AN ASSESSMENT OF THE PICEANCE BASIN REMOTE SENSING VEGETATION DATA BASE

IVO E. LINDAUER
Department of Biological Sciences
University of Northern Colorado
Greeley, Colorado 80639

SAMUEL C. WILLIAMSON
Western Energy and Land Use Team
U. S. Fish and Wildlife Service
Fort Collins, Colorado 80526

PATRICIA DEPLAZES
Department of Biological Sciences
University of Northern Colorado
Greeley, Colorado 80639

December 31, 1984

A supplemental publication to a series of reports prepared by the Northwest Colorado Wildlife Consortium for the Colorado Division of Wildlife.

Suggested Citation

Lindauer, I. E., Williamson, S. C., and P. Deplazes. 1984. An assessment of the Piceance Basin remote sensing vegetation data base. Rep. to Ecol. Serv. Sect., Colo. Div. Wildl., Denver, Colo. Northwest Colo. Wildl. Consortium, Boulder, Colo. 67 p.

NORTHWEST COLORADO WILDLIFE

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TABLE OF CONTENTS

ACKNOWLEDGMENTS

Appreciation is extended to the Colorado Division of Wildlife and the Bureau of Land Management for the funding and support necessary to complete this project and to the Western Energy and Land Use Team of the U. S. Fish and Wildlife Service for their contributions of personnel and facilities. A number of individuals have contributed significantly to this project, including John Szajgin, Technicolor Government Services, Inc., Denver Federal Center and Stephen O'Kane, Jr. of the University of Northern Colorado, Greeley. Special appreciation is extended to Fred Neill, Shane Briggs, and Kellan Duncan of the Colorado Division of Wildlife for their invaluable assistance on locating and flagging access to section corners. In addition James P. Fitzgerald, University of Northern Colorado and Wilson Crumpacker of the University of Colorado provided special assistance and support in the completion of this project.

Appreciation is also extended to the reviewers of this publication; however, the authors accept full responsibility for all methods used, interpretations reached, and accuracy assessments reported herein.

ABSTRACT

A project was initiated in the fall of 1983 to quantitatively assess the accuracy of vegetation cover maps produced by three remote sensing techniques: machine classified Landsat [MCL] digital multispectral scanner [MSS] data, color composite Landsat [CCL] MSS images and medium scale color infrared [MSCIR] aerial photography. Information from the three techniques was compared to ground truth data gathered in the Piceance Basin Planning Area of northwest Colorado.

Assessments were made using a site-specific stratified random sampling design and analyses based on error matrices. Several comparisons were made to compensate for differences among the vegetation classification systems used with each remote sensing technique. The heterogeneous mixture in the upland shrub surface cover type was difficult to map accurately, particularly with Landsat imagery. Using the preferred classification system (without overlays of cover types) machine classified Landsat (MCL) accuracy was 26%, CCL accuracy was 27% and MSCIR accuracy was 58%. Color composite Landsat (CCL) had the lowest total mapping costs at .062 cents/acre, followed by MCL at 4.14 cents/acre and MSCIR at 8.20 cents/acre. Using a combination of MSCIR for heterogeneous, high interest areas and CCL for homogeneous, low interest areas may provide the most cost-effective procedure for mapping large expanses of rangelands.

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

As world energy demands become greater and natural resources decrease, the assessment and management of those resources becomes increasingly important. The need for resource information that meets minimum accuracy levels will rise in importance as the need for better management of natural resources becomes more vital (Aronoff, 1982). Mapping of natural resources, particularly those concerning wildlife habitat, by remote sensing methods continues to be refined. However, standard methods for estimating cost and map accuracies of various remote sensing techniques used for specific operational applications need to be developed before one can confidently choose between mapping alternatives. Several of these issues are addressed in this report.

Vegetation inventories should be designed to obtain the desired information at the lowest cost. There is an increasing need and trend to incorporate rangeland inventories into a Geographic Information System (GIS), (Carneggie, et. al., (1983). The incorporation of data into a digital GIS has a high initial cost. However, when amortized over a number of years the cost becomes competitive with traditional systems, and the ability to manipulate and analyze map based information is greatly enhanced. A standard test methodology is needed for selecting the most efficient and effective remote sensing technique for a GIS application (Aronoff, 1982). This study presents an approach that compares remote sensing techniques with the objective of maximizing mapping accuracy and utility while minimizing mapping cost per unit area.

Any map accuracy assessment requires a knowledge of error-producing factors, as well as mapping methods, procedures, applications and technological limitations. An assessment of surface cover map accuracy should include a statement about the type of accuracy assessment, identification of the relevant error causing variables, an examination of the types of site specific mapping errors, and a description of the physical representation of the Minimum Mapping Unit (MMU).

The relevant error causing variables in a surface cover mapping project include the number of surface cover classes to be identified, the scale or resolving power of the input data and output map, and the size of the MMU. Generally, as the number of surface cover classes utilized increases, as the map scale decreases and as the minimum mapping unit increases, overall map accuracy decreases. The minimum level of resolution in Landsat MSS may be as small as a single pixel (50m x 50m). In 1:24,000 aerial photography (MSCIR), the resolution is less than 3m x 3m. However, it is impractical to map at the minimum level of resolution, partly because resolution implies detection but not necessarily recognition. Therefore, in mapping, the MMU is generally much larger than the minimum level of resolution. This implies that large MMUs may contain a number of unrecognized cover types in a heterogeneous mixture with the recognized dominant cover type.

At aerial photo scales of 1:125,000 to 1:250,000, the MMU is 160 to 640 acres (Carneggie, et. al., 1983). For aerial photo scales of 1:31,680 to 1:63,360, the MMU is 10 to 40 acres. Highly valued vegetation classes such as wetlands may be delineated by a smaller MMU than low value classes. For Landsat MSS digital data use in rangeland mapping, cover types need to be 20 to 40 acres in size to be detected and recognized. Manual classification of Landsat MSS imagery for rangeland mapping generally uses a MMU of 160 to 640 acres.

There are at least three types of site specific mapping errors. 1) Control point location (map registration) error is a measure of the inaccuracy of the position of a known point on the ground as it is represented on the map (Hord and Brooner, 1976). National map accuracy standards measure control point location error only. Because of the homogeneous and relatively undeveloped nature of the study area, sufficient points could not be identified for evaluating control point location error. 2) Classification error measures the agreement of a point on a map with the true class (e.g., vegetation type) observed on the ground (ground truth/reference). Classification error assessment requires a relatively unambiguous classification as a basis for comparison. Error matrices, also called confusion tables, can be used to assess the effects of classification error on the final product. 3) Boundary line error involves a boundary line on the map that does not necessarily conform to the true position. Because boundaries are largely an abstraction of the cartographer or cartographic process and the definition of mapping units is frequently ambiguous, ground location of a gradational boundary usually cannot be verified. Boundary line error is not readily measured, but boundary location can be estimated by utilizing vegetation cover measurements from line transects perpendicular to the boundary line.

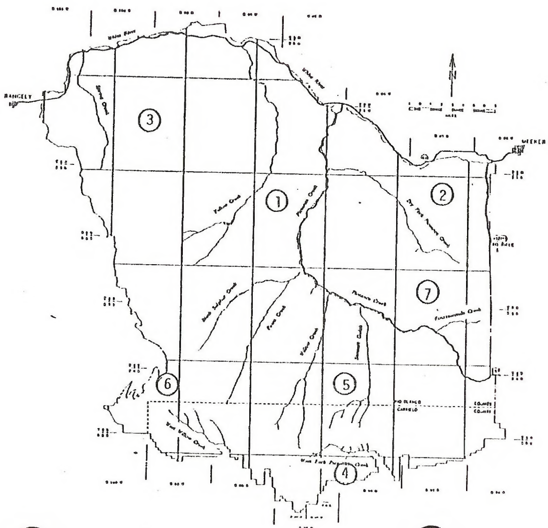
The minimum mapping unit may be depicted as a cell (raster) or a polygon. A number of cell based MMU's are in use, with the MSS pixel being one of the more common. Vegetation types are frequently depicted as polygons, consisting of numerous cells, that are constructed to represent the dominant recognizable vegetation. Due to the mixture of vegetation types frequently present in a MMU polygon and the subjectively recogniz[illegible] edges used for polygon delineation, overall polygon accuracy may not be as great as it appears.

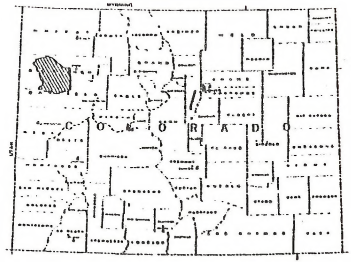
In the fall of 1983 this project was initiated to conduct a quantitative accuracy assessment of a vegetation data base used in a simulation model designed by the Northwest Colorado Wildlife Consortium to predict the cumulative impact of energy development upon deer and elk in northwestern Colorado. The principal objectives of this project were to evaluate the accuracy of three different methods used to produce vegetation data bases and to identify which of the methods met minimum accuracy needs and cost requirements for the deer and elk model. The methods examined were 1) A Machine Classified Landsat (MCL) MSS system using digital data, 2) manually classified false Color Composite Landsat (CCL) MSS images, and 3) manually classified Medium Scale Color Infrared aerial photography (MSCIR).

DESCRIPTION OF THE STUDY AREA

This study was restricted to the Bureau of Land Management's (BLM) Piceance Basin Planning Area, which has been extensively mapped by various agencies in the last few years (USDI, BLM, 1984). The boundaries established for Spatial Unit 1 of the Northwest Colorado Wildlife Consortium deer-elk model lie within this planning unit and correspond to Management Unit 22 of the Colorado Division of Wildlife. Spatial Unit 1 includes approximately 85% of the Piceance Basin Planning Unit, excluding areas west of Range 100 West or in the Parachute Creek and Roan Creek drainages.

