteppe, cropland, and forest/shrub landcover classes which comprise about 94% of the study area, had mapping accuracies near or above 90%. The accuracy assessment results suggest this mapping effort would provide effective GIS data products for many natural resource management applications. Shrubsteppe landcover as of 1993 covered only 30% of the eastern Washington landscape compared to approximately 60% historically. The diminishing extent and fragmentation of shrubsteppe makes it imperative this habitat and other interspersed landcover be monitored at least every 5-10 years. Such a mapping effort will assist in the effective management of shrubsteppe and the many wildlife species dependant upon this vital habitat.

INTRODUCTION

Shrubsteppe provides important habitat for many wildlife species in Washington State, such as the sage grouse (*Centrocerus urophasianus*), sharp-tailed grouse (*Tympanuchus phasiannellus*), and pygmy rabbit (*Brachylagus idahoensis*), which are currently listed as threatened or endangered with extinction under the Federal Endangered Species Act (ESA) (McAllister 1995, Tirhi 1995). Conservationists and research biologists realize shrubsteppe is a fragile and intricate habitat type, and many of the animal species which have evolved with it require extensive and unfragmented areas of shrubsteppe.

Shrubsteppe consisting predominately of sagebrush (*Atemisia* spp.) and bunch grasses once extended over nearly all of the non-forested land in Washington east of the Cascade Mountain Range (Daubenmire 1970). However, settlers arrived in Washington during the 1840s and began converting and fragmenting shrubsteppe into dryland and irrigated agriculture, and livestock rangeland. Whereas agricultural conversion usually involves rapid and extensive removal of vegetation and constant soil disturbance, heavy livestock grazing causes a slow, yet often irreversible effect on native vegetative composition and community structure (Dobler and Eby 1990).

In the late 1980s, Washington Department of Wildlife personnel used Landsat satellite Thematic Mapper (TM) data to map a study area consisting of the majority of shrubsteppe landcover in eastern Washington (Dobler et al. 1996) (Figure 1). That mapping effort estimated nearly 60% of the state's original shrubsteppe had been converted to other landcover. The diminishing extent and fragmentation of shrubsteppe makes it imperative the spatial distribution and characteristics of this habitat and interspersed landcover be monitored over time. Commitment to this monitoring effort will assist in the effective management of shrubsteppe and the many wildlife species dependant upon this vital habitat.

In 1995 the Washington Department of Fish and Wildlife (WDFW) continued the monitoring of shrubsteppe habitat, but expanded the area previously mapped by Dobler et al. to include all eastern Washington counties (Figure 1). The extensive areal coverage of shrubsteppe landcover throughout eastern Washington made the data obtained from the TM sensor onboard the Landsat 5 satellite platform (Appendix A) a logical and cost-effective choice for producing a landcover inventory**.** The project duration was from early 1995 through early 1999, and evolved to provide effective and efficient methods of processing TM data for identifying shrubsteppe landcover in eastern Washington.

Figure 1. Current study area (shaded) compared to Dobler et al. study area (hatched).

LANDCOVER CLASSIFICATION

The initial intent of this mapping project was to discern the considerable variation which exists among shrubsteppe habitat. This variation can range from lithosol soils devoid of shrubs and having sparse vegetative groundcover, to areas of loamy soils with dense shrubs and dense vegetative groundcover. The amount of shrub cover within shrubsteppe is considered to be the most important habitat component for many wildlife species (M. Vander Haegen and M. Schroeder, pers. comm.). An exhaustive literature review and research effort was conducted to determine an image processing methodology which would optimally discriminate between numerous shrubsteppe habitat conditions, and other landcover in eastern Washington (e.g. McGraw and Tueller 1983, Horvath et al. 1984, Heilman and Boyd 1986, Ustin et al. 1986, Tueller 1989, Smith et al. 1990, Homer et al. 1993, Pickup et al. 1993, Knick et al. 1997). The conclusion from those efforts indicated TM data could consistently differentiate only a few shrubsteppe classes, while still maintaining a high degree of mapping accuracy throughout the study area. A shrubsteppe class with less than 10% shrub cover and one with greater than or equal to 10% shrub cover were identified as maintaining a high mapping accuracy, while still providing valuable information for many natural resource management needs.

Although it was important to produce a digital spatial inventory of shrubsteppe, it was also considered important to determine the distribution of other general landcover classes interspersed with shrubsteppe habitat. The following list of landcover classes were decided upon by project principals to meet many natural resource management needs, while still maintaining a high degree of mapping accuracy.

***Open Water*:** Areas of open water greater than one meter in depth, with less than five percent emergent or aquatic vegetative component.

Palustrine Wetland: All palustrine wetland types as determined by the National Wetland Inventory (NWI), which was developed by the USFWS (Cowardin et al. 1979).

***Sand Dune*:** Areas of sand primarily accumulated from wind action, which is greater than one-half meter in depth and has less than five percent vegetative cover.

***Cropland*:** Areas used for the production of crops for harvest purposes, including row, small-grain, hay, orchard, and other specialty crops.

***Forest / Shrub*:** Areas of coniferous and/or deciduous woody vegetation greater than two meters in height, or areas of non-shrubsteppe deciduous species of shrubs, all which cover at least 30% of the ground surface from a vertical perspective.

***Barren*:** Areas of impervious surface material with less than five percent vegetative cover, such as large rock outcroppings, talus slopes, gravel pits, and urban structures.

***Shrubsteppe*:** Areas of native species of grasses, forbs, and shrub vegetation generally dominated by bunch grasses and arid-land shrubs such as sagebrush (*Artemisia* spp.), and/or disturbed areas which have allowed establishment of exotic plants such as cheatgrass (*Bromus tectorum*).

***Snow*:** Areas of permanent snow usually existing at very high elevations or in shadowed northerly aspects, and/or non-permanent snow which obscures the underlying landcover.

CRP LANDUSE MAPPING

Conservation Reserve Program (CRP) areas are agricultural cropland which are replanted in a grass cover for up to 10 years to provide wildlife habitat and reduce potential soil erosion. This program is administered by each county's Farm Service Agency (FSA) office under the jurisdiction of the Natural Resource Conservation Service (NRCS) of the United States Department of Agriculture (USDA). A landowner is compensated financially for maintaining this grass cover over the term of the contract with the county FSA.

CRP land provides significant habitat for numerous wildlife species, so it is important for wildlife managers to know the distribution of CRP areas over time, especially in context with the diminishing shrubsteppe habitat. A digital inventory of CRP land was developed for Okanogan, Douglas, Lincoln, Grant, Adams, Franklin, Benton, Klickitat, Walla Walla, and Yakima counties (Figure 2). Although budget and time constraints prevented mapping the remaining counties within eastern Washington, the mapped counties contained approximately 80% of CRP land in eastern Washington during 1994 (J. McClinton, pers. comm.).

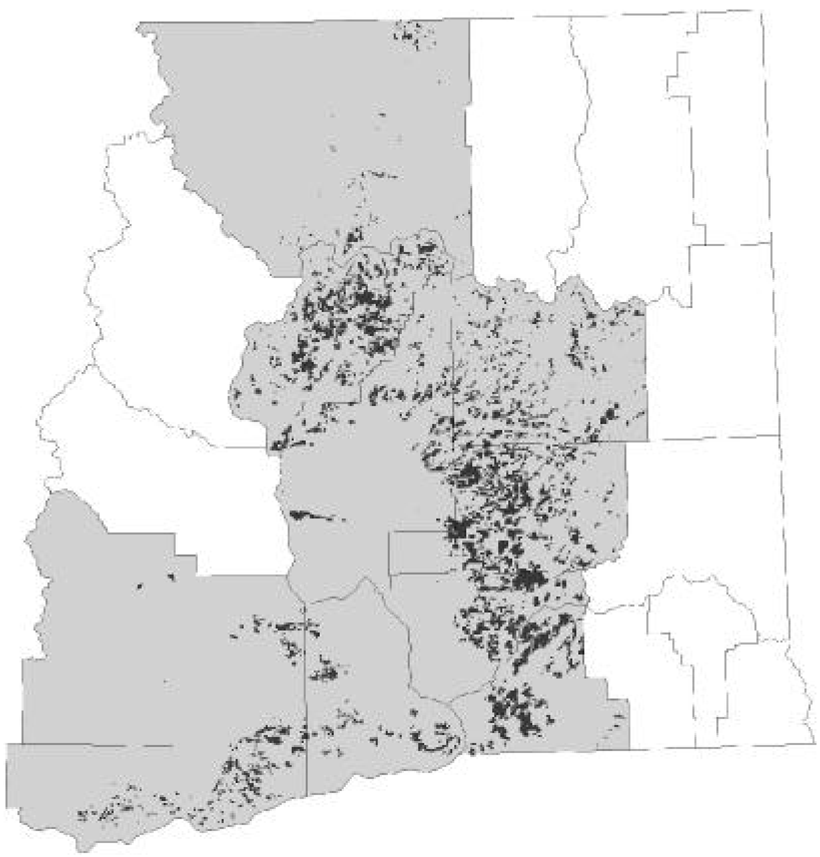

Figure 2. Distribution of pre-1995 CRP land (black) within the mapped counties (grey).

