Assessing Rangeland Vegetation Mapping Alternatives for Geographic Information Systems

Samuel C. Williamson
National Ecology Center, U.S. Fish and Wildlife Service, 2627 Redwing Road, Fort Collins, CO 80526
Ivo E. Lindauer
Department of Biological Sciences, University of Northern Colorado, Greeley, CO 80639

ABSTRACT: The accuracy and cost of three sources of geographic information system vegetation-cover data were assessed for use in wildlife habitat simulation modeling. Maps derived from machine classified Landsat digital multispectral scanner data were 26 percent accurate; maps produced from manual interpretation of false color composite Landsat multispectral scanner images were 27 percent accurate; and maps produced from manual photointerpretation of medium scale (1:24,000) color infrared aerial photography were 58 percent accurate. Maps from color composite Landsat data cost the least at 0.15 cents/hectare, followed by machine classified Landsat data at 10.2 cents/hectare, and aerial photography data at 20.3 cents/hectare.

INTRODUCTION

THERE IS AN INCREASING NEED and trend to incorporate rangeland vegetation inventories into a geographic information system (Carneggie *et al.*, 1983). Vegetation mapping can be a major cost of setting up a geographic information system data base and should be designed to obtain the required information, with the desired accuracy and precision, at a reasonable cost. We believe, as Walsh *et al.* (1987) recommended, that land managers and computer specialists should be more critical of data bases assembled for inclusion into a geographic information system.

In the intermountain West, there is an intense need to inventory wildlife habitat as part of an effort to reduce the cumulative impacts of energy development. In developing ecosystem simulation models to predict these impacts on wildlife habitat, we needed a geographic information system data base that had a relatively low cost but acceptable accuracy. A quantitative assessment was conducted to evaluate the accuracy and cost of three remote sensing techniques that had been used to produce vegetation-cover data bases in geographic information system formats. A manually classified, false color composite Landsat (CCL) multispectral scanner image data base was being used for northwest Colorado, but its accuracy was undetermined. The primary objective of our study was to determine if we were obtaining an acceptable level of accuracy from CCL in comparison with much more expensive techniques, such as machine classified Landsat (MCL) multispectral scanner digital data and manually classified medium scale (1:24,000) color infrared (CIR) aerial photography data.

BACKGROUND

The U.S. Fish and Wildlife Service (Service) conducted an operational mapping project of five counties in northwest Colorado and nine counties in northeast Utah as part of an effort to assess the cumulative impacts of coal, shale oil, and tarsands development on wildlife habitat. False color composite (1:250,000) Landsat multispectral scanner imagery purchased from the EROS Data Center, U.S. Geological Survey, provided the source for the CCL data base (Landsat scenes 94416492 dated 23 August 1977 and 134016561 dated 23 September 1978). The mapping products that resulted from manual interpretation were 1:250,000 scale transparent overlays of Geological Survey topographic maps using a 260-hectare minimum mapping unit (65-hectare for wetlands) and a classification system of Level 2 as specified by Anderson *et al.* (1976).

The Service Energy Program and Bureau of Land Management (BLM) Colorado State Office conducted a mapping project that provided a surface cover and vegetation data base for the Piceance Basin Resource Management Plan. The medium scale (1:24,000) CIR 9- by 9-inch transparency and print aerial photography was acquired from missions flown in the summer of 1981. The mapping products were 1:24,000-scale transparent overlays of Geological Survey topographic maps using a 4-hectare minimum mapping unit (0.2-hectare for wetlands) and a classification system of Level 4 (overstory species or species association with percent canopy closure category and understory species association). The BLM's Resource Management Plan and Environmental Impact Statement used the CIR data base in the Map Overlay and Statistical System (MOSS) geographic information system.

An MCL mapping project was conducted by the BLM Denver Service Center for land-use planning in the White River Resource Area, which included the Piceance Basin Planning Area. The MCL mapping task used Landsat scene 8223471750X0 dated 20 July 1980. The project area was registered to a 50-m by 50-m grid using one ground control point for reach of the 34 7.5-minute quadrangles of the Planning Area. Forty-two spectral classes in four elevation breaks were grouped into 32 resource categories (Level 3) using an unsupervised classification and a maximum likelihood decision rule. Procedures for computer-assisted image interpretation (MCL) and manual image interpretation (CCL and CIR) have been described by Estes *et al.* (1983).

STUDY AREA

The Piceance Basin Planning Area, located principally in Rio Blanco County in northwest Colorado, comprises approximately 327,000 hectares of land as delineated in the BLM's Resource Management Plan (U.S. Department of the Interior, Bureau of Land Management, 1984). Approximately 77 percent (249,000 hectares) of this land 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 rises

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in elevation from about 1,700 metres at the White River in the northwest to 2,600 metres on the Roan Plateau to the south.