Physical Description: The Piceance Basin Planning Area, located principally in Rio Blanco County in northwest Colorado, comprises approximately 804,500 acres of land as delineated in the BLM's Resource Management Plan (USDI, BLM, 1984). It is bounded by the White River on the north, the Cathedral Bluffs on the west, the Roan Cliffs on the south and Highway 13 and 789 on the east (Figure 1). Approximately 23% of this land is privately owned; the remainder (615,489 acres) is federally owned and managed by the BLM. The climate of the basin is semiarid continental, with hot summers and cold winters. The Piceance Basin shows a gradual rise in elevation from approximately 5,500 feet at the White River in the northwest to 8,500 feet on the Roan Plateau to the south. The basin is an extension of the Uintah Basin of Utah, and is principally Cretaceous in its age of formation. The Green River Formation, which has some members rich in oil shale, is an important geologic constituent of this basin (USDI, BLM, 1984).





PICEANCE BASIN

PLANNING AREA

Figure I

USGS Quadrangles Sampled

1. Square S Ranch
2. Segar Mountain
3. Calamity Ridge
4. Circle Dot Gulch
5. Cutoff Gulch
6. Razorback Ridge
7. No Name Ridge

Vegetation Description: Moisture and substrate are the major physical parameters that influence the floristic composition and community structure of the vegetation in the Basin. Species composition is closely related to moisture, exposure, substrate and, to a limited extent, grazing. Variation in community types results largely from differences in relief, exposure and elevation (Cook, 1974).

The vegetation of the Piceance Basin can, in a general way, be divided into seven major community types based on aspect, as influenced by the dominant vegetation (USDI, BLM, 1984). These are: 1) Halophytic shrub, including lowland sagebrush, saltbush and greasewood; 2) Sagebrush, in various associations; 3) Pinyon pine and Utah juniper woodland, in various associations; 4) Upland shrub, including serviceberry, sagebrush, rabbitbrush, snowberry, oakbrush, mountain mahogany, and chokecherry; 5) Aspen; 6) Douglas fir; 7) Grassland (Appendix I). Acreages and percent occurrence are from the Bureau of Land Management's Resource Management Plan (USDI, BLM, 1984), and are given for public lands.

Halophytic shrub: The halophytes are severely limited by elevation, occurring below 6600 feet and covering 2% or 14,403 acres of the Basin. They are found in bottomlands and broad, flat valleys where salinity in the surface soils is high. Rabbitbrush and sagebrush often occur with halophytes but disappear with increasing salinity. Greasewood and saltbush (shadscale) are the dominant species.

Sagebrush: Sagebrush is the major community type of the Basin and occupies 42% or 256,833 acres of the area. It occurs across an elevational range of 6,000 to 8,300 feet and is found on relatively deep, fertile, well drained soils. It thrives on both westerly and easterly slopes while generally reaching its fullest expression on bottomlands and west-facing slopes. It is often found in association with rabbitbrush and a variety of grasses. Sagebrush is not recognized as a separate community in the Northwest Colorado Wildlife Consortium deer-elk model.

Pinyon-Juniper woodland: Pinyon pine and Utah juniper dominate this community type which is found on ridgetops and sideslopes below 7,800 feet and which occupies 172,146 acres, or 28%, of the Basin. These woodlands occur on soils which are much shallower than those that support sagebrush communities. Pinyon-juniper, occurring on all slopes as well as on the bottomlands, is often found in association with serviceberry, mountain mahogany, sagebrush, bitterbrush, and several grasses. The optimum development of this community is found on north-facing slopes at elevations from 7,000 to 7,500 feet. Moisture is less than that received by upland shrub communities.

Upland shrub: This vegetation type is frequently dominant at elevations above 7,200 feet but does range from 6,500 feet to 8,700 feet on well developed soils. It occupies 107,210 acres, or 17%, of the Basin and is most prevalent on north-facing slopes and ridgetops. West-facing slopes are favored over east-facing slopes. Major shrub species in this vegetation type include serviceberry, snowberry, Gambel's oak, sagebrush, and mountain mahogany. Rabbitbrush, chokecherry and juniper are found in lesser amounts. This vegetation type tends to occur in a mosaic with most vegetation types found in the Piceance Creek Basin.

Aspen: Aspen covers 10,755 acres, or 2% of the Basin, and is restricted to elevations above 7,000 feet, with most stands occurring above 8,000 feet. This broadleaf tree may occur in pure stands, as a dominant overstory and in mixed communities. At upper elevations it occurs on well developed soils and forms dense forest. It more commonly occurs in drainage bottoms and along perennial streams at lower elevations. Aspen is found in association with serviceberry, Gambel's oak, chokecherry and snowberry in various combinations, and occurs on ridge tops and all slopes at the higher elevations. On drier sites at lower elevations, aspen is restricted to snow accumulation areas. The understory may include several species of fern and a variety of herbaceous taxa.

Douglas fir: These communities occur on 9,221 acres, 1.5% of the Basin, and are restricted to the north and northwest slopes between 7,500 and 9,000 feet. They occur most frequently on slopes greater than 25%. Most stands consist of mature to overmature trees. Douglas fir forms closed canopies over a shrub layer dominated by serviceberry, chokecherry, snowberry and wild rose. The herbaceous layer is poorly developed.

Grassland: Grasslands occupy 18,168 acres, or 3% of the Basin. Although found at all elevations, grassland is most prevalent below 7,000 feet. Some of these lower elevation areas consist of hay meadows. Major species include western wheatgrass, Letterman needlegrass, Idaho fescue and a variety of bluegrasses. Rabbitbrush is often associated with grassland.

Public lands not included in the above vegetation descriptions occupy 4%, or 26,753 acres. Roads, borrow pits, building compounds, barren lands, cliffs, rock outcrops, etc. are included here.

With the exception of the halophytic shrub and Douglas fir communities, all major vegetation types in the Piceance Basin may intergrade with each other. Elevation, aspect, soil type, geologic parent material and slope position are responsible for gradients expressed in the vegetation. For example, the percentage composition of low elevation pinyon-juniper communities is conspicuously different from high elevation communities, the latter having much more juniper. A more detailed vegetation classification can be found in Lindauer, et al. (1982). A list of plant species identified in this project may be found in Appendix I.

METHODS

Public Land Survey section corners within seven U. S. Geological Survey 7 1/2 minute quadrangles in the Piceance Basin Planning Area were ground truthed in an effort to evaluate three remote sensing data bases. The map sources and methods used in this study are described as follows:

Source of Vegetation Maps: Three vegetation mapping techniques are evaluated in this project. The only digital data-base (with vegetation types quantified) available to the Consortium for constructing its model was prepared by the U.S. Fish and Wildlife Service (FWS). That agency conducted a mapping project in northwest Colorado, including the Piceance Basin, as part of an effort to determine the impact of coal, shale oil, and tarsands development on wildlife habitat. The manually classified 1:250,000 Color Composite Landsat (CCL) imagery purchased from the EROS Data Center, U.S. Geological Survey, provided the data-base for the Consortium's model. In addition, the BLM Colorado State Office and the FWS conducted an intensive medium scale (1:24,000) color infrared (MSCIR) mapping project of Northwest Colorado that provided a surface cover/land use data-base for the Piceance Basin Resource Management Plan (USDI, BLM, 1984). The Resource Management Plan utilized the MSCIR data-base in the MOSS (Map Overlay and Statistical System) GIS. A Machine Classified Landsat mapping project was conducted by the BLM Denver Service Center for land use planning in the White River Resource Area, including the Piceance Basin Planning Area. Procedures for computer-asssisted image interpretation (MCL) and manual image interpretation (CCL and MSCIR) have been described by Estes, et. al. (1983).

The MCL mapping task utilized Landsat scene 8223471750X0, acquir[ed] July 20, 1980 (D. Osborne, unpublished report, 1983). The project area portion of the scene was entered into the BLM's HP-3000 using ESL IDIMS software. The project area was registered to a 50m grid in a Universal Transverse Mercator Projection using ground control point for each of the 34 7.5 minute quadrangles. An unsupervised classification, using a maximum likelihood decision rule, was performed on the image. The resulting classified image was stratified into four elevation breaks (5000 to 5300 ft., 5301 to 6000 ft., 6001 to 7000 ft., above 7000 ft.) based on associated vegetation differences. Forty-two spectral classes were grouped into 32 resource categories for the area.

Intrepretation of Landsat color composite imagery and MSCIR has been extensively described by others including Carneggie et al., 1983.

Sample Selection: The site-specific map accuracy assessment approach, in which two registered data sets (one of them ground truth) are compared for amount of agreement, was selected over the non-site specific assessment in which total acreages are compared without regard to location. The site-specific assessment was selected since it is considered more rigorous and informative (Mead and Szajgin, 1982). To quantitatively assess the accuracy of the vegetation data from the MCL, CCL and MSCIR mapping methods, it was necessary to determine on-site vegetation types at a minimum of 50 sample stations (Hay, 1979).

A stratified, systematic, unaligned sampling design was used so that unbiased estimates of the probability of occurrence of each vegetation class would be provided and the classification system could be evaluated and improved (Dozier and Strahler, 1983). The sampling design containe[d] two strata (low elevation quadrangles, high elevation quadrangles), three replicates (7.5 minute quadrangles) per strata, ten clusters (Public Land Survey section corners marked with "brass caps") per replicate, and nine sampling units (pixels) per cluster. To select the sample sites, the 23 mapped quadrangles were stratified by elevation and identified as high elevation (above 7,000 feet) or low elevation (below 7,000 feet). This categorization was accomplished by finding the minimum and maximum elevations of each of the quadrangles and then using the mid-range elevation for assignment. This resulted in 11 quadrangles being assigned to the high elevation type and 10 to the low elevation type. Two quadrangles could not be clearly separated by elevation (midrange elevation was within 100 feet of the 7000 foot contour) and were not included in the assessment.