Farm Service Agency offices inventory the CRP land by manually delineating boundaries of CRP parcels on large-scale aerial photographs. At each FSA office, a search through their extensive library of photographs was conducted by WDFW staff to identify those photographs which contained CRP information. Photostatic copies were made of the photographs which contained the delineated CRP parcel boundaries, and the public land survey information was recorded for each copy as reference for subsequent processing. This process first required nearly 5700 CRP parcel boundaries be accurately transferred from these copies onto numerous 1:24,000 scale orthophoto maps. Once transferred, these polygons were digitized to produce a digital CRP inventory which could be incorporated into the TM-derived landcover inventory.

It is important to note this CRP information represents pre-1995 enrollment in this program, and therefore may not reflect current CRP land distribution due to new land being enrolled or existing land being withdrawn from the program. Also, no effort was made to incorporate ancillary information such as parcel number and enrollment year into the CRP digital inventory.

IMAGE PROCESSING

Landsat Satellite Scenes

Fourteen Landsat *scenes* acquired from the Space Imaging Corporation were used to map the landcover of eastern Washington (Table 1). Each scene consisted of about 12,000 square miles of recorded TM data arranged in a block of approximately 100 miles by 120 miles. Prior to purchase, these data were georeferenced to the Washington State Plane South coordinate system with a 1927 North American Datum, and were geometrically corrected to minimize topographic relief distortion.

Landsat scenes have side overlap of about 40% at the geographic latitudes within Washington, so either complete or partial scenes were selected and processed using specialized image processing software designed to process TM data. The Imagine software from ERDAS, Inc. was used for image processing over most of the mapping project's duration. Several aspects of the project also required the use of the geographic information system (GIS) ARC/INFO software from ESRI, Inc.

Landsat scenes are indexed by a standard number for satellite orbital path and scene row, where the row is a partitioned block of data along the orbital path. Full or partial scenes required to cover the entire study area were processed either from a single date, or from a multitemporal set of scenes from two dates for the same area (Table 1 and Figure 3).

Table 1. Characteristics of Landsat scene segments used for landcover mapping.

Segment (see Fig. 3)	*Path*	*Row*	*Date(s)*
A	45	26	5/18/93 & 9/23/93
B	45	27	6/19/93
C	45	28	6/19/93
D	44	26	5/11/93
E	44	27	5/11/93
F	44	27	5/11/93 & 8/18/94
G	44	28	5/11/93 & 8/18/94
H	43	26	8/8/93
I	43	27	8/8/93
J	43	27	8/8/93
K	43	28	9/9/93

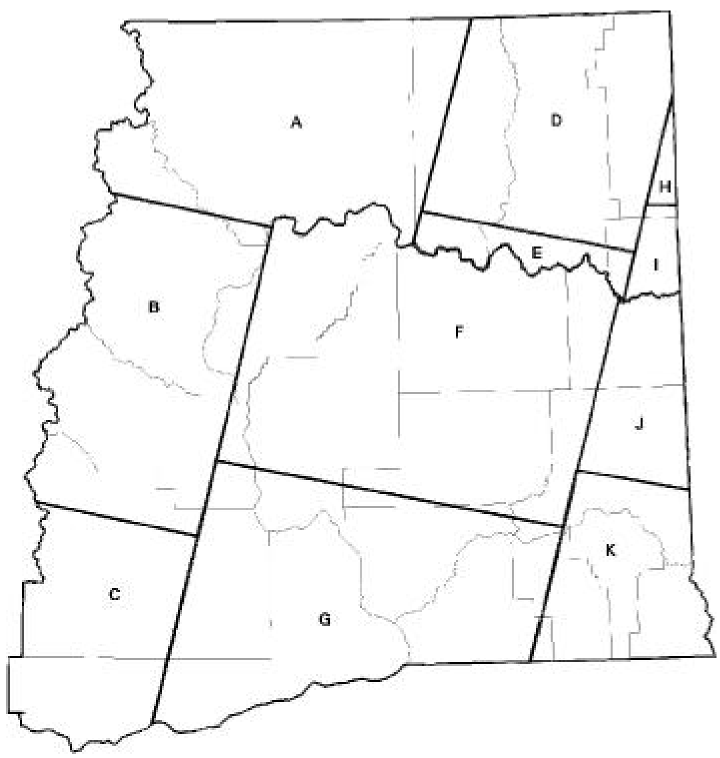

Figure 3. Distribution of Landsat scene segments used for landcover mapping.

At the beginning of this mapping project, the study area did not include all of eastern Washington, but during the course of the project, a re-assessment of shrubsteppe information needs dictated the initial study area boundaries be extended to include all the counties in eastern Washington. Therefore, portions of Landsat scenes were added to the study area and processed using the image processing software. This situation resulted in the smaller Landsat scene segments E, H, and I in Figure 3.

Thematic Mapper Data Processing

The TM sensor scans the earth and records the reflectance of light energy from landcover in the visible, near-infrared, and mid-infrared wavelengths (Appendix A). At any instance in time during the scanning process, the field of view of the TM sensor is 30x30 meters, or about one-quarter acre. A value from a minimum reflectance value of 0 up to a maximum reflectance value of 255 is recorded for each wavelength channel for each of these quarter-acre areas. Figure 4 shows a typical *spectral signature* over these recorded wavelengths for three basic types of landcover (adapted from Lillesand and Kiefer, 1994).

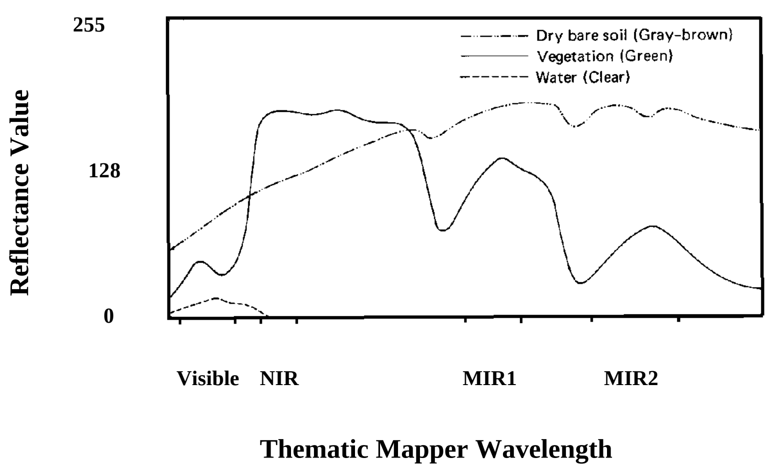

Figure 4. Thematic Mapper spectral signatures for three basic landcover classes.

Thematic Mapper *channels* 3,4,5, and 7 representing the red visible, near-infrared, and two mid-infrared wavelengths respectively, were selected because they consistently proved to be the most effective for discriminating between landcover classes. For each Landsat scene segment, these channels were processed with the image processing software using an unsupervised clustering statistical technique (ERDAS, 1994) which grouped the enormous amount of spectral variability within the TM data, into a set of 175 unique *spectral classes*. Each of these spectral classes represents a variation of landcover, such as one representing shrubsteppe with bare soil groundcover, and another being shrubsteppe with lush grass and forb groundcover. Next, the parametric statistics describing each of these spectral classes were applied to a maximum likelihood classification statistical technique. For each TM data element, this technique determines the best probability of it belonging to one of the 175 spectral classes, and codes the data element to the highest probability class (ERDAS, 1994). This process resulted in a file which represented the spatial distribution of these spectral classes, and which would ultimately need to be converted into a file representing the selected landcover classes.

Multitemporal Thematic Mapper Data Processing

Early investigations using the TM data for mapping shrubsteppe landcover demonstrated considerable confusion between different landcover classes when processing single date TM data. This *spectral confusion* often occurs when two different landcover classes have similar spectral characteristics based on the reflected light energy recorded by the TM sensor. As an example, a newly mowed hayfield has large amounts of exposed soil and senesced vegetation, which is spectrally similar to many shrubsteppe areas of low shrub density. (Appendix D provides further examples of potential spectral confusion between TM-derived landcover classes).

Substantially less spectral confusion occurred when multitemporal TM data sets were processed using early spring and mid to late summer Landsat scenes. The substantial phenological changes in vegetation between these times within the eastern Washington landscape greatly improved the spectral differentiation of most landcover types, especially between cropland and shrubsteppe landcover. Therefore, multitemporal data sets were used to develop landcover information from select Landsat scenes as allowed by budget and availability of scene pairs (Table 1). When performing multitemporal analyses, it was important to ensure the two Landsat scenes were spatially coregistered to prevent possible errors in subsequent processing. Once the Landsat scenes were correctly coregistered, the same unsupervised clustering statistical technique used for single date TM data was applied to the multitemporal TM data.