The vegetation of the Piceance Basin has been divided into seven major community types (U.S. Department of the Interior, Bureau of Land Management, 1984). These are (1) halophytic shrubland, including saltbush (*Atriplex* spp.) and greasewood (*Sarcobatus vermiculatus*); (2) sage (*Artemisia* spp.) shrubland in various associations with other species; (3) pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus* spp.) woodland, in various associations; (4) upland shrubland, including serviceberry (*Amelanchier alnifolia*), snowberry (*Symphoricarpos occidentalis*), Gambel's oak (*Quercus gambelli*), sage, mountain mahogany (*Cercocarpus montanus*), bitterbrush (*Purshia tridentata*), chokecherry (*Prunus virginiana*), and rabbitbrush (*Chrysothamnus* spp.); (5) aspen (*Populus tremuloides*) woodland; (6) Douglas-fir (*Pseudotsuga menziesii*) woodland; and (7) grassland. Roads, barren lands, wetlands, and rock outcrops occupy 4 percent, or 11,000 hectares, of the basin.

METHODS

To quantitatively assess the accuracy of vegetation data from various mapping methods, at least 50 sample stations are required (Hay, 1979). Our sampling design contained six randomly selected replicates (7.5-minute quadrangles), ten randomly selected sites (surveyed public land survey section corner monuments) per replicate, and nine sampling units (50-metre by 50-metre cells) per site. Legal access problems and an incomplete public land survey caused a reduction in the sample size to 52 sites.

Two project crews conducted the ground reference data collection in September 1983. The area surrounding the section corner monument was divided into a three-cell by three-cell (150 metres by 150 metres) area centered on the monument. After measuring the canopy cover of woody species along a 150-metre line transect running north to south and centered on the section corner monument, project crews assigned each cell to a vegetation type.

At the cell level, a one-to-one manual comparison was made between the ground reference vegetation assignments for a cell and those obtained from MCL, CCL, and CIR. Vegetation assignment at the site level was determined by identifying the most frequently occurring vegetation type within the nine cells. Data obtained from the above comparisons were analyzed using a classification error matrix approach that identifies the number of correctly identified points (concurrence between ground reference and remotely sensed data) as well as errors due to omission or commission (Rosenfield, 1986). Overall error was 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 complete classification error matrices were reported in Lindauer *et al.* (1984).

Because the original classification systems were not directly comparable, it was necessary to assign all of the systems to a "combined" classification system containing only 13 categories (Level 2). Some categories were absent in one or more of the remote sensing systems used. To circumvent this problem, a second comparison was made by reducing the 13 categories to four categories, forming a "collapsed" classification system (Level 1).

RESULTS

A non-site-specific comparison of the areas in the six sampled quadrangles found major differences in woodland and shrubland areas between the MCL and CIR mapping techniques. The MCL technique mapped much more aspen woodland (14,600 hectares versus 2,800 hectares) and pinyon pine-juniper woodland (29,900 hectares versus 20,200 hectares), but less sage shrubland (15,800 hectares versus 35,600 hectares) than did the CIR technique.

For the first set of site-specific comparisons, each of the original classification systems was condensed into 13 categories (Table 1). Using the combined classification system, CCL maps were 27 percent accurate, MCL maps were 26 percent accurate, and CIR maps were 58 percent accurate (Table 2). At the site level, CCL maps were 33 percent accurate, MCL maps were 29 percent accurate, and CIR maps were 60 percent accurate.

In the combined classification system, some categories were missing. For example, the MCL classification system did not distinguish among the pinyon pine-juniper woodland associations. Thus, it had no matches for the pinyon pine-juniper/sage or pinyon pine-juniper/upland shrub categories in the other classifications. To evaluate this negative bias, the combined classification was collapsed to four vegetation types to provide matches for all categories (Table 1). Using the collapsed classification system, CCL maps were 45 percent accurate, MCL maps were 41 percent accurate, and CIR maps were 81 percent accu-

TABLE 1. COMBINED AND COLLAPSED CLASSIFICATION SYSTEM (13 CATEGORIES OF THE COMBINED CLASSIFICATION SYSTEM WERE CONDENSED TO FOUR CATEGORIES).

Combined Classification System	Collapsed Classification System
1. AS	AS
2. AS/US	AS
3. DF	OT*
4. GR	OT*
5. HA	OT*
6. PJ	PJ
7. PJ/SG	PJ
8. PJ/US	PJ
9. SG	SH
10. WE	OT*
11. US	SH
12. SO	OT*
13. RD	OT*

AS Aspen woodland
DF Douglas-fir woodland
GR Grassland
HA Halophytic shrubland
OT Other
PJ Pinyon pine/juniper woodland
RD Road
SG Sage shrubland
SH Upland/sage shrubland
SO Shale outcrop
US Upland shrubland
WE Wetland

*Those classes with less than 23 (5 percent of total) occurrences (DF, GR, HA, WE, SO, RD) were classified into a new "other" grouping.