Three quadrangles were randomly selected from each of the assigned elevation areas and ten Public Land Survey section corners were chosen randomly from each quadrangle for a total of 60 sample sites. However, the absence of a complete Public Land Survey in one high elevation quadrangle and the inability to gain legal access to several section corners in another high elevation quadrangle necessitated the selection of an adjacent quadrangle and a reduction in the sample size to 52 sites. Each of the 52 sampling sites contained nine pixels, giving a total of 468 pixel samples. In addition, the nine pixels comprising each group were aggregated into a single vegetation class for comparison at the site level. Locations of sample sites are given in Appendix II.

Field Methods: Two project crews were organized to conduct the ground truthing in September of 1983. Two crews of Colorado Division of Wildlife (DOW) employees located, marked and flagged access to section corners. The surveyed section corner markers ("brass caps") provided the only positively identifiable, uniformly distributed locations present both on the ground and on U. S. Geological Survey topographic maps.

Two types of information were gathered at each sampling site (section corner). First the percent canopy cover of woody vegetation was determined using a 150 meter line transect. This line ran north and south and was centered over the brass cap. Second, the area surrounding the brass cap was divided into 9 pixels in order to designate vegetation types. This gave a 3 pixel by 3 pixel (150m by 150m) area centered on the brass cap. Project crews visually assigned each pixel to a vegetation type.

Vegetation Classification: As is often the case, different vegetation classification categories were used in the various mapping projects. All three mapping projects generally followed the surface cover classification scheme used by the U. S. Geological Survey (Anderson, et. al., 1976) which includes several levels of detail (Appendix III and IV). Level 1 divides the earth into nine categories, and Level 2 further divides these general categories into more specific hierarchical units. The MSCIR project mapped the Piceance Basin, for the most part, at levels 3 and 4 using a species association subunit (Appendix III). The canopy cover of the dominant vegetation and the understory were both quantified (S. Williamson, unpublished report, 1983).

An initial comparison of total acreages in the six original quadrangles, as obtained from MCL and MSCIR data, suggested a considerable variation in the acreages of the vegetation types between the two mapping projects (Table 1). Since the classification systems were not parallel, it was necessary to assign all of the systems to a combined classification system. For the first set of comparisons, the classification systems were condensed into 13 categories (Table 2). In this comparison some categories were absent in one or more of the remote sensing systems used. For example, the MCL classification system did not distinguish two of the pinyon-juniper associations (PJ/SG and PJ/US). To circumvent this problem, a second comparison was made by reducing the 13 categories to 7 categories, forming a "collapsed" classification system (Table 3). This provided a one-to-one correspondence in all systems. A third "general" classification was made by comparing those dominant species or species mixtures of the three mapping projects to the 13 categories of the combined classification system (Table 4). A match was identified when either the dominant species or a dominant association fell within one of the 13 categories.

Data Analysis: Data were analyzed at both a pixel and a site level. At the pixel level, a one-to-one manual comparison was made between the ground truth vegetation assignments for a pixel and those obtained from MCL, CCL and MSCIR. Vegetation assignment at the site level was determined by identifying the most frequently occurring vegetation type within the nine pixels. This was done for ground truth and remotely sensed data.

The data obtained from the above comparisons were analyzed using an error matrix approach that identifies the number of correctly identified

Table 1 Comparison of Total Acreages in the Six Original Quadrangles as Obtained from Machine Classified Landsat (MCL) and Medium Scale Color Infrared Photography (MSCIR) Data

Quadrangle		Square S Ranch		No Name Ridge		Razorback Ridge		Segar Mountain		Circle Dot Gulch		Calamity Ridge		Total Acres	
Vegetation Type	Remote Sensing Method	MCL	MSCIR	MCL	MSCIR	MCL	MSCIR	MCL	MSCIR	MCL	MSCIR	MCL	MSCIR	MCL	MSCIR
Aspen		1	-	4,682	-	9,139	6,059	8,025	156	10,816	553	2,947		35,610	6,768
Grassland		5,445	1,640	648	817	11	2,538	427	307	762	89	1,143	746	8,436	6,137
Halophytes[1]		606	3,117	781	988	214	167	2,013	572	1,010	1,125	1,912	2,617	6,536	8,316
Douglas fir		6	16	907	3,286	1,214	3,216	653	1,553	592	1,478	497	478	3,869	10,027
Sagebrush		17,061	9,177	6,520	19,858	2,556	14,713	3,923	15,153	1,892	22,491	6,929	6,166	38,881	87,558
Pinyon/ Juniper[2]		12,331	19,035	14,739	5,168	8,979	1,804	14,185	8,706	7,259	298	16,464	15,167	73,957	50,178
Upland Shrub[3]		14	-	7,650	5,620	13,844	7,726	7,312	9,521	12,718	4,280	7,507	10,741	49,045	37,888
Total		35,464	32,985	35,927	35,737	35,957	36,223	36,538	35,968	35,049	30,314	37,399	35,915		

[1]Sage bottomlands (MCL) included in MCL halophyte acres
Greasewood (MSCIR) and Saltbush (MSCIR) included in MSCIR halophyte acres

[2]Pinyon (MCL) included in MCL pinyon/juniper acres

[3][illegible]ountain shrub (MCL), oakbrush (MSCIR) and serviceberry [illegible]rush (MCL) included in upland shrub acres

Table 2 Relationship of a Combined Classification System to three other Classification Systems used in Piceance Basin Ground Truth Remote Sensing Vegetation Data Base

Combined Classification System			Ground Truth Classification System (APPENDIX I)	Machine Classified Landsat System (APPENDIX III)		Color Composite Landsat and Medium Scale Color Infrared Classification System (APPENDIX IV)
1.	AS	Aspen	AS	4	AS	AS
2.	AS/US	Aspen/Upland Shrub	AS/SB, AS/SN, AS/SG, AS/SB/CC, AS/SN/SB	5	AS/US	AS/US
3.	DF	Douglas Fir	DF, DF/SG, DF/MD, DF/PJ	1	DF	DF
4.	GR	Grassland	GR, MD, GR/SG	26,28*	GR	BN/SH, BN/BS, 211, 212
5.	HA	Halophytic Shrub	GW, GW/SG	(8,9, 10,11,12 poten-tially)*	HA	HA/SG, GR/SG
6.	PJ	Pinyon/Juniper	PN, PJ, JN, PJ/DF	(18,19, 20,21,22 23,24)*	PJ	PJ, PY, JN, PJ/HR
7.	PJ/SG	PJ/Sage	PJ/SG, PJ/SG/GW	None		PJ/SG
8.	PJ/US	PJ/Upland Shrub	PJ/MS, PN/SB, PJ/OB	None		PJ/US
9.	SG	Sage	SG, SG/GW	(13,14, 15,16, 17)*	SG	SGHR, SG
10.	WE	Wetlands	MD/ST	3	-	National Wetland* Inventory Classes
11.	US	Upland Shrub	OB, SB/CC, SB, MM, MS SG/RB, SG/SB, SG/SN SB/SG, SB/PN	6,7	-	US, OB/US, OB, OB/SG, SG/US
12.	SO	Shale Outcrop	None	32	-	None
13.	RO	Roads	None	None	-	None

*See the indicated Appendices for detailed classification.

Table 3: Collapsed Classification System (13 categories of the Combined Classification System were condensed to 7 categories).

Collapsed Classification System			Combined Classification System	
1.	AS	Aspen	1,2	AS, AS/US
2.	GR	Grass	4	GR
3.	HA	Halophytics	5	HA
4.	PJ	Pinyon/Juniper	6,7,8	PJ, PJ/SG, PJ/US
5.	SG	Sage	9	SG
6.	US	Upland Shrub	11	US
7.	OT	Other*	3,10,12,13	DF, WE, SO, RD

* Those classes with less than 10 occurrences were classified into a new "other" grouping.

Table 4: General Classification System (This table illustrates the vegetation types - dominant and mixed vegetation - that was identified as a match with the 13 categories from Combined Classification categories).

13 Categories From Combined Classification	Matches for General Classification	
1. AS	1,2	AS, AS/US
2. AS/US	1,2,11	AS, AS/US, US
3. DF	3	DF
4. GR	4	GR
5. HA	5,9	HA, SG
6. PJ	6,7,8	PJ, PJ/SG, PJ/US
7. PJ/SG	6,7,8,9	PJ, PJ/SG, PJ/US, SG
8. PJ/US	6,7,8,11	PJ, PJ/SG, PJ/US, US
9. SG	5,7,9	HA, PJ/SG, SG
10 WE	10	WE
11. US	2,8,11	AS/US, PJ/US, US
12. SO	12	SO
13. RD	13	RD

AS Aspen
DF Douglas Fir
GR Greasewood
HA Halophytic Shrub
JN Juniper
PJ Pinyon/Juniper Assoc.
RD Road
SG Sagebrush
SO Shale Outcrop
US Upland Shrub
We Wetland

points (concurrence between ground truth and remotely sensed data) as as errors due to omission or commission. An omission error occurs when a sampling unit representing a particular classification type is misclassified, thus under-representing that classification type. A commission error occurs when that misclassified sampling unit is added to the list for another classification type, thus over-representing that classification type. Overall error is the proportion of the total number of sampling units that were incorrectly identified in comparison to the actual field determinations, regardless of classification type. The small number of occurances observed for individual classes in the classification precludes an analysis (e.g., calculation of confidence intervals) of individual class classification accuracy.

Cost comparisons for MCL, CCL and MSCIR were made in an effort to assist land managers in selecting the most economical mapping method wi available resources. A final comparison was made by separating the remotely sensed data from quadrangles with midrange elevations above and below 7,000 feet. This was done to determine if elevation, and its associated effects, had an appreciable influence upon the accuracy levels obtained.