Ground-Truth Methods

Assignment of the 175 spectral classes to the landcover classes was accomplished primarily by collecting field data on the landcover composition and topographic characteristics of homogeneous landcover areas with areal extents of at least 10 acres. The relationship between this *ground-truth* data and the spatially corresponding spectral classes allowed the image analyst to make an informed landcover class assignment.

During 1995, a transect method of ground-truthing was employed where the plant type and ground condition was recorded at 10 centimeter intervals over two parallel 25 meter transects which were spaced 25 meters apart. This quantitative method required considerable time at each sampling site, thereby limiting the amount of data obtained during the summer data collection period (Appendix B). During similar data collection periods in 1996 and 1997, a faster qualitative method was developed which used ocular estimation of the areal extent of major cover types (Appendix C). Training prior to field data collection helped to standardize this ocular estimation method among field personnel. Ground-truth sampling of nearly 1300 sites occurred over a majority of the study area from 1995-1997, and provided considerable information from which the image analyst could extrapolate to areas not ground-truthed.

Thematic Mapper Data Editing

Due to the spectral confusion between different landcover classes which often occurs with TM data, a considerable amount of time was required to edit the data to eliminate as much confusion as possible. The image analyst’s interpretation experience, and ancillary data such as aerial photographs were used to resolve the spectral confusion. The shape, size, pattern, texture, and color of an image feature are important characteristics which the image interpreter used to determine the correct landcover class.

This editing procedure consisted of systematically checking the landcover data as viewed on a computer monitor to determine potential confusion areas. Once the correct landcover was determined for the confusion areas displayed on the screen, the image processing software was used to digitally draw polygons around these areas. Within these polygons, the data elements constituting the confusion areas were edited to a value which would represent the correct landcover class in the GIS data file.

GIS Data File

The spectral class and edited data values from each of the Landsat scene segment files were recoded to a standard set of values representing nine landcover classes, and then mosaicked together to produce a single GIS landcover data file. In addition, the palustrine wetland data obtained from the NWI digital database, and the CRP data which the WDFW compiled into a digital file, had unique values embedded into this GIS landcover file. This resulted in a total of 11 classes which would be beneficial to numerous natural resource applications (Table 2).

Table 2. Landcover classes and corresponding values within the GIS data file.

Value	***Landcover Class***
1	Open Water
2	Palustrine Wetland
3	Sand Dune
4	Shrubsteppe with less than 10% shrub cover*
5	Shrubsteppe with equal to or greater than 10% shrub cover*
6	Shrubsteppe (combined values 4 and 5)*
7	Cropland
8	Forest / Shrub
9	Barren
10	Snow
11	Conservation Reserve Program

*Where adequate ground-truth information was available, shrubsteppe landcover was separated into two classes: one of less than 10% shrub areal cover (value 4), and the second of greater than or equal to 10% shrub areal cover (value 5). Landsat scene segments K and J from Table 1 did not have shrubsteppe separated into two classes due to limited ground-truth and ancillary data, as well as discriminatory problems associated with late-summer TM data (value 6).

As the TM sensor samples each one-quarter acre of the earth, the recorded data for a particular sample data element can often represent a mixture of different landcover classes within the sampled area. This situation can cause these data to be mis-classified relative to the adjacent data elements which represent homogeneous landcover. Manual editing of these data would be extremely time consuming, so the mosaicked data file was processed with a *majority filter* software algorithm to automatically recode these mis-classified data to the same value as the majority of the surrounding eight data values (ERDAS, 1994). Appendix F is a map which illustrates the culmination of the data processing procedures which were used to produce a GIS data file of landcover information for eastern Washington. Note the three classes of shrubsteppe were combined into one class for display within this map, and topographic relief was added based on 100 foot contour digital elevation data.

LANDCOVER ACCURACY ASSESSMENT

Accuracy Assessment Methods

The mapping accuracy of the TM-derived landcover classes was determined by an accuracy assessment procedure which used data selected from the NRCS 1992 National Resources Inventory (NRI) (USDA NRI 1994). The NRI serves as the federal government's principle source of information on the status, condition, and trends of soil, water, and related resources for all non-federal lands. Some of the significant advantages to using the NRI data for the accuracy assessment were the resource savings realized by the WDFW, data collection by an independent agency, fairly even distribution of randomly selected sites throughout the study area, and information collected for sites which would have been logistically very difficult to ground reconnaissance. Large blocks of United States Forest Service (USFS) and Indian Reservation land existed within the northern and western portions of the study area. Fortunately, the NRCS did collect NRI data for these federal lands, which allowed these areas to be included in the accuracy assessment of the TM-derived landcover classes.

The NRI is based on a hierarchal classification for which the most general landcover and landuse classes have detailed sub-classes. The NRI attribute data collected for these classes were obtained from randomly placed, circular two-acre sites usually located on non-federal land throughout Washington State (USDA NRI 1994). Over 75% of the 1992 NRI data were collected by NRCS personnel from medium-scale (mostly 1:40,000 scale) aerial photos, and the remaining sites were ground checked due to the lack of adequate aerial photographs (James McClinton, pers. comm.).

It was difficult for NRCS staff to accurately classify detailed landcover classes from medium-scale aerial photographs, so the NRI data were evaluated by WDFW staff to determine the extent of their usefulness in the accuracy assessment procedure. This evaluation consisted of collecting landcover composition information at 46 NRI sites which had a wide range of shrubsteppe characteristics, and comparing this information to the corresponding NRI site attribute information. The results indicated substantial errors existed within the NRI data which described more detailed landcover information, such as percent shrub cover. However, the NRI data were determined to be quite accurate for identifying an area as shrubsteppe, regardless of the density of shrubsteppe landcover components. To provide some measure of accuracy for at least shrubsteppe in general, the two subclasses of shrubsteppe from the TM-derived landcover information were combined, and compared against a selected set of NRI sites which had shrubsteppe characteristics.

The geographic center of a NRI two-acre site was used to identify the corresponding landcover class in the TM-derived landcover data file. It is important to emphasize only the landcover class at this corresponding quarter-acre data element in the landcover data file was used to determine mapping accuracy relative to the larger two-acre extent of the NRI data. Therefore, it was important to select NRI sites which had landcover and landuse attributes which indicated a homogeneous cover condition for the entire two-acre site.

It was also crucial the attribute data recorded for these NRI sites represent the landcover and landuse for the exact spatial extent of a two-acre NRI site as mapped by NRCS personnel. The selected homogenous NRI sites were visually inspected by overlaying the two-acre polygons onto the TM-derived landcover data. In some instances, NRI site centers were located within 25 meters of landcover classes which differed from the landcover at the NRI site centers. This situation resulted in a heterogenous landcover condition within the two-acre sites which the NRI indicated as having a homogenous landcover condition. Positional inaccuracies may have occurred during the transfer of the NRI site center coordinates from 7.5 minute United States Geological Survey maps to the aerial photographs used to determine landcover and landuse, or by field orientation errors by NRCS field data collection personnel. Sites with questionable positional accuracy were removed from the final set of sites used to determine mapping accuracy of the TM-derived landcover classes.

In addition, the criteria and categories developed by the NRCS to attribute the NRI landcover classes (Appendix E) were not fully compatible with the TM-derived landcover class definitions. This situation required further evaluation by the image analyst to determine which of the selected homogeneous NRI sites might have landcover inappropriate for assessing a particular TM-derived landcover class. Those NRI sites which were questionable were eliminated from the final set of over 3200 sites which were used in the accuracy assessment of the TM-derived landcover classes. Unfortunately, the TM-derived landcover classes of Barren and Sand Dune could not be assessed for accuracy due to the incompatibility between the NRI and the TM-derived class definitions.

Shrubsteppe Accuracy Assessment

The limitation of the NRI data to accurately discriminate between shrubsteppe with less than or greater than 10% shrub cover, dictated that an accuracy assessment be performed by grouping these two subclasses into one general shrubsteppe class. The NRI sites used to assess the accuracy of the TM-derived shrubsteppe class were chosen when a NRI site's attributes indicated it was *rangeland*, and had zero percent composition for the possible components of *water, barren, artificial surface, crop, tree, shrub fruit, shrub vine, shrub evergreen, shrub other, grass/herb legume, grass/herb forb, grass/herb sedge, and grass/herb moss* (NRI class definitions provided in Appendix E). The NRI landcover classification system did not use class assignment criteria which were fully compatible with the TM-derived classification system. In particular, the NRI agriculture class could include certain conditions of shrubsteppe landcover as defined by the TM-derived classification system. Image interpretation and review of aerial photographs indicated 46 of 76 NRI sites thought to be shrubsteppe landcover were actually agricultural landcover. These 46 sites were eliminated from the accuracy assessment to help insure a more valid set of NRI sites for performing the shrubsteppe accuracy assessment, thereby resulting in a final set of 946 NRI sites.