TABLE 2. ACCURACY, USING THE COMBINED CLASSIFICATION SYSTEM, OF THREE RANGELAND VEGETATION MAPPING ALTERNATIVES AS COMPARED TO GROUND REFERENCE DATA. THE NUMBERS INDICATE THE CELLS (468 TOTAL) CLASSIFIED AS SUCH. THE NUMBER IN PARENTHESES IS THE NUMBER OF CELLS CORRECTLY CLASSIFIED.

	Ground Reference	CCL (Correct)	MCL (Correct)	CIR (Correct)
Aspen woodland	4	9(0)	38(0)	37(4)
Pinyon pine-juniper woodland	63	18(0)	149(30)	31(25)
Sage shrubland	42	0(0)	93(9)	82(26)
Upland shrubland	249	117(90)	115(77)	199(181)
All others	110	324(38)	73(4)	119(34)

rate (Table 3). Using the collapsed classification at the site level, CCL maps were 48 percent accurate, MCL maps were 42 percent accurate, and CIR maps were 85 percent accurate.

Larger mapping units frequently contain a number of detected but unrecognized cover types in a heterogeneous mixture with the recognized dominant cover type. Due to the mixture of vegetation types frequently present and the subjectively recognized edges used for polygon delineation, overall polygon accuracy may not be as great as it appears. Site comparisons (larger mapping units consisting of nine cells) were very similar to cell comparisons, with site comparisons always 1 to 6 percent higher in accuracy. The relatively minor and consistent differences between the two levels of comparison indicate that either could be used in other comparisons, but the cell level comparison is recommended because it provides larger samples sizes and slightly better resolution at little additional data collection cost. The small differences between cell and site comparisons may be an indication that map registration errors and boundary line delineation errors were minor compared with classification errors (Hord and Brooner, 1976). The MCL accuracy was slightly less than CCL accuracy, which was always much less than CIR accuracy.

A comparison of the costs for mapping vegetation demonstrates the reduced costs associated with satellite imagery (Table 4). The cost for CIR vegetation mapping at 1:24,000 scale was approximately 130 times greater than CCL at 1:250,00 scale and twice the cost of MCL at 1:24,000 scale. Mapping cost-efficiency was defined as percent accuracy (from the cell level and combined classification system) divided by cost for a digital vegetation data base (in cents/hectare). For regional mapping tasks, where lower overall accuracy may be acceptable, CCL was 60 times more cost-effective than either MCL or CIR. For certain high interest areas, however, the accuracy and precision may not be high enough. In those areas, the use of CIR (with much greater accuracy and precision but much lower cost-effectiveness) is justifiable.

TABLE 3. ACCURACY, USING THE COLLAPSED CLASSIFICATION SYSTEM, OF THREE RANGELAND VEGETATION MAPPING ALTERNATIVES AS COMPARED TO GROUND REFERENCE DATA. THE NUMBERS INDICATE THE CELLS (468 TOTAL) CLASSIFIED AS SUCH. THE NUMBER IN PARENTHESES IS THE NUMBER OF CELLS CORRECTLY CLASSIFIED.

	Ground Reference	CCL (Correct)	MCL (Correct)	CIR (Correct)
Deciduous woodland	25	36(13)	89(8)	43(23)
Coniferous woodland	102	297(93)	149(52)	96(74)
Shrubland	291	117(95)	208(126)	281(244)
All others	50	18(9)	22(6)	48(36)

TABLE 4. COMPARISON OF GOVERNMENT AGENCY COSTS FOR THREE MAPPING PROJECTS CONDUCTED IN THE PICEANCE BASIN PLANNING AREA.

	CCL	MCL	CIR
Cost for acquisition of imagery* (cents/hectare)	0.005	0.10	3.7
Cost to convert imagery or data to final digital format (cents/hectare)	0.15	10.1	16.6
Total cost for digital vegetation data base (cents/hectare)	0.15	10.2	20.3
Cost-efficiency (cell level, combined classification system percent accuracy/cost for digital vegetation data base in cents/hectare)	180.	2.5	2.9

*Actual costs are based upon 1982 government agency contract rates of $15 for Landsat false color composite at 1:250,000 scale if the master already existed (otherwise $90), $300 for a Landsat digital data tape, and 3.7 cents/hectare for 1:24,000-scale aerial photography. Government agency costs for Landsat imagery have increased dramatically since 1982.