RESULTS

Differences among the vegetation classification systems used in the three methods created the greatest problem in comparing Machine Classified Landsat (MCL), Color Composite Landsat (CCL) and Medium Scale Color Infrared (MSCIR) aerial photography with the ground truthing data gathered in the Piceance Basin during September, 1983.

The results which follow show the percent accuracy of the interpreted vegetation community types (from remotely sensed data) compared with the vegetation types recorded during ground truthing. Three classification comparisons were made using the Combined Classification System (13 categories), the Collapsed Classification System (7 categories) and the General Classification System (13 categories). The General Classification System includes as a match any vegetation types which share dominant species in both the remote sensing data and the ground truth data. In an effort to determine how accuracy was influenced by the examination of a larger area, a comparison of the accuracy of the 9 pixels at each study site (pixel level) was made with a combined characterization of all nine pixels into one type (site level). In addition, aerial cover measurements of the woody vegetation were recorded at each site, cost estimates were compared for MSCIR, MCL and CCL, and a final comparison examined the influence of elevation on accuracy obtained by the various remote sensing methods.

Combined Classification System: For the first set of comparisons, each of the original classification systems was condensed into 13 categories (Table 2). At this level of pixel comparison, the accuracy of

MCL was 26% , CCL was 27%, and MSCIR was 58%. When this classification system was used on the study site level, MCL accuracy increased to 29%, CCL accuracy increased to 33%, and MSCIR accuracy increased to 60% (Appendices V to X).

Collapsed Classification System: In the Combined Classification System, some categories were not present in all of the remote sensing methods. For example, the MCL classification system did not distinguish among the pinyon-juniper associations. Thus, it had no matches for the pinyon-juniper/sagebrush or pinyon-juniper/upland shrub categories in the other classifications. To evaluate this negative bias, the Combined Classification was collapsed to 7 vegetation types as discussed earlier, to provide matches for all categories (Table 3). At the pixel level, MCL accuracy was 31%, CCL accuracy was 42%, and MSCIR accuracy was 70%. On the study site level, MCL accuracy increased to 35%, CCL accuracy increased to 44% and MSCIR accuracy increased to 71% (Appendices XI to XVI).

General Classification System: A third comparison was made using the 13 categories from the Combined Classification and matching these categories with other categories within that system that contained similar vegetation, as discussed earlier (Table 4). Types having the same or nearly the same dominant taxa, which is reflected in their type name, were considered to be matches, e.g., aspen now matches with aspen and with aspen/upland shrub. In this more general comparison at the pixel level, MCL accuracy was 48%, CCL accuracy was 78%, and MSCIR accuracy was 78%. On the study site level, MCL accuracy increased to 58, CCL accuracy increased to 79%, and MSCIR accuracy increased to 83% (Appendices XVII to XXII).

Pixel/Site Comparison: Accuracy evaluations of the individual pixels at each sampling site (pixel level) were compared to a combined characterization of all nine pixels into one type (site level). Pixel comparisons were very similar to site comparisons with pixel comparisons always 1% to 10% lower in accuracy (Table 5). The relatively minor and consistent differences between the two levels of comparison indicate that either could be used in other comparisons, but the pixel level comparison is recommended because it provides larger sample sizes and slightly better resolution at little or no additional data collection cost. The pixel and site comparisons indicate that registration error was minor compared with classification error.

Remote Sensing Technique Comparison: The MCL accuracy was always less than the CCL accuracy, which, with one exception, was always less than the MSCIR accuracy (Table 5). As classification system complexity was reduced (from the Combined Classification to the Collapsed Classification to the General Classification), the accuracy of each remote sensing technique increased (Table 5). The accuracy of CCL increased faster (from 27% to 78% at the pixel level) than the accuracy of MCL (from 26% to 48%) or the accuracy of MSCIR (from 58% to 78%).

Vegetation Cover: Vegetation cover measurements as determined from a line transect at each study site provided the basis for more accurate interpretations of the diversity and composition of the woody vegetation. Cover values for each sample are presented in Appendix XXIII. Average values for each quadrangle are found in Table 6, where the quadrangles are grouped according to elevational stratum (either below or above 7000 feet). The cover values from Appendix XXIII were used, along with visual estimation, to assign each pixel a ground truth cover class. A comparison of the assigned ground truth cover classes and the classification derived

Table 5: Summary of the percent accuracy of the three vegetation mapping projects (MCL, CCL and MSCIR) as compared to ground truth in the Piceance Basin.

	MCL Landsat Digital		CCL Landsat Manual		MSCIR Color Infrared	
	Pixel	/Site	Pixel	/ Site	Pixel	/ Site
Combined Classification	26%	29%	27%	33%	58%	60%
Collapsed Classification	31%	35%	42%	44%	70%	71%
General Classification	48%	58%	78%	79%	78%	83%

Pixel level of measurement = 50 x 50 meters. Site level of measurement = [illegible] x 150 meters or 9 Pixels centered on a section corner.

Table 6 Average percent cover of woody vegetation determined from 52 section corner sites. (These cover values represent an average cover value from transect in which the species occurs. Four (4) to ten (10) transects were taken in each quadrangle.)

Quadrangle and Elevation	Vegetation Type											
	AS	BB	CC	JN	MM	OB	PN	RB	SB	SG	SN	OT
Below 7,000'												
Square S				36			15			21	46	3
Segar Mountain		6		7	10	29	12	12	25	17	15	2
Calamity Ridge					9		12	10	47	18	19	2
Above 7,000'												
No Name				14		15			29	14	26	3
Razorback Ridge		9						13	16	48	31	4
Circle Dot	18					11		2	28	8	27	4
Cut Off Gulch			3			24		5	22	10	33	3

AS	Aspen	MM	Mountain Mahogany	RB	Rabbitbrush
BB	Bitterbrush	OB	Oakbrush	SB	Serviceberry
CC	Choke Cherry	OT	Other	SG	Sagebrush
JN	Juniper	PN	Pinyon	SN	Snowberry

from MCL and MSCIR are found in Appendix XXIV. Rabbitbrush was found in heterogeneous stands in all of the quandrangles sampled but does not have a large cover at any site. Because it is a small plant (below the minimum resolution size of MSCIR) that occurs in evenly dispersed stands and does not have a distinctive spectral signature, rabbitbrush was generally missed in all three mapping efforts.

Cost Comparisons of MSCIR, MCL and CCL: A comparison of the costs for mapping vegetation clearly demonstrates the reduced costs associated with Landsat imagery (Table 7). Although land managers prefer projects to be mapped at larger scales such as 1:24,000, the cost for vegetation mapping at this scale was approximately 132 times greater than the CCL at a scale of 1:250,000 and the cost of MCL was approximately 66 times greater than the cost for CCL.

Elevation Comparisons: A comparison of the accuracy levels of the remote sensing methods at elevations above and below 7,000 feet was made to determine if one system is more accurate at either of the elevation ranges (Table 8). Data were compared on the basis of the elevation assigned to each quadrangle. In those quadrangles with midrange elevation below 7,000 feet (Square S Ranch, Segar Mountain and Calamity Ridge), using the Collapsed Classification at the pixel level of comparison, MCL accuracy was valued at 37%, CCL was 38% and MSCIR was 68%. In those quadrangles with midrange elevation above 7,000 feet (No Name Ridge, Razorback Ridge, Circle Dot Gulch and Cutoff Gulch), the accuracy of MCL was estimated at 24%, CCL at 19% and MSCIR at 69%. Thus, there was less accuracy in MCL (35% less) and CCL (50% less) at higher elevations (above 7,000 feet) than at lower elevations. Differences in elevation made no perceptible difference in the accuracy of MSCIR data. The reduced accuracy at higher elevations may be

TABLE 7: Comparison of specifications and costs for the CCl, MCL AND MSCIR Piceance Basin Mapping Projects.

	CCL	MCL	MCIR
Scale of input data	1:250,000	N/A	1:24,000
Resolution	79m	79m	3m
Minimum mapping unit	640 acres (160 acres for wetlands)	20-40 acres	10 acres (0.5 acres acres for wetlands)
Classification Level Anderson, et. al. (1976)	2 to 3	3 to 4	4 to 5
Cost to reformat data to digital format - (cents/acre)	0.06 (to category or species/ assoc. level)	4.1 (to species association level)	6.7 (species or % canopy closure level)
Cost for acquisition of imagery * (cents/acre)	0.002	0.04	1.5
Total cost (cents/acre)	0.062	4.14	8.2

* The costs are based upon 1983 rates of $9.60/square mile for contract aerial photography, $300 for a Landsat digital data tape, and $15 for a Landsat false color composite at 1:250,000 scale.

attributed to species diversity and density in the upland shrub vegetation type. MCL apparently did not distinguish aspen from upland shrub at higher elevations (Appendix XXIV).

Table 8: Summary of the percent accuracy of the three mapping projects (MCL, CCL, and MSCIR) when the sample sites are separated by quadrangles with midrange elevations below and above 7,000 feet (Collapsed Classification, pixel level).