Due to certain restrictions for federally sensitive land areas, the NRCS did not collect NRI data on the Hanford Works (Department of Energy) property in northern Benton County, or the Yakima Firing Center (Department of Defense) property spanning across northeastern Yakima County and southeastern Kittitas County. Past studies by the WDFW have determined both of these federal areas have predominately shrubsteppe landcover. Although no accuracy assessment could be conducted for these areas using the NRI data, review of the TM-derived landcover data suggests these federal areas were mapped with a high degree of accuracy.

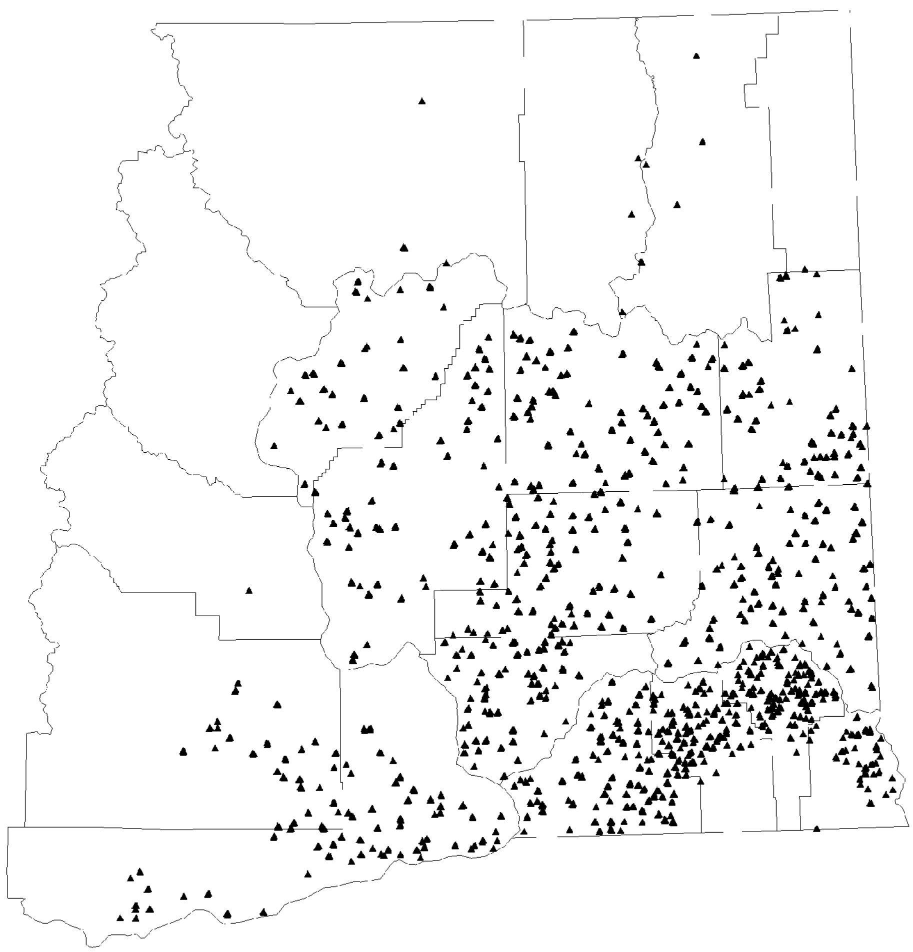

Figure 5. Distribution of NRI sites used for shrubsteppe accuracy assessment.

Cropland Accuracy Assessment

The 1742 NRI sites used to assess the accuracy of the TM-derived cropland class (Figure 6) were chosen based on the NRI attribute *crop* equaling 100% coverage. The *crop* attribute included row and close-grown crops, as well as residue and bare soil cover.

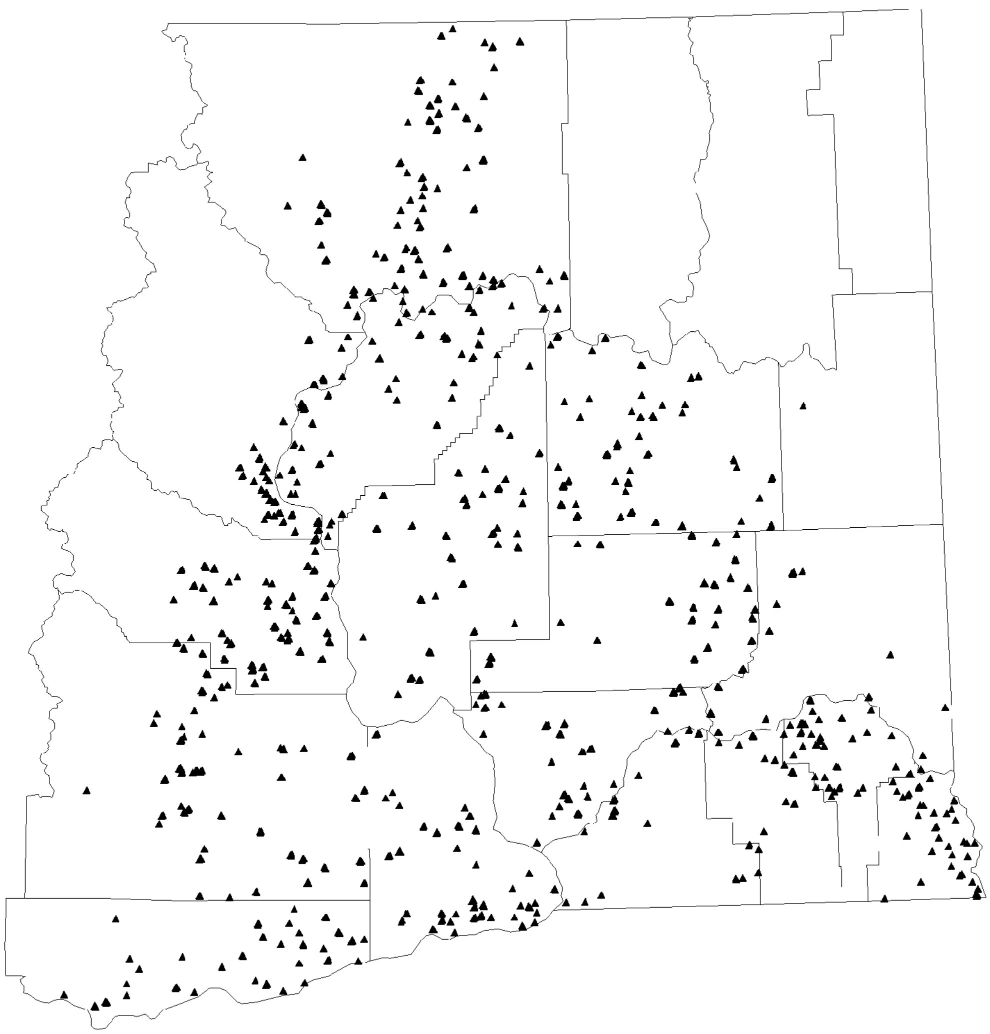

Figure 6. Distribution of NRI sites used for cropland accuracy assessment.

Forest / Shrub Accuracy Assessment

The 500 NRI sites used to access the accuracy of the TM-derived forest/shrub class (Figure 7) were chosen based on the NRI attribute *tree* being greater than or equal to 75% coverage, and agricultural fruit and nut trees (orchards) equal to zero percent coverage (NRI class definitions provided in Appendix E). Analyst experience indicated less than 75% canopy closure could cause sparsely vegetated ground areas exposed to the TM sensor to spectrally influence and shift these forest/shrub areas into another landcover class such as shrubsteppe.