DISCUSSION

A tradeoff for the poor resolution of CCL (minimum mapping unit of 65 to 260 hectares) is the low cost per unit area. Linden *et al.* (1981) reported an accuracy of 83 to 88 percent and a CCL cost of 0.5 cents/hectare with a minimum mapping unit of 260 hectares. Because of the recent availability of satellite data with higher resolution and additional spectral bands, more can now be accomplished with satellite photographic products (Philipson, 1986).

For Landsat multispectral scanner digital data use in rangeland mapping, cover types need a minimum mapping unit of at least 8 to 16 hectares, due to the spatial heterogeneity and sparsity of vegetation (Carneggie *et al.*, 1983). Costs of MCL rangeland cover mapping were reported as 15 cents/hectare (Rohde and Miller, 1981) and 7.8 cents/hectare (Linden *et al.*, 1981). We found little justification for use of MCL data at the 1982 cost and stage of technology for rangeland mapping applications because of its high cost per unit area (60 times as much as CCL) and modest accuracy (no better than CCL). The cost for satellite digital data has greatly increased since the time of our study (Philipson, 1986).

Only with CIR and the collapsed classification system did we obtain an accuracy value of at least 70 percent, which is frequently used as a breakoff point for map acceptability. A more inexpensive source of CIR imagery, but unavailable at the time of this study, is medium-scale (1:58,000) photography from the National High Altitude Photography program. The 1982 government cooperator cost for stereo imagery was 0.2 cents/hectare, and the cost to convert the photography into a final digital format in MOSS was estimated to be a third less than for 1:24,000 aerial photography.

We recommend that agencies quantitatively assess and document their needs and the accuracy and cost of vegetation mapping alternatives before constructing large geographic information system data bases. For our purpose of combining wildlife habitat simulation modeling with a spatial data base from a geographic information system, we concluded that CCL map data provided sufficient accuracy (as good as MCL map data) at less than 2 percent of the cost of MCL map data. By increasing cost 130-fold, we could double the accuracy and greatly increase the precision using medium-scale CIR aerial photography. The BLM, with its land management responsibilities, found the greater precision and accuracy of rangeland vegetation mapping from medium scale CIR aerial photography to be worth the additional cost (U.S. Department of the Interior, Bureau of Land Management, 1984).

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REFERENCES

Anderson, J.A., E.E. Hardy, J.T. Roach, and R.E. Witmer, 1976. *A land use and land cover classification system for use with remote sensor data.* U.S. Geological Survey Prof. Paper 964, 28 p.

Carneggie, D.M., B.J. Schrumpf, and D.A. Mouat, 1983. Rangeland

applications. *Manual of Remote Sensing*. American Society of Photogrammetry, Falls Church, Va., Vol. 2, pp. 2325–2384.

Estes, J.E., E.J. Hajic, and L.R. Tinney, 1983. Fundamentals of image analysis: Analysis of visible and thermal infrared data. *Manual of Remote Sensing*, American Society of Photogrammetry, Falls Church, Va., Vol. 1, pp. 987–1124.

Hay, A.M., 1979. Sampling designs to test land use map accuracy. *Photogrammetric Engineering and Remote Sensing* 45:529–533.

Hord, R.M. and W. Brooner, 1976. Land-use map accuracy criteria. *Photogrammetric Engineering and Remote Sensing* 42:671–677.

Lindauer, I.E., S.C. Williamson, 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.

Linden, D.S., W.G. Rohde, and K.G. Bonner, 1981. Estimating the area of vegetation types with Landsat and ancillary data. *Proceedings Arid Land Resource Inventories: Developing Cost-efficient Methods*. U.S. Forest Serv. Gen. Tech. Rep. WO-28, pp. 279–286.

Philipson, W.R., 1986. Problem solving with remote sensing: an update. *Photogrammetric Engineering and Remote Sensing* 52:109–110.

Rohde, W.G., and W.A. Miller, 1981. *Arizona Vegetation Resources Inventory final report*. U.S. Geological Survey, EROS Data Center, internal report to BLM-Denver, 200 p.

Rosenfield, G.H., 1986. Analysis of thematic map classification error matrices. *Photogrammetric Engineering and Remote Sensing* 52:681–686.

U.S. Department of the Interior, Bureau of Land Management, 1984. *Piceance Basin Resource Management Plan and Environmental Impact Statement*. White River Resource Area, Meeker, Colo., 270 p.

Walsh, S.J., D.R. Lightfoot, and D.R. Butler, 1987. Recognition and assessment of error in geographic information systems. *Photogrammetric Engineering and Remote Sensing* 53:1423–1430.

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