Low Elevation Quadrangles

MCL				Total
# Possible	90	90	90	270
# Correct	32	35	34	101
%Accuracy				37

CCL				Total
# Possible	90	90	90	270
# Correct	30	34	38	102
%Accuracy				38

MSCIR				Total
# Possible	90	90	90	270
# Correct	63	62	58	183
%Accuracy				68

High Elevation Quadrangles

					Total
# Possible	45	63	54	36	198
# Correct	7	11	22	8	48
%Accuracy					24

CCL					Total
# Possible	45	63	54	36	198
# Correct	7	11	16	3	37
%Accuracy					19

MSCIR					Total
# Possible	45	63	54	36	198
# Correct	38	37	36	25	136
%Accuracy					69

Low Elevation Quadrangles: Below 7000 Feet
Square S Ranch, Segar Mountain, Calamity Ridge

HIgh Elevation Quadrangles: Above 7000 Feet
No Name Ridge, Razorback Ridge, Circle Dot Gulch, Cutoff Gulch

DISCUSSION

The results of this assessment suggest that the vegetation data base derived from CCL images for use in the Consortium's deer-elk model may not be sufficiently accurate. Carneggie, et al. (1983) report that overall accuracy figures of less than 70% are often considered unacceptable for site specific mapping. Although values of 78% and 79% were obtained with CCL in the general classification (Table 5), the detail of this classification system may not be sufficient for either wildlife management decisions or for model interpretations. The Piceance Basin Landsat data (MCL and CCL) are less accurate at elevations above 7,000 feet than they are for elevations below 7,000 feet. Broad leafed species at elevations above 7,000 feet, such as oakbrush, serviceberry, snowberry and aspen, appear to be more difficult to separate using Landsat than lowland species such as sagebrush, greasewood and saltbush.

The choice of a remote sensing data source in a mapping project is a function of land value and uses, management information needs, and project budget (Aldrich, 1981). The increased cost of aerial photography for mapping projects can more easily be justified when and where the greater need for management intensifies the importance of higher accuracy. Wildlife habitat assessment may be done at a site specific or a regional level. Site specific studies usually include a small area in which the cost of an aerial photography mapping project is appropriate (Carneggie et al. 1983.) Regional assessments are more cost effective when done from a combination of satellite images and aerial photographs. The combination of Landsat digital data and Landsat image format data with medium scale aerial photographs allows for the mapping of large areas in an efficient and cost-effective approach. The high resolution and potentially high accuracy of aerial photography in combination with the synoptic and sequential coverage from Landsat provides managers with an excellent capability to analyze, assess, and monitor habitat over broad areas.

Color Composite Landsat (CCL) is the most interpretable of the Landsat data and, at a scale of 1:250,000, is widely accepted as a map base for resource information (Carneggie, et. al., 1983). This Landsat form (CCL) is rapidly replacing photo-mosaics for general management planning and for displaying and orienting geographic information. However, as stand-alone products, CCL maps have their greatest use in areas where: 1) other imagery is not available, 2) habitat maps are not available and 3) CCL is used for stratification of effort allocation in sampling.

A trade-off for the poor resolution of CCL (MMU of 160 to 640 acres) is the low cost per unit area. Linden, et al. (1981) reported a cost of 0.2 cents/acre with a MMU of 640 acres. They interpreted evergreen woodland, Mohave desert shrub, Great Basin desert shrub, and other vegetation in Arizona from CCL and achieved 83% accuracy from a standard false color composite and 88% accuracy from an enhanced image; however, these figures were not statistically different. The accuracy of CCL maps carried to classification Level I (Anderson, et al., 1976) was 70% as compared with 77% from small-scale aerial photography (Fitzpatrick-Lins, 1978). The predominant Level II land uses were mapped with higher accuracy than those occurring less frequently. CCL was most accurate for forest (band 5) and water (band 7) categories.

The variability of results in the literature make the assessment of the accuracy and usefulness of MCL rangeland cover maps difficult (Carneggie, et al., 1983). Most of the MCL rangeland mapping studies report an overall accuracy at Level I ranging from 75% to 90% (see e. g., Krumpe et al., 1973). At Level III, accuracy figures are generally less than 70%, a frequently used break-off point for map acceptability. Classification accuracy is higher in mesic environments which are characterized by having relatively few cover types and less dense vegetation. Cost estimates of MCL rangeland cover mapping was reported at 6 cents/acre (Rohde and Miller, 1981) and 2.8 cents/acre (Linden, et al., 1981).

There are a number of technical difficulties with using MCL in rangeland mapping (Carneggie, et al., 1983). Training statistics definition (training the computer to look for the best match of spectral signature with vegetation types) for rangelands is particularly difficult due to the spatial heterogeneity of vegetation and soil. Supervised classifications are time consuming and leave some data unclassified (Tueller, 1980 and Hoffer, 1980). Classification accuracy in rangeland mapping was improved from 54 to 73 percent by class sorting based on elevation classes (Miller et al., 1981). This technique was incorporated into the unsupervised MCL classification for the Piceance Basin.

For site-specific mapping of rangeland vegetation, MSCIR aerial photography is the choice of agencies such as the Bureau of Land Management and the Fish and Wildlife Service. Color infrared photography is preferred because of better contrast between vegetated and nonvegetated areas, differentiation between surface water and wet areas without surface water, better detection of stressed vegetation, and better contrast between vegetation types (Aldrich, 1981).

An economical alternative to any of the three options evaluated here may be use of medium scale (1:58,000) color infrared photography from the

National High Altitude Photography (NHAP) program. This photography may soon be available for the entire United States, but was not available for the Piceance Basin Planning Area at the time the three mapping projects were conducted. The 1983 cost for stereo NHAP imagery was 8 cents/acre. The cost to reformat the data into digital format is estimated to be 4.4 cents/acre, a third less than the cost for 1:24,000 scale color infrared aerial photography. Although fewer frames of photography are handled, less detail (lower resolution) is available to the photointerpreter. The NHAP imagery can be interpreted to nearly the same MMU as 1:24,000 scale photography but the classification accuracy is likely to be somewhat less. For some rangeland applications, NHAP color infrared photo enlargements at a nominal scale of 1:24,000 (12 cents/acre) may be useful. Medium scale (1:65:000) color infrared photography is used by the U. S. Fish and Wildlife Service's National Wetland Inventory to map the wetlands of the United States to 0.5 acre MMU using the Cowardin et al. (1978) wetland classification system.

In summary, there is little justification for the use of Landsat digital (MCL) data analysis at the present stage of technology in rangeland mapping applications because of its high cost and low accuracy which is little better than that obtained from manual interpretation of color composite Landsat 1:250,000 scale images. These conclusions do not necessarily hold for non-rangeland mapping (Sabins, 1978), but comparisons similar to the ones reported here are recommended for other vegetation types. Medium Scale Color Infrared (MSCIR) imagery continues to be the choice for mapping rangelands because its accuracy of vegetation mapping is near or above 70% and is requested by most land managers if funds are available (Carneggie, et al., 1983). Vegetation typing as determined by

MSCIR and available in the MOSS data base is, therefore, recommended for use as the data base for the Northwest Colorado Wildlife Consortium deer-elk model.

The most cost effective and accurate large scale mapping effort for rangeland applications may be a stratified selective effort using a combination of MSCIR aerial photography for heterogeneous and high interest areas (such as ecotones, riparian zones, and wetlands) and small scale aerial or satellite imagery for homogeneous and low interest areas where lower accuracy is acceptable. New technologies, such as the Landsat thematic mapper and airborne video, may enhance the precision of satellite and aerial digital data in the near future to the point of improved cost-efficiency and effectiveness for rangeland vegetation mapping and construction of digital data bases.

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APPENDIX I

Piceance Creek Ground Truth Classification and Species List

AS	Aspen	Populus tremuloides
BB	Bitterbrush	Purshia tridentata
CC	Chokecherry	Prunus virginia
DF	Douglas Fir	Pseudostuga menziesii
GR	Grass	
GW	Greasewood	Sarcobatus vermiculatus
JN	Juniper	Juniperus spp.
MD	Meadow	
MM	Mountain Mahogany	Cercocarpus montanus
MS	Mountain Shrub	
OB	Oakbrush	Quercus gambelli
PN	Pinyon Pine	Pinus edulis
PJ	Pinyon/Juniper	
RB	Rabbitbrush	Chrysothamnus spp.
RD	Road	
SB	Serviceberry	Amelanchier alnifolia
SG	Sagebrush	Artemesia tridentata
SN	Snowberry	Symphoricarpus spp.
SO	Shale Outcrop	
ST	Stream	
WE	Wetlands	

APPENDIX II

Selected Sample Sites and Locations For
Piceance Creek Basin Ground Truth Project
September 1983

Quad	Sample Number	Township and Range	Section Corner
Square S Ranch	7	T1S, R97W	3 2 10 11
	12	T1S, R97W	8 9 17 16
	14	T1S, R97W	10 11 15 14
	16	T1S, R98W	14 13 23 24
	17	T1S, R97/98W	13 18 24 19
	22	T1S, R98W	22 23 27 26
	25	T1S, R97W	19 20 30 29
	30	T1S, R98W	26 25 35 36
	44	T2S, R98W	2 1 11 12
	47	T2S, R97W	5 4 8 9
No Name Ridge	1	T2S, R95/96W	18 24 19
	8	T2S, R95W	19 20 30 29
	12	T2S, R95 W	23 24 26 25
	17	T2S, R95W	27 26 34 35

APPENDIX II Selected Sample Sites and Locations for Piceance Creek Basin Ground Truth Project - September 1983 Cont.

No Name Ridge Cont.	20	T2/3S, R95W	31 32 no PLS
Razorback Ridge	6	T3/4S, R99W	32 33 5 4
	12	T4S, R99W	5 4 8 9
	22	T4S, R99/100W	13 18 24 19
	24	T4S, R99W	17 16 20 21
	29	T4S, R99W	19 20 30 29
	41	T4/5S, R99W	no PLS 6 5
	48	T5S, R99W	5 4 8 9
Segar Mountain	6	T1S, R95W	2 1 11 12
	10	T1S, R95W	16 10 15
	13	T1S, R95/96W	13 18 24 19
	25	T1S, R95/96W	25 30 36 31
	28	T1S, R95W	27 33 34
	31	T1/2S, R95/96W	36 31 1 6
	36	T1/2S, R95W	36 1 2
	37	T2S, R95/96W	1 6 12

APPENDIX II Selected Sample Sites and Locations for Piceance Creek Basin Ground Truth Project - September 1983 Cont.