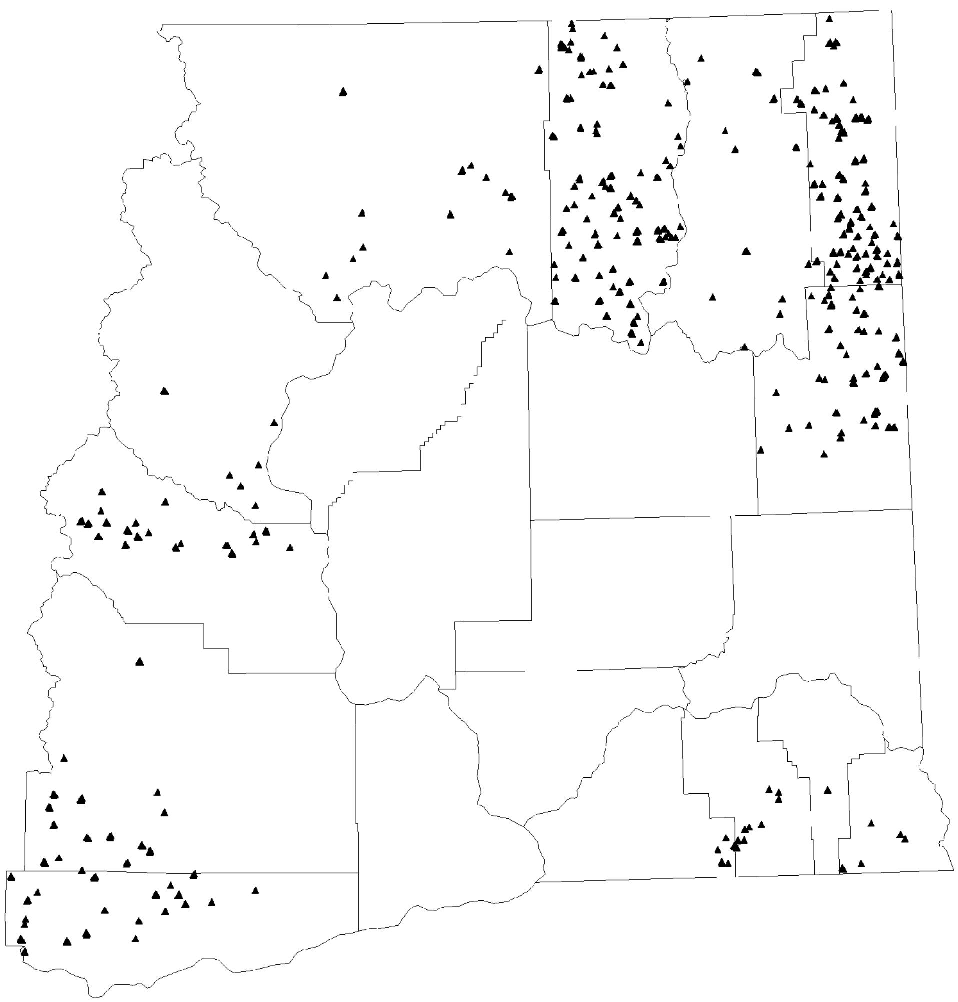

Figure 7. Distribution of NRI sites used for forest/shrub accuracy assessment.

Open Water Accuracy Assessment

The 60 NRI sites used to access the accuracy of the TM-derived open water class (Figure 8) were chosen based on the NRI attribute *water* equaling 100% coverage. These sites represent permanent open water bodies of less than 40 acres, or perennial streams less than an eighth-mile wide. These water sites do not include palustrine wetlands which contain significant emergent vegetation throughout their areal extent.

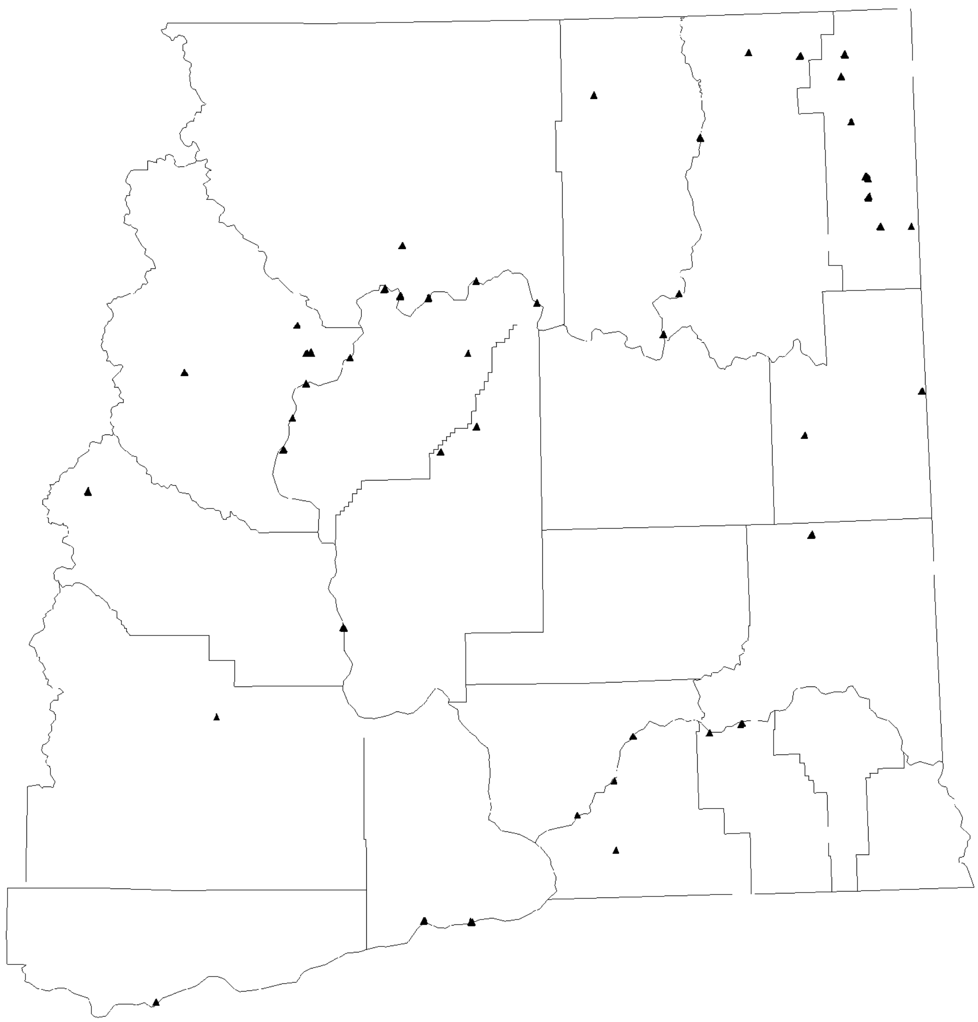

Figure 8. Distribution of NRI sites used for open water accuracy assessment.

Barren and Sand Dune Assessment

No accuracy assessment could be performed for the TM-derived barren and sand dune classes because the NRI landcover classification system did not use class assignment criteria which were fully compatible with the TM-derived classification system. Thin-soiled areas having less than five percent vegetation cover were included in the NRI barren class. This cover condition can exist for shrubsteppe areas, especially heavily grazed shrubsteppe areas used as rangeland for domestic animals. Therefore, inclusion of certain shrubsteppe conditions in the NRI barren class created potential problems for the accuracy assessment of the TM-derived barren class.

Twenty NRI sites had the attribute *barren* equaling 100% coverage (NRI class definition provided in Appendix E). These sites were reviewed using aerial photographs and image interpretation, and 17 were determined to be shrubsteppe landcover, so these NRI sites were eliminated from the 20 selected sites. It was decided an accuracy assessment for barren landcover would not be preformed because only three valid barren NRI sites remained in the final set of assessment sites.

The NRI classification system also included sand dune landcover in the barren class, which precluded an accuracy assessment from being conducted for the TM-derived sand dune class. Sand dune areas in eastern Washington are fairly unique and limited to certain geographic locations, so based on empirical information about these areas, it was determined they were mapped with a high degree of accuracy.

CRP and Wetland Accuracy Assessment

Stringent compilation and quality control procedures helped ensure accurate creation of the digital CRP data. However, these CRP polygons would be digitally embedded into the GIS landcover file, so it was important to have accurate spatial co-registration with the TM data. A large sample of CRP polygons were digitally overlaid onto the TM data, and were determined to have accurate alignment along field boundaries and roads which were visible in the TM data.

The palustrine wetland digital data obtained from the USFWS NWI database were also embedded into the GIS landcover file, so it was important to make sure these data were accurate for content and spatial co-registration. The USFWS does conduct an accuracy assessment procedure for wetland mapping, so no evaluation of mapping accuracy was performed by the WDFW. However, the NWI palustrine data were verified for spatial co-registration to the TM data by reviewing the registration of a large sample of NWI palustrine polygons overlaid onto the TM data.

Accuracy Assessment Results

The accuracy assessment results from the comparison of the TM-derived landcover classes shrubsteppe, cropland, forest/shrub, and open water, to the NRI sites selected as representing these landcover classes, are summarized in Table 3.

Table 3. Accuracy assessment matrix for the TM-derived landcover classes.

		Thematic Mapper Derived Landcover Classes						
NRI Classes		***Shrubsteppe***	***Cropland***	***Forest/Shrub***	***Open Water***	***Total****	***Producer's Accuracy%***	***Barren****
	Shrubsteppe	861	30	47	0	**946**	**91.0**	8
	Cropland	89	1643	5	0	**1742**	**94.3**	5
	Forest/Shrub	24	17	457	1	**500**	**91.4**	1
	Open Water	0	2	1	55	**60**	**91.7**	2
	Total	**974**	**1692**	**510**	**56**	**3248**		
	User's Accuracy%	**88.4**	**97.1**	**89.6**	**98.2**		**Overall 92.8%**	N/A

* The barren NRI class was not used in the accuracy assessment because of conflicting characteristics with the TM-derived shrubsteppe class in particular. Although the TM-derived barren landcover class could not be assessed for accuracy due to this situation, it is informative to include it in the row totals and calculation of omission for the TM-derived classes.