Segar Mountain Cont.	39	T2S, R95W	5 4 8 9
	43	T2S, R95/96W	7 13 18
Circle Dot Gulch	1	T5S, R97W	14 13 23 24
	10	T5S, R96W	20 21 29 28
	15	T5S, R96W	30 29 31 32
	20	T5/6S, R96/97W	36 31 4
	32	T6S, R97W	9 10 16 15
	39	T6S, R97W	15 14 22 23
Cutoff Gulch	23	T4S, R96W	16 15 21 22
	30	T4S, R96W	22 23 27 26
	40	T/5S, R96W	32 33 4
	42	T4 5S, R96W	34 35 2
Calamity Ridge	5	T2N, R99W	19 20 30 29
	6	T2N, R99W	20 21 29 28
	16	T1/2N, R99/100W	36 31 1 6
	17	T1/2N, R99W	31 32 6 5

APPENDIX II Selected Sample Sites and Loctions for Piceance Creek Basin Ground Truth Project - September 1983 Cont.

Calamity Ridge Cont.	22	T1N, R99/100	1	6
			12	7
	23	T1N, R99W	6	5
			7	8
	30	T1N, R99FW	8	9
			17	16
	35	T1N, R99W	18	17
			19	20
	40	T1N, R99/100W	24	19
			25	30
	46	T1N, R99/100W	25	30
			36	31

APPENDIX III

Machine Classified Landsat Classification
Piceance Basin

1. Douglas Fir Woodland
2. Cottonwood Bottomland
3. Willow/Tamarisk Floodplain
4. Aspen Woodland
5. Aspen/Shrubland Association
6. Serviceberry Shrubland
7. Serviceberry Oakbrush Association
8. Mat Saltbush Shrubland
9. Mat Saltbush/Shadscale Association
10. Desert Shrub-Swelling Clays
11. Greasewood Shrubland
12. Greasewood/Big Sagebrush Bottomland
13. Low Elevation Big Sagebrush Bottomland (5300-7000 ft.)
14. Low Elevation Upland Big Sagebrush (5300-7000 ft.)
15. Low Elevation Sagebrush - Exposed Slopes (6000-7000ft.)
16. High Elevation Upland Big Sagebrush (above 7000 ft.)
17. Black Sagebrush/Grassy Ridges (above 7000 ft.)
18. Low Elevation Pinyon-Juniper - Shallow Soils (5300-6000ft.)
19. Low Elevation Pinyon-Juniper - North Facing Slope (5300-6000ft.)
20. Moderate Elevation Pinyon Juniper - Moderately Deep Soils - North Facing Slopes (6000-7000ft.)
21. Moderate Elevation Pinyon-Juniper - Exposed Shallow Soils
22. Pinyon-Juniper Rockland Complex
23. High Elevation Pinyon/Rockland (above 7000 ft.)
24. High Elevation Pinyon (above 7000 ft.)
25. Wet Meadow
26. Hillside Bunchgrass/Forb Community (6000-7000 ft.)
27. Agriculture - Irrigated
28. Agriculture - Subirrigated
29. Industrial/Disturbance
30. Low Elevation Barren Slopes (5300-6000 ft.)
31. Cathedral Bluff Shale Outcrop - Steep Slopes
32. Water

APPENDIX IV

Color Composite Landsat Classification and Medium Scale Color Infrared Photography Classification Piceance Basin

AN	Annual Grass
AS	Aspen
BN	Bunch Grass
BR	Bare Rock
BS	Bare Soil
CN	Coniferous
DF	Douglas Fir
DS	Desert Grass
GR	Greasewood
HA	Halophytic Shrub
HR	Herbaceous
JN	Juniper
LP	Lodgepole Pine
OB	Oakbrush
OT	Other
PD	Ponderosa Pine
PJ	Pinyon/Juniper Assn.
PY	Pinyon Pine
SA	Subalpine Fir
SF	Spruce/Fir Assn.
SG	Sagebrush
SH	Shortgrass
SL	Saltbush
SP	Spruce Species
UD	Upland Deciduous
US	Upland Shrub

APPENDIX V

A Comparison of Machine Classified Landsat (MCL) with Ground Truth Using a Combined Classification at the Pixel Level

Classified Vegetation Type

		1	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL	% Correct
	1	0	0	0	0	0	1	0	0	0	0	3	0	0	4	0
G	2	4	4	0	0	0	0	0	0	0	0	13	0	0	21	19
r	3	2	0	0	0	0	3	0	0	0	0	2	0	0	7	0
o	4	1	0	0	0	0	9	0	0	5	0	6	0	0	21	0
u	5	0	0	0	4	0	4	0	0	12	0	0	0	0	20	0
n	6	1	0	3	5	0	30	0	0	21	0	3	0	0	63	48
d	7	0	0	0	0	0	14	0	0	7	0	1	0	0	22	0
	8	0	0	0	0	0	8	0	0	7	0	2	0	0	17	0
T	9	1	4	0	1	0	17	0	0	9	2	8	0	0	42	21
r	10	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
u	11	29	43	2	0	0	63	0	0	32	0	77	3	0	249	31
t	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
h	13	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
TOTAL		38	51	5	12	0	149	0	0	93	2	115	3	0	468	
%Corr		0	8	0	0	0	20	0	0	10	0	67	0	0		

Total Accuracy: 26%

Underlined values indicate correctly classified cells.

APPENDIX VI

A Comparison of Color Composite Landsat (CCL) with Ground Truth Using a Combined Classification at the Pixel Level.

Classified Vegetation Type

		1	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL	% Correct
G	1	0	1	0	0	0	0	0	0	0	0	3	0	0	4	0
r	2	1	11	0	0	0	0	0	0	0	0	9	0	0	21	52
o	3	0	0	0	0	0	0	0	7	0	0	0	0	0	7	0
u	4	0	0	0	2	0	0	0	9	0	0	10	0	0	21	1
n	5	0	0	0	7	0	2	11	0	0	0	0	0	0	20	0
d	6	0	0	0	0	0	0	28	35	0	0	0	0	0	63	0
	7	0	0	0	0	0	0	21	1	0	0	0	0	0	22	95
T	8	0	0	0	9	0	0	4	4	0	0	0	0	0	17	24
r	9	8	0	0	0	0	5	8	16	0	0	5	0	0	42	0
u	10	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
t	11	0	15	0	0	0	9	0	135	0	0	90	0	0	249	36
h	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	13	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
TOTAL		9	27	0	18	0	18	72	207	0	0	117	0	0	468	
%Corr		0	41	0	11	0	0	29	2	0	0	77	0	0		

Total Accuracy: 27%

Underlined values indicate correctly classified cells.

APPENDIX VII

A Comparison of Medium Scale Color Infrared (MSCIR) Photography Data with Ground Truth Using a Combined Classification at the Pixel Level.

Classified Vegetation Type

		1	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL	% Correct
	1	4	0	0	0	0	0	0	0	0	0	0	0	0	4	100
G	2	19	0	0	1	0	0	0	0	1	0	0	0	0	21	0
r	3	0	0	6	0	0	0	1	0	0	0	0	0	0	7	86
o	4	1	0	1	11	7	0	0	0	0	0	1	0	0	21	52
u	5	0	0	0	2	7	0	3	0	8	0	0	0	0	20	35
n	6	0	0	0	0	1	25	18	8	2	0	9	0	0	63	40
d	7	0	0	0	0	0	1	9	0	11	0	1	0	0	22	41
	8	0	0	0	0	0	0	13	0	0	0	4	0	0	17	0
T	9	5	0	0	2	2	4	0	0	26	0	3	0	0	42	62
r	10	0	0	0	0	0	0	0	0	0	1	0	0	0	1	100
u	11	8	6	0	1	5	1	7	6	34	0	181	0	0	249	73
t	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
h	13	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
TOTAL		37	6	7	18	22	31	51	14	82	1	199	0	0	468	
%Corr		11	0	86	61	32	81	18	0	35	100	91	0	0		

Total Accuracy: 58%

Underlined values indicate correctly classified cells.

APPENDIX VIII

A Comparison of Machine Classified Landsat (MCL) with Ground Truth Using a Combined Classification at the Site Level

Classified Vegetation Type

		1	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL	% Correct
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	2	0	3	0	0	0	0	0	0	0	0	1	0	0	4	75
r	3	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
o	4	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0
u	5	0	0	0	0	0	0	1	0	2	0	0	0	0	3	0
n	6	0	0	0	0	0	3	0	0	3	0	0	0	0	6	50
d	7	0	0	0	0	0	2	0	0	1	0	0	0	0	3	0
	8	0	0	0	0	0	1	0	0	1	0	0	0	0	2	0
T	9	0	0	0	1	0	1	0	0	0	0	1	0	0	3	0
r	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
u	11	1	8	0	0	0	4	3	0	3	0	9	0	0	28	32
t	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
h	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL		1	11	0	1	0	13	4	0	10	0	12	0	0	52	
%Corr		0	27	0	0	0	23	0	0	0	0	75	0	0		

Total Accuracy: 29%

Underlined values indicate correctly classified cells.

APPENDIX IX

A Comparsion of Color Composite Landsat (CCL) with Ground Truth Using a Combined Classification at the Site Level.

Classified Vegetation Type

		1	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL	% Correct
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
G	2	0	1	0	0	0	0	0	0	0	0	3	0	0	4	25
r	3	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
o	4	0	0	0	0	0	0	1	0	0	0	1	0	0	2	0
u	5	0	0	0	1	0	0	2	0	0	0	0	0	0	3	0
n	6	0	0	0	0	0	0	6	0	0	0	0	0	0	6	0
d	7	0	0	0	0	0	0	3	0	0	0	0	0	0	3	100
	8	0	0	0	1	0	0	0	1	0	0	0	0	0	2	50
T	9	0	0	0	0	0	1	0	1	0	0	1	0	0	3	0
r	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
u	11	0	1	0	0	1	0	0	14	0	0	12	0	0	28	43
t	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
h	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
TOTAL		0	2	0	2	0	2	13	16	0	0	17	0	0	52	
%Corr		-	50	-	0	0	0	23	6	-	-	71	-	-		

Total Accuracy: 33%

Underlined values indicate correctly classified cells.