The overall mapping accuracy is calculated as the number of correctly identified NRI sites for each of the TM-derived landcover classes, divided by the total number of NRI sites used in the accuracy assessment, which resulted in an overall accuracy of 92.8% (3016 of 3248). However, it is also important to consider the accuracy percentages from the map user and map producer's perspective to have a complete understanding of the landcover classification accuracy. Producer's accuracy (omission) is calculated as the number of correctly identified NRI sites for a particular TM-derived landcover class, divided by the total number of NRI sites (row total) used to assess that landcover class. User's accuracy (commission) is calculated as the number of correctly identified NRI sites for a particular TM-derived landcover class, divided by the total number of NRI sites (column total) associated with that landcover class. As an example from the table above, the map producer can say their map is 91% accurate for the TM-derived shrubsteppe class, because only 9% of the shrubsteppe NRI sites were omitted to other TM-derived classes. However, from the map user's perspective, the reliability of the map for shrubsteppe landcover is approximately 88%, because about 12% of the NRI sites assessed as TM-derived shrubsteppe areas were actually cropland and forest/shrub landcover.

Approximately 79% (89 of 113) of the total commission error for shrubsteppe came from cropland, yet only 35% (30 of 85) of the total omission error (including barren landcover) for shrubsteppe was from omission to cropland. In comparison, only 61% (30 of 49) of the total commission error for cropland came from shrubsteppe, whereas 90% (89 of 99) of the total omission error (including barren landcover) for cropland was from omission to shrubsteppe. These results suggest an overestimation of cropland within shrubsteppe landcover areas in the GIS landcover file. This situation could occur in part because there is considerable spectral confusion between agricultural areas having limited green biomass and considerable exposed soil and plant residue (e.g. newly mowed hayfield), and shrubsteppe areas which typically have similar cover composition.

About 21% (24 of 113) of the total commission error for shrubsteppe came from forest/shrub, whereas 55% (47 of 85) of the total omission error (including barren landcover) for shrubsteppe was from omission to forest/shrub. In comparison, 89% (47 of 53) of the total commission error for forest/shrub came from shrubsteppe, whereas 56% (24 of 43) of the total omission error (including barren landcover) for forest/shrub was from omission to shrubsteppe. These results suggest an overestimation of shrubsteppe landcover within forest/shrub areas. This situation could occur in part because of the spectral confusion between recent (as of 1993) timber harvest areas consisting of limited green biomass and considerable exposed soil and plant residue, and shrubsteppe areas which typically have similar cover composition.

The only commission error for open water came from a single forest/shrub NRI site, and there were only five of 50 open water NRI sites omitted between the cropland, forest/shrub, and barren classes. Visual inspection of these omission NRI sites suggested positional inaccuracies of the sites, or variation in water extent or levels along rivers and lakes may have contributed to this omission error.

DISCUSSION

Daubenmire (1970) indicated more than 15 thousand acres of shrubsteppe landcover existed in eastern Washington previous to land conversion after the arrival of white settlers, and constituted nearly 60% of the landscape. This current mapping study determined only about 30% of the eastern Washington landscape in 1993/1994 consisted of shrubsteppe landcover (Table 4). Therefore, approximately 50% of the historical distribution of shrubsteppe within eastern Washington has been altered to other types of landcover.

Table 4. Areal statistics for the TM-derived landcover classes within eastern Washington.

Landcover Class	*Acres*	*% of Study Area*
Open Water	429,610	1.58
Palustrine Wetland	209,960	0.77
Sand Dune	8,864	0.03
Shrubsteppe*	7,412,622	27.24
Forest / Shrub	9,976,430	36.67
Cropland**	8,123,630	29.86
Barren	269,208	0.98
Snow	779,266	2.86
Total	27,209,590	

* The portion of the study area (sections A-I, Figure 3) which had shrubsteppe landcover separated into two subclasses resulted in 3,118,010 acres with less than 10% shrub cover and 3,656,520 acres with greater than or equal to 10% shrub cover. The remainder of the study area (sections J and K, Figure 3) for which only one general shrubsteppe class was mapped, contained the other 638,092 acres of shrubsteppe landcover.

** Conservation Reserve Program land was included in the cropland class because it originated from, and could revert back to cropland after the 10 year contract term. Also, not all counties had their CRP land mapped, so these statistics would bias the other class statistics. There were 867,530 total acres of CRP land for the counties which had been mapped for this landcover (Figure 2).

The results from the accuracy assessment for this mapping effort suggest the TM-derived landcover classes have accuracies which make the GIS data file useful for many natural resource management applications. This is especially true because the shrubsteppe, cropland, and forest/shrub classes comprise about 94% of the study area, and these landcover classes each had around 90% accuracy estimates. The importance of shrubsteppe habitat to many wildlife species and its continued conversion to other landcover makes it imperative this vital habitat be monitored at least every 5 to 10 years to determine its distribution and status across eastern Washington.

Dobler et al. (1996) determined nearly 60% of shrubsteppe habitat had been lost since early settlement of Washington in comparison to the 50% reduction determined by this mapping effort. This 10% difference could result from various factors affecting the estimation of shrubsteppe landcover. It is unlikely additional shrubsteppe habitat has been restored since 1989 (TM data used in the earlier mapping study), as there is a yearly trend of land conversion to primarily cropland in eastern Washington. The lack of a landcover accuracy assessment by Dobler et al. may have contributed to underestimating shrubsteppe habitat due to the typical spectral confusion between shrubsteppe and other landcover types derived from TM data.

Also, their study area did not encompass the entire eastern Washington extent of shrubsteppe habitat, whereas this mapping project included all of eastern Washington as the study area. Dobler et al.'s study area encompassed the main areas of agriculture which have experienced the greatest amount of shrubsteppe conversion since early settlement (Michael Schroeder, pers. comm.). The shrubsteppe areas outside of their study area which were included in this mapping effort have not experienced similar rates of conversion, so percent loss of shrubsteppe for all of eastern Washington could be less when these areas are included in the calculation.

The sand dune and barren landcover classes were not assessed for mapping accuracy due to limiting factors with the NRI data. Unfortunately, time and budget constraints prevented WDFW personnel from being able to collect field site data for these classes which could have been used to access their map accuracy. Sand dune areas in eastern Washington are fairly unique and limited to certain locations, and were probably mapped with a high degree of mapping accuracy. However, barren landcover is more prevalent and evenly distributed throughout the study area, and could be confused with certain conditions of bare cropland or lithosol shrubsteppe areas. Any natural resource management applications which require information about sand dune and barren areas within eastern Washington would benefit from an accuracy assessment for these classes from this mapping effort.

Wildlife managers would benefit from the monitoring of CRP land throughout eastern Washington due to its importance to many wildlife species. Hopefully, a working relationship between the NRCS and WDFW can be fostered in the future to produce a dynamic digital inventory of CRP land for all counties within eastern Washington, which would include important attribute information such as year of enrollment/withdrawal and planted cover composition. This CRP database could be updated at 5 to 10 year intervals to coincide with the enrollment cycle for the CRP. The combined monitoring of CRP land and shrubsteppe habitat would provide valuable information for natural resource managers for critical efforts such as endangered species management, landscape ecology, habitat restoration, and conservation planning. Furthermore, the time required to map shrubsteppe habitat and CRP land with the same level of resources should be reduced in future efforts because successful methodologies for processing these data have been established through this mapping project.

Natural resource scientists have expressed a need for mapping more detailed composition within shrubsteppe landcover, such as being able to separate areas of annual grass from perennial grass. New satellite sensor technology with increased spectral and spatial resolution is being implemented now, and further technological advances will continue to occur. These new sensors should be investigated in future WDFW image processing research to determine their usefulness for accurately identifying more detailed composition within shrubsteppe and other landcover types. The increased spatial and spectral capabilities from new remote sensing technologies may require development of new algorithms and procedures for successfully extracting the required information from these data. Also, there is greater availability and access to many forms of spatial data through avenues such as the Internet. Recent cost reductions for the new Landsat 7 TM data has prompted interest in developing a consortium of state, federal, and municipal governments to acquire yearly or biennial TM coverage for Washington State.

As we begin the new millennium, the continued development of exciting new technologies and the application of those technologies, are providing unique opportunities for the effective and efficient assessment and management of the earth's natural resources.

REFERENCES CITED

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildl., FWS/OBS-79/31. 103pp.

Daubenmire, R. 1970. Steppe Vegetation of Washington. Wash. Agri. Exp. Stn. Bull. 62, Pullman. 131pp.

Dobler, F.C., and J.R. Eby. 1990. An Introduction to the Shrub Steppe of Eastern Washington: A Brief Appraisal of Current Knowledge and Need. Unpublished Report, Wash. Dept. Wildl., Olympia. 4pp.

Dobler, F. C., J. Eby, C. Perry, S. Richardson, and M. Vander Haegen. 1996. Status of Washington's Shrub-Steppe Ecosystem: Extent, ownership, and wildlife/vegetation relationships. Wash. Dept. Fish and Wildl., Olympia. 39pp.

ERDAS, Inc. 1994. Pages 230-244 *in* ERDAS Field Guide. Third Edition, Atlanta, Georgia.

Heilman, J.L., and W.E. Boyd. 1986. Soil background effects on the spectral response of a three-component rangeland scene. Remote Sens. Environ. 19:127-137.