APPENDIX X

A Comparison of Medium Scale Color Infrared (MSCIR) Photography Data With Ground Truth Using a Combined Classification at the Site Level.

Classified Vegetation Type

Ground Truth	1	2	3	4	5	6.	7	8	9	10	11	12	13	TOTAL	% Correct
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
2	2	2	0	0	0	0	0	0	0	0	0	0	0	4	50
3	0	0	1	0	0	0	0	0	0	0	0	0	0	5	20
4	0	0	0	1	1	0	0	0	0	0	0	0	0	2	50
5	0	0	0	0	1	0	1	0	1	0	0	0	0	3	33
6	0	0	0	0	0	3	1	1	0	0	1	0	0	6	50
7	0	0	0	0	0	0	1	0	2	0	0	0	0	3	33
8	0	0	0	0	0	1	1	0	0	0	0	0	0	2	0
9	0	0	0	0	0	0	0	0	3	0	0	0	0	3	100
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
11	1	1	0	0	1	0	0	2	4	0	19	0	0	28	68
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
TOTAL	3	3	1	1	3	4	4	3	10	0	20	0	0	52	
%Corr	0	67	100	100	33	75	25	0	30	-	95	-	-		

Total Accuracy: 60%

Underlined values indicated correctly classified cells.

APPENDIX XI

A Comparison of Machine Classified Landsat (MCL) with Ground Truth Using a Collapsed Classification at the Pixel Level.

Classified Vegetation Type

		1	2	3	4	5	6	7	TOTAL	% Correct
Ground Truth	1	8	0	0	1	0	16	0	25	32
	2	1	0	0	9	5	6	0	21	0
	3	0	4	0	4	12	0	0	20	0
	4	1	5	0	52	35	6	3	102	51
	5	5	1	0	17	9	8	2	42	21
	6	72	0	0	63	32	77	5	249	31
	7	2	2	0	3	0	2	0	9	0
TOTAL		89	12	0	149	93	115	10	468	
%Corr		9	0	-	35	10	67	0		

Total Accuracy: 31%

Underlined values indicate correctly classified cells.

APPENDIX XII

A Comparison of Color Composite Landsat (CCL) With Ground Truth Using a Collapsed Classification at the Pixel Level.

Classified Vegetation Type

Ground Truth		1	2	3	4	5	6	7	TOTAL	% Correct
	1	13	0	0	0	0	12	0	25	52
	2	0	2	0	9	0	10	0	21	10
	3	0	7	0	13	0	0	0	20	0
	4	0	9	0	93	0	0	0	102	91
	5	8	0	0	29	0	5	0	42	0
	6	15	0	0	144	0	90	0	249	36
	7	0	0	0	9	0	0	0	9	0
TOTAL		36	18	0	297	0	117	0	468	
%Corr		36	11	-	31	-	77	-		

Total Accuracy: 42%

Underlined values indicate correctly classified cells.

APPENDIX XIII

A Comparison of the Medium Scale Color Infrared (MSCIR) Photography Data With Ground Truth Using a Collapsed Classification at the Pixel Level

Classified Vegetation Type

		1	2	3	4	5	6	7	TOTAL	% Correct
Ground Truth	1	<u>23</u>	1	0	0	1	0	0	25	92
	2	1	<u>11</u>	7	0	0	1	1	21	52
	3	0	2	<u>7</u>	3	8	0	0	20	35
	4	0	0	1	<u>74</u>	13	14	0	102	73
	5	5	2	2	4	<u>26</u>	3	0	42	62
	6	14	1	5	14	34	<u>181</u>	0	249	73
	7	0	1	0	1	0	0	<u>7</u>	9	78
TOTAL		43	18	22	96	82	199	8	468	
%Corr		53	61	32	77	32	91	88		

Total Accuracy: 70%

Underlined values indicate correctly classified cells.

APPENDIX XIV

A Comparison of Machine Classified Landsat (MCL) With Ground Truth Using a Collapsed Classification at the Site Level.

Classified Vegetation Type

		1	2	3	4	5	6	7	TOTAL	% Correct
Ground Truth	1	3	0	0	0	0	1	0	4	75
	2	0	0	0	2	0	0	0	2	0
	3	0	0	0	1	2	0	0	3	0
	4	0	0	0	6	5	0	0	11	55
	5	0	1	0	1	0	1	0	3	0
	6	9	0	0	7	3	9	0	28	32
	7	0	0	0	0	0	1	0	1	0
TOTAL		12	1	0	17	10	12	0	52	
%Corr		25	0	-	35	0	75	-		

Total Accuracy: 35%

Underlined values indicate correctly classified cells.

APPENDIX XV

A Comparison of Color Composite Landsat (CCL) With Ground Truth Using a Collapsed Classification at the Site Level.

Classified Vegetation Type

		1	2	3	4	5	6	7	TOTAL	% Correct
Ground Truth	1	1	0	0	0	0	3	0	4	25
	2	0	0	0	1	0	1	0	2	0
	3	0	1	0	2	0	0	0	3	0
	4	0	1	0	10	0	0	0	11	91
	5	0	0	0	2	0	1	0	3	0
	6	1	0	0	15	0	12	0	28	43
	7	0	0	0	1	0	0	0	1	0
TOTAL		2	2	0	31	0	17	0	52	
%Corr		50	0	-	32	-	71	-		

Total Accuracy: 44%

Underlined values indicate correctly classified cells.

APPENDIX XVI

A Comparison of Medium Scale Color Infrared (MSCIR) Photography Data With Ground Truth Using a Collapsed Classification at the Site Level.

Classified Vegetation Type

		1	2	3	4	5	6	7	TOTAL	% Correct
Ground Truth	1	4	0	0	0	0	0	0	4	100
	2	0	1	3	0	0	0	0	2	50
	3	0	0	1	1	1	0	0	3	33
	4	0	0	0	8	2	1	0	11	73
	5	0	0	0	0	3	0	0	3	100
	6	2	0	1	2	4	19	0	28	68
	7	0	0	0	0	0	0	1	1	100
TOTAL		6	1	3	11	10	20	1	52	
%Corr		67	100	33	73	30	95	100		

Total Accuracy: 71%

Underlined values indicate correctly classified cells.

APPENDIX XVII

A Comparison of Machine Classified Landsat (MCL) with Ground Truth
Using a General Classification at the Pixel Level.

Classified Vegetation Type

Ground Truth	1	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL	% Correct
1	0	0	0	0	0	1	0	0	0	0	3	0	0	4	0
2	4	4	0	0	0	0	0	0	0	0	13	0	0	21	100
3	2	0	0	0	0	3	0	0	0	0	2	0	0	7	0
4	1	0	0	0	0	9	0	0	5	0	6	0	0	21	0
5	0	0	0	4	0	4	0	0	12	0	0	0	0	20	60
6	1	0	3	5	0	30	0	0	21	0	3	0	0	63	48
7	0	0	0	0	0	14	0	0	7	0	1	0	0	22	95
8	0	0	0	0	0	8	0	0	7	0	2	0	0	17	59
9	1	4	0	1	0	17	0	0	9	2	8	0	0	42	21
10	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
11	29	43	2	0	0	63	0	0	32	0	77	3	0	249	48
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
13	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
TOTAL	38	51	5	12	0	149	0	0	93	2	115	3	0	468	
%Corr	11	92	0	0	-	30	-	-	30	0	80	0	-		

Total Accuracy: 48%

Underlined values indicate correctly classified cells.

APPENDIX XVIII

A Comparison of Color Composite Landsat (CCL) with Ground Truth Using a General Classification at the Pixel Level.

Classified Vegetation Type

Ground Truth	1	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL	% Correct
1	0	1	0	0	0	0	0	0	0	0	3	0	0	4	25
2	1	11	0	0	0	0	0	0	0	0	9	0	0	21	100
3	0	0	0	0	0	0	0	7	0	0	0	0	0	7	0
4	0	0	0	2	0	0	0	9	0	0	10	0	0	21	10
5	0	0	0	7	0	2	11	0	0	0	0	0	0	20	0
6	0	0	0	0	0	0	28	35	0	0	0	0	0	63	100
7	0	0	0	0	0	0	21	1	0	0	0	0	0	22	100
8	0	0	0	9	0	0	4	4	0	0	0	0	0	17	47
9	8	0	0	0	0	5	8	16	0	0	5	0	0	42	19
10	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
11	0	15	0	0	0	9	0	135	0	0	90	0	0	249	96
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–
13	0	0	0	0	0	1	0	0	0	0	0	0	3	0	–
TOTAL	9	27	0	18	0	18	72	207	0	0	117	0	0	468	
%Corr	11	96	–	11	–	0	85	85	–	–	85	–	–		

Total Accuracy: 78%

Underlined values indicate correctly classified cells.

APPENDIX XIX

A Comparison of Medium Scale Color Infrared (MSCIR) Photography Data With Ground Truth Using a General Classification at the Pixel Level.

Classified Vegetation Type

Ground Truth	1	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL	% Correct
1	4	0	0	0	0	0	0	0	0	0	0	0	0	4	100
2	19	0	0	1	0	0	0	0	1	0	0	0	0	21	90
3	0	0	6	0	0	0	1	0	0	0	0	0	0	7	86
4	1	0	1	11	7	0	0	0	0	0	1	0	0	21	52
5	0	0	0	2	7	0	3	0	8	0	0	0	0	20	75
6	0	0	0	0	1	25	18	8	2	0	9	0	0	63	81
7	0	0	0	0	0	1	9	0	11	0	1	0	0	22	95
8	0	0	0	0	0	0	13	0	0	0	4	0	0	17	100
9	5	0	0	2	2	4	0	0	26	0	3	0	0	42	67
10	0	0	0	0	0	0	0	0	0	1	0	0	0	1	100
11	8	6	0	1	5	1	7	6	34	0	181	0	0	249	78
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–
13	0	0	0	1	0	0	0	0	0	0	0	0	0	0	–
TOTAL	37	6	7	18	22	31	51	14	82	1	199	0	0	468	
%Corr	62	100	86	61	41	81	78	100	55	100	93	–	–		

Total Accuracy: 78%

Underlined values indicate correctly classified cells.

APPENDIX XX

A Comparison of Machine Classified Landsat (MCL) Data With Ground Truth Using a General Classification at the Site Level.

Classified Vegetation Type

Ground Truth	1	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL	% Correct
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
2	0	3	0	0	0	0	0	0	0	0	1	0	0	4	100
3	0	0	0	0	0	0	0	0	0	0	1	0	0	1	-
4	0	0	0	0	0	2	0	0	0	0	0	0	0	2	-
5	0	0	0	0	0	0	1	0	2	0	0	0	0	3	67
6	0	0	0	0	0	3	0	0	3	0	0	0	0	6	50
7	0	0	0	0	0	2	0	0	1	0	0	0	0	3	100
8	0	0	0	0	0	1	0	0	1	0	0	0	0	2	50
9	0	0	0	1	0	1	0	0	0	0	1	0	0	3	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1	8	0	0	0	4	3	0	3	0	9	0	0	28	61
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
TOTAL	1	11	0	1	0	13	4	0	10	0	12	0	0	52	
%Corr	0	100	-	0	-	46	0	-	30	0	83	0	0		

Total Accuracy: 58%

Underlined values indicate correctly classified cells.

APPENDIX XXI

A Comparison of Color Composite Landsat (CCL) With Ground Truth Using a General Classification at the Site Level.

Classified Vegetation Type

Ground Truth	1	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL	% Correct
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–
2	0	1	0	0	0	0	0	0	0	0	3	0	0	4	100
3	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
4	0	0	0	0	0	0	1	0	0	0	1	0	0	2	0
5	0	0	0	1	0	0	2	0	0	0	0	0	0	3	0
6	0	0	0	0	0	0	6	0	0	0	0	0	0	6	100
7	0	0	0	0	0	0	3	0	0	0	0	0	0	3	100
8	0	0	0	1	0	0	0	1	0	0	0	0	0	2	50
9	0	0	0	0	0	1	0	1	0	0	1	0	0	3	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	1	0	0	1	0	0	14	0	0	12	0	0	28	96
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–
TOTAL	0	2	0	2	0	2	13	16	0	0	17	0	0	52	
%Corr	–	100	–	0	0	0	69	94	–	–	88	–	–		

Total Accuracy: 79%

Underlined values indicate correctly classified cells.

APPENDIX XXII

A Comparison of Medium Scale Color Infrared (MSCIR) Photography Data With Ground Truth Using a General Classification at the Site Level

Classified Vegetation Type

Ground Truth	1	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL	% Correct
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
2	2	2	0	0	0	0	0	0	0	0	0	0	0	4	100
3	0	0	1	0	0	0	0	0	0	0	0	0	0	5	100
4	0	0	0	1	1	0	0	0	0	0	0	0	0	2	50
5	0	0	0	0	1	0	1	0	1	0	0	0	0	3	67
6	0	0	0	0	0	3	1	1	0	0	1	0	0	6	83
7	0	0	0	0	0	0	1	0	2	0	0	0	0	3	100
8	0	0	0	0	0	1	1	0	0	0	0	0	0	2	100
9	0	0	0	0	0	0	0	0	3	0	0	0	0	3	100
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
11	1	1	0	0	1	0	0	2	4	0	19	0	0	28	79
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
TOTAL	3	3	1	1	3	4	4	3	10	0	20	0	0	52	
%Corr	67	100	100	100	33	100	75	100	70	-	95	-	-		

Total Accuracy: 83%

Underlined values indicate correctly classified cells.

APPENDIX XXIII

Percent Aerial Cover from Ground Truth Vegetation Measurements

Piceance Basin

Quad Name	Sample Number	AS	BB	CC	DF	GW	JN	MM	OB	PN	RB	SB	SG	SN	OT
Square S Ranch	7						28	1		4	3	58	4	2	
	12						18			5	6		75		
	14										28	2	57	7	6
	16						10				2		88		
	17						33			2	4		61		
	22		5				65	1		20	1		8		
	25		1				61	10		19	6	4			
	30		2				27			17			54		
	44						46			40	1		13		1
	47					44					2		54		
No Name Ridge	1		1						7			48	26	18	1
	8						1		37		1	23	10	26	3
	12			1	20		26					21	5	23	6
	17		1		5		22	1	1			27	15	26	3
	20			1			6				16	26	16	39	1
Razorback Ridge	6		5								38	1	50	6	
	12		21									31	40	9	
	22		1								17		31	48	3
	24										6		40	54	
	29	4									11		46	32	7
	41										4		84	12	
	48	46									1			53	1
Segar Mtn.	6						2	14	32	32	1	8	4	7	
	10							11	33	8		46		1	
	13		17		22		13		1	29	2	1	1	13	1
	25										52		48		
	31		6	2			9	5	44	1	4	16	4	8	4
	33		1					9	28			46	8	9	
	36										23	2	47	28	
	37		1	1					26	1	1	43	10	17	1
	39				1		9	11	39	3	1	17	1	18	2
	43		5				1					47	31	17	
Circle Dot Gulch	1	1		4					7		1	33			1
	10								21		1	40	12	25	4
	15								2		3	38	8	46	5
	20	6							20		3	9	7	6	
	32	8							4		3	40	6	36	4
	39	58		6								9		22	6

APPENDIX XXIII Percent Aerial Cover from Ground Truth Cont.

Quad Name	Sample Number	AS	BB	CC	DF	GW	JN	MM	OB	PN	RB	SB	SG	SN	
							VEGETATION TYPE								
Cutoff Gulch	23			6					50			12	8	24	
	30			1				9	13		2	39	4	26	7
	40			1					1		13	15	21	48	1
	42		1	2					30		1	20	5	35	1
Clamity	5		11				2	3		8	3	54	8	10	
	6							4			16	45	25	11	
	16						7	15		29		44	1	4	
	17										3	70	22	6	
	22						1	16		1		82			
	23										41	9	4	47	
	30									8		37	20	35	
	35							6			1	57	1	33	2
	40							10			3	32	43	11	2
	46							6			1	40	35	18	1

APPENDIX XXIV

Comparison of Landsat MCL and MSCIR (1:24,000)
With Ground Truthing (GT)
In Pixels 2, 5, & 8
(Combined Classification - 13 Classes)

QUAD	SAMPLE NUMBER	MCL	MSCIR	GT
Square S Ranch	7	SG	PJ	PJ
	12	SG	SG	SG, PJ/SG, PJ/SG
	14	GR, WE, WE	GR, SG, SG	RD, SG, SG
	16	SG	SG	SG, SG, HA
	17	PJ, PJ, SG	PJ/SG, PJ/SG,SG	PJ/US, HA, HA
	22	PJ	PJ/SG	PJ/SG, PJ/SG, PJ/US
	25	SG, SG, PJ	PJ	PJ
	30	PJ	SG	PJ/SG, SG, PJ/SG
	44	SG, GR, SG	PJ	PJ/SG, PJ, PJ
	47	SG, GR, SG	HA	HA
No Name Ridge	1	AS	US	US
	8	PN, AS/US,AS/US	US	US
	12	US, PJ, US	GR, DF, DF	GR, DF, DF
	17	PJ, PJ, US	US, US, PJ/SG	US, PJ, PJ
	20	PJ, US, US	US	US
	24	PJ, AS/US, US	US, US, AS	US

APPENDIX XXIV Comparison of Landsat MCL and MSCIR (1:24,000) with Ground Truthing (GT) In Pixels 2, 5, & 8 Cont.

Razorback Ridge	6	SG	SG	US
	12	PJ	SG	US
	29	US	SG, SG, AS	SG
	22	US, AS/US, US	US	US
	41	AS/US, US, AS	US	US
	48	US	AS, AS, GR	AS/US, AS/US, GR
Segar Mountain	6	SG	PJ/SG	PJ/US
	10	US, AS/US, PJ	US	US
	13	PJ	PJ/SG	PJ
	25	PJ, PJ, SG	HA	US, SG, SG
	31	PJ	SG	US, SG, SG
	28	US, US, PJ	US	US
	36	PJ, SG, PJ	SG	SG, US, US
	37	US	US	US
	39	PJ	US, PJ/SG, SG	US, PJ, PJ
	43	PJ	US	US
Circle Dot Gulch	1	US, US,AS/US	US	US
	10	AS, AS, AS/US	AS, AS, SG	US
	15	US	US	US
	20	AS/US, US, US	SG	US, US, AS/US
	32	AS/US, AS, AS	AS, US, US	AS/US, US, US
	39	AS, US, US	AS	AS/US

APPENDIX XXIV Comparison of Landsat MCL and MSCIR (1:24,000) with Ground Truthing (GT) In Pixels 2, 5, & 8 Cont.

Cutoff Gulch	23	PJ	US, GR, GR	US, GR, GR
	30	AS	US	US, GR, US
	40	US	AS, US, US	SG, US, US
	42	AS, AS/US, AS/US	AS/US, AS/US, US	US
Calamity Ridge	5	SO, SG, SG	US, US, PJ/SG	US
	6	AS/US, AS, US	US, SG, US	SG, US, US
	16	PJ	US, PJ/US, PJ/US	PJ
	17	PJ	US	US
	22	DF, PJ, SG	PJ/US	PJ, US, US
	23	PJ, PJ, US	US, HA, HA	US