Homer, C.G., T.C. Edwards, Jr., R.D. Ramsey, and K.P. Price. 1993. Use of remote sensing methods in modelling sage grouse winter habitat. J. Wildl. Manage. 57(1):78-84.

Horvath, E.H., D.F. Post, and J.B. Kelly. 1984. The relationships of Landsat Digital Data to the Properities of Arizona Rangelands. Soil Sci. Soc. Am. J. 48:1331-1334.

Jerrold F.M., and P.T. Tueller. 1983. Landsat computer-aided analysis techniques for range vegetation mapping. J. Range. Manage. 36(5):627-631.

Knick, S.T., J.T. Totenberry, and T.J. Zarriello. 1997. Supervised classification of Landsat Thematic Mapper imagery in a semi-arid rangeland by nonparametric discriminant analysis. Photogramm. Eng. And Rem. Sens. 63(1):79-86.

Lillesand, T. M., and R. W. Kiefer. 1994. Remote Sensing and Image Interpretation. John Wiley and Sons, New York.

McAllister, K. R. 1995. Washington State Recovery Plan for the Pygmy Rabbit. Wash. Dept. Fish and Wildl., Olympia. 73pp.

Pickup, G., V.H. Chewings, and D.J. Nelson. 1993. Estimating changes in vegetation cover over time in arid rangelands using Landsat MSS data. Remote Sens. Environ. 43:243-263.

Smith, M.O., S.L. Ustin, J.B. Adams, and A.R. Gillespie. 1990. Vegetation in deserts: I. a regional Measure of abundance from multispectral images. 1990. Remote Sens. Environ. 31:1-26.

Sullivan, S. 1986. Plant Ecology of Washington's Steppe and Shrubsteppe Habitats. Wash. Dept. Game., Olympia. 66pp.

Tirhi, M. J. 1995. Washington State Management Plan for Sage Grouse. Wash. Dept. Fish and Wildl., Olympia. 101pp.

Tirhi, M. J. 1995. Washington State Management Plan for Sharp-tailed Grouse. Wash Dept. Fish and Wildl., Olympia. 99pp.

Tueller, P.T. 1989. Remote sensing technology for rangeland management applications. J. Range Manage. 42(6):442-453.

Ustin, S.L., J.B. Adams, C.D. Elvidge, M. Rajmanek, B.N. Rock, M.O. Smith, R.W. Thomas, and R.A. Woodward. 1986. Thematic mapper studies of semiarid shrub communities. BioScience. 36(7): 446-452.

U.S. Department of Agriculture. 1991. Instructions for Collecting 1992 National Resources Inventory Sample Data. Nat. Resourc. Conserv. Serv., 67pp.

U.S. Department of Agriculture. 1994. National Resources Inventory Training Modules. Nat. Resourc. Conserv. Serv.

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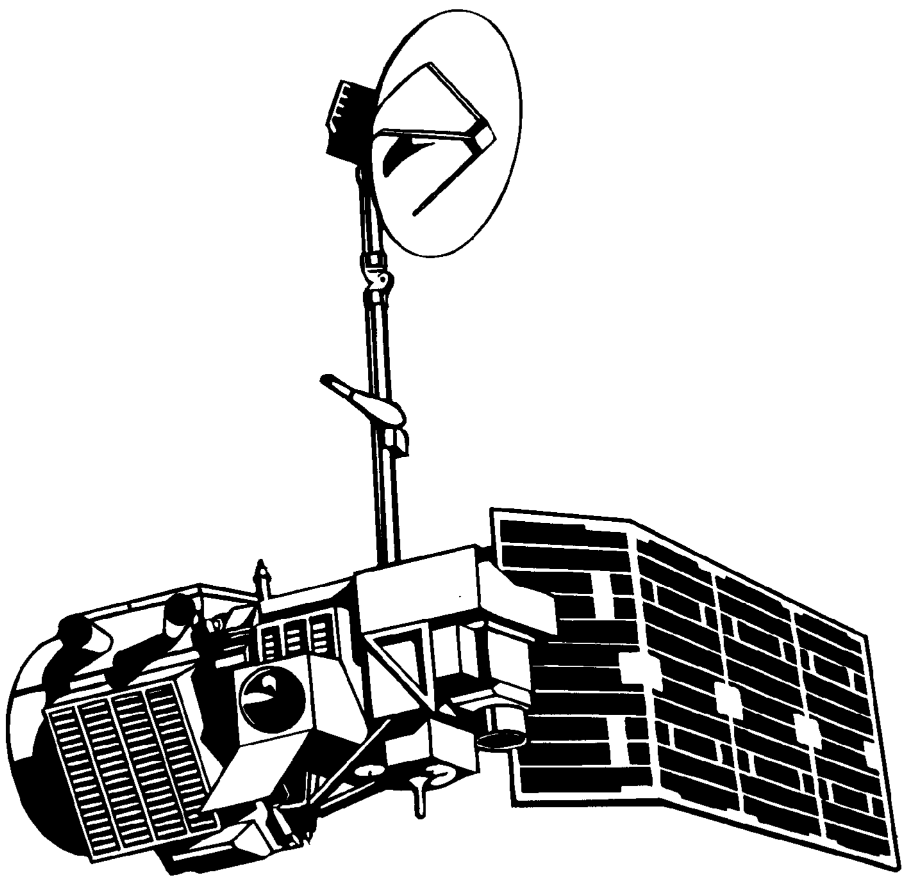
Appendix A. Landsat 5 satellite and Thematic Mapper recorded wavelength channels.



Wavelength Channels Recorded by the Thematic Mapper Sensor

Channel 1	**0.45 - 0.52 μm**	**Blue Visible**
Channel 2	**0.52 - 0.60 μm**	**Green Visible**
Channel 3	**0.63 - 0.69 μm**	**Red Visible**
Channel 4	**0.76 - 0.90 μm**	**Near-Infrared**
Channel 5	**1.55 - 1.75 μm**	**Mid-Infrared**
Channel 6	**10.40 - 12.50 μm**	**Thermal (emitted energy)**
Channel 7	**2.08 - 2.35 μm**	**Mid-Infrared**

Appendix B. Field form used for ground-truth data collection during 1995.

PLOT ID: **7.5' QUAD**: **CREW**:
DATE: **T/R/S**: T N R E **SECTION:** **QTR: NW NE SW SE**
ELEVATION: ft **SLOPE**: degrees **ASPECT**: N NE E SE S SW W NW FLAT
UTM MAP COORDS: N E **UTM GPS COORDS**: N E
PHOTO ROLL# **FRAME #**

TRANSECT #1 **TRANSECT #2**

Appendix B. Field form used for ground-truth data collection during 1995. (continued)

SHRUBS (predominant): **DESCRIBE:**

Height: m
Height: m

GRASSES (predominant): **DESCRIBE (annual vs perennial):**

Height: m
Height: m

FORBS (predominant)**:** **DESCRIBE:**

Height: m
Height: m

SOIL TYPE: SANDY
LOAMY
SHALLOW

CRYPTOGAMS: none(insignificant) / present

CRP site: Y / N

DISTURBANCE:

Sign of grazing on grass/forb Y / N

Cow dung: fresh old none
Grazing paths: new old none

Sign of burnt shrub stumps: yes no

Sign of spraying: yes no

SITE COMPOSITION:

Uniform / Heterogeneous If heterogeneous, **DESCRIBE**: (patch composition & size in m^2)

OTHER COMMUNITY DESCRIPTORS/COMMENTS:

PLOT DIAGRAM:

Appendix C. Field form used for ground-truth data collection during 1996 and 1997.

PROJECT: SHRUBSTEPPE (Summer 1996) **SITE ID**:__________________

Month: (May / June / July / _________) **Day:** ___________ **Time**: ___________________ **Observers**: (WMB / MAR / __________)

USGS 7.5 Map: ____ **Town** _________ **Range** _________ **Sec** _________ **Quart**___________

Map UTM X:____________________________ **UTM Y**:__________________________

Uncorr GPS UTM X:_____________________ **UTM Y**__________________________ **Corr GPS UTM X:**_____________________**Y**_____________________

Ground Photo Frames: _______________________ **Photo Notes**:____

____

Aerial Photo Type: __________________________ **Identifier:** ______________________ **Date (D/M/Y format):** _____________________

Aspect: (N NE E SE S SW W NW) **Slope**: ____________ degrees

Changes Through Site: (**CA**spect / **CS**lope) **Describe**:____

____

	SHRUB	**GRASS**	**FORB**	**RESIDUAL**	**SUBSTRATE**
Light Intercept	_______________%	_______________%	_______________%	_____________%	_____________%
Avg Height	_______________m	_______________dm	_______________dm	_____________dm	Color (D / M / L)
Avg Leaf Posture	(E / F)	(E / F)	(E / F)		Text (C / M / F)
Most Dom Species	______________________	______________________	______________________		Currently (W / D)
2nd Dom Species	______________________	______________________	______________________		Type (LO / SA / SH)

TREES Light Intercept ___________% Avg Height _________m Crown Closure: _________%

Site Category: (Shrubsteppe / CRP / Cropland / Decid / Conif / Mixwood / Other Shrubland / Wet Meadow / Other Wetland / Altered)

Site Cover: (**S**ame / **D**ifferent) Describe Below **Site Distrubance**: Since 1993 (Y / N) Describe Below

Site Description: ____

____

____

PUT SITE DIAGRAM ON BACK OF PAGE

Appendix D. Examples of spectral confusion between TM-derived landcover classes.

Open Water: Turbid water which is less than two feet deep and has considerable suspended solids could be confused as cropland landcover which is primarily composed of wet bare soil, such as occurs in newly sowed irrigated fields. Also, heavily shadowed land areas along northerly exposures of steep canyon walls could be confused as open water.

Palustrine Wetland: Wetland areas which have a dense mat of emergent vegetation such as cattails could be confused as cropland landcover or forest/shrub. In this situation, each landcover class has similar amounts of green biomass, and water within the wetland is obscured by the dense vegetation.

Sand Dunes: Sand dune areas could be confused as cropland landcover which has a composition of very dry soil and sparse vegetation. If greater density of vegetation occurs on sand areas, they could be confused or possibly considered as shrubsteppe landcover. Also, large dry sand bars having sparse vegetation along rivers could be confused as sand dunes.

Cropland: The large variation of soil and vegetative composition existing in agricultural areas ranging from fruit orchards to dry residue in wheat fields, causes considerable confusion with nearly all other landcover classes, and in particular with shrubsteppe landcover.

Forest / Shrub: Forest/shrub areas could be confused as cropland landcover which has a similar composition of green biomass and exposed soil, or confused with wetlands areas consisting of a dense mat of emergent vegetation. If the forest component within a forest/shrub area is quite sparse, this class might be confused as shrubsteppe, especially in the dry ecotone between shrubsteppe and higher elevation forest/shrub landcover.

Barren: Land features such as steep canyon walls with northerly exposures can cause heavy shadowing. Even if these shadowed areas have substantial vegetative cover, they could be confused as barren landcover, or even as open water if very little light is reflected from these areas.

Shrubsteppe: Large variations of soil and vegetative conditions within shrubsteppe landcover can range from dense shrub cover with dense forb and grass groundcover, to sparse grass with exposed soil and rock. These conditions can cause considerable confusion with barren, forest/shrub, and especially cropland landcover.

Snow: Snow which has a thin layer of wind-blown dirt covering it could be confused as an area of turbid water. Also, snow which is heavily compacted or starting to melt could be confused as open water.

Appendix E. Excerpts from the NRCS data collecting guidelines document.

Earth Cover Determination

The collection of earth cover information is a new element for the 1992 NRI data collection process. Both the information being determined and the procedure are different.

Earth Cover is the natural or artificial material that is observed to cover a portion of the earth's surface. It is determined (at least conceptually) as a vertical projection downward.

Earth cover is determined only for the year 1992. The procedure for making this determination for a 1992 NRI sample point is:

1) Construct a 2-acre circular area, centered around the point; the diameter of the circle will be 333 feet [Note: At a photo scale of 8 inches to the mile, the circle will have a one-half-inch diameter]. Do not free the point or move the circle for any reason; the circle may extend outside of the PSU.

2) Identify the major (Level I) earth cover categories which occur within this 2-acre area.

Level-I Categories

Crop Cover -- vegetative cover of annual or perennial plants that are cultivated or harvested, or both, for the production of food, feed, oil, and fiber other than wood; excluded are horticultural shrubs and trees, hay cover, and aquaculture areas; included are recently tilled and fallow portions of fields, as well as plant residue in any stage [summer fallow in rotation is considered as crop cover even though it may appear to be bare land]

Grass/Herbaceous Cover -- non-woody vegetative cover composed of annual or perennial grasses, grasslike plants (sedges/rushes), forbs, mosses, lichens, and ferns.

Tree Cover -- vegetative cover recognized as woody plants which usually have one perennial stem, a definitely formed crown of foliage, and a mature height of at least 4 meters; this category contains all trees, even those planted for the purpose of producing food, ornamentals, including Christmas trees.

Appendix E. Excerpts from the NRCS data collecting guidelines document. (continued)

Shrub Cover -- vegetative cover composed of multi-stemmed woody plants and single-stemmed species that attain less than 4 meters in height at maturity; this category contains all shrubs and woody vines, even those planted for the purpose of producing food

Barren -- non-vegetative natural cover often having a limited capacity to support vegetation, with a surface of sand, rock, thin soil, or permanent ice or snow; this category also includes bare soil resulting from construction activities, extractive activities such as mining, or clear-cutting.

Artificial Cover -- non-vegetative cover either made or modified by human activity and prohibiting or restricting vegetative growth and water penetration (for example, highways, rooftops).

Water Cover -- earth covered by water in a fluid state.

3) Record (to nearest whole percent) the percentage of the 2-acre area that is covered by each of the Level-I earth covers. These percentages should be determined as though the area is being viewed from a vertical projection downward; e.g., tree cover would be viewed rather than grass or shrubs which might be below the canopy of the tree.

4) For each Level-I earth cover identified, estimate and record percentages (to the nearest whole percent) for the Level-II categories; the Level-II percentages must sum to 100% for each Level-I category that appears. No Level-II data are being collected for the Level-I categories Artificial Cover and Water Cover.

The hierarchical structure for earth cover being used for the 1992 NRI is presented below. All Level-I and Level-II categories are shown.

Earth Cover Categories--Levels I and II (level II examples given in parentheses)

Crop Cover

1. Row (corn, soybeans, cotton, tomatoes, tulips)
2. Close-Grown (wheat, rice, oats, rye)
3. Residue
4. Bare

Appendix E. Excerpts from the NRCS data collecting guidelines document. (continued)

Grass/Herbaceous Cover

1. Grasses (fescue, bluestems, mixed midgrass, shortgrass, annual grasses, marshgrass)
2. Legumes (alfalfa, clover, vetch, lespedeza)
3. Forbs and Ferns
4. Sedges/Rushes
5. Mosses/Lichens
6. Intermixed (grasses/legumes, grasses/legumes/forbs)

Tree Cover

1. Fruit and Nut Trees
   (apples, pecans, date palms, citrus)
2. Conifers (spruce-fir, Douglas fir)
3. Hardwoods (oak-hickory, aspen-birch, live oak)
4. Intermixed (oak-pine)
5. Tropicals (mangrove, gumbo-limbo, royal palm)

Shrub Cover

1. Fruit and Nut Shrubs (filbert, blueberry)
2. Fruit Vines (grapes)
3. Evergreen (creosotebush, saw palmetto, shrub live oak)
4. Deciduous/Semi-Deciduous (sumac, sagebrush, mesquite)
5. Intermixed (evergreens/deciduous)
6. Other (kudzu, cacti, yucca)

Barren

1. Rock
2. Sands and Gravels
3. Bare Soil Areas--capable of supporting vegetation under
   natural conditions
4. Permanent Snow and Ice
5. Other Areas--not capable of supporting vegetation
   (saline seeps, slick spots, oil-waste, salt flats)

Artificial Cover (road surfaces, roof surfaces, paved and stone-surface parking areas, sidewalks, driveways)

Water Cover

Appendix E. Excerpts from the NRCS data collecting guidelines document. (continued)

Land Use

Land Cover/Use is a term that includes categories of land use and land cover. Land cover is the vegetation or other kind of material that covers the land surface. Land use is the purpose of human activity on the land; it is usually but not always related to the land cover. The NRI uses the term Land Cover/Use to identify the categories that account for all the surface area of the United States. Cropland, for example, is basically a land use category that includes a variety of land covers (grass, trees, shrubs, bare soil, small grains, etc.); it is classed primarily by its use and secondarily by its cover. In contrast, forest land is basically a land cover category that includes a variety of uses or multiple concurrent uses; it is classified primarily by its cover and secondarily by its use. The term Land Cover/Use permits both cropland and forest land to be properly included in the same grouping.

2. Importance

This data element is necessary even though separate Earth Cover and Use of Land and Water determinations are being made. The combined concept allows land to be assigned to one and only one category (not possible with a land use system that includes multiple use), while supporting SCS and other agency needs to define land by use.

Categories and Codes

Rangeland--includes land on which the climax or potential plant cover is composed principally of native grasses, grass-like plants, forbs or shrubs suitable for grazing and browsing, and introduced forage species that are managed like rangeland. This would include areas where introduced hardy and persistent grasses such as crested wheat grass are planted and practices such as deferred grazing, burning, chaining, and rotational grazing are used with little or no chemicals or fertilizer being applied. Grasslands, savannas, many wetlands, some deserts, and tundra are considered to be rangeland. Certain low forb and shrub communities such as mesquite, chaparral, mountain shrub, and pinyon-juniper are also included as rangelands. (Areas classified as native pasture are not included as rangelands.)

Code	**Category**
250	Rangeland