Accuracy Assessment of a Landsat-Assisted Vegetation Map of the Coastal Plain of the Arctic National Wildlife Refuge

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ABSTRACT: An accuracy assessment of a vegetation map based on Landsat multispectral scanner data was conducted on the coastal plain of the Arctic National Wildlife Refuge. The overall map accuracy was 37 percent (SD = 4 percent) based on ground data collected at 126 sites. The majority of errors (27 percent of the total observations) occurred between closely related land-cover classes. Classes were related to each other along gradients of moisture, shrub cover, or total plant cover. Misclassification errors, where the plant community observed on the ground clearly did not agree with the map classification, occurred at 22 percent of the polygons sampled. The most common misclassifications occurred for braided river floodplain communities which were classified as very wet, wet, or moist/wet graminoid tundra. Description errors occurred for 4 percent of the polygons indicating that some of the land-cover class descriptions need additions or modifications to allow the user to accurately identify the class. In conclusion, the Landsat MSS map provides information on the distribution of general vegetation types across the coastal plain, but does not provide site-specific vegetation data.

INTRODUCTION

THE U.S. FISH AND WILDLIFE SERVICE (FWS) has developed land-cover maps of refuges in Alaska to provide a basis for planning and management decisions. A vegetation map based on digital classification of Landsat multispectral scanner (MSS) data was produced for the coastal plain of the Arctic National Wildlife Refuge by the Institute of Arctic and Alpine Research under contract to the FWS in 1982 (Walker *et al.*, 1982). A modified and expanded land-cover map was produced for the entire Arctic Refuge in 1985 through a cooperative effort of the FWS and the U.S. Geological Survey's (USGS) EROS Field Office in Anchorage, Alaska (Markon, 1986).

This land-cover map provided information on the distribution of vegetation types across the 630,000-hectare coastal plain study area for the baseline studies required by section 1002 of the Alaska National Interest Lands Conservation Act of 1980. Geological studies of oil and gas potential and biological studies of wildlife resources were conducted concurrently to provide information to the U.S. Congress. Congress is presently considering proposals ranging from wilderness designation to opening the area to oil and gas development.

The value of certain portions of the coastal plain to wildlife species is currently being studied to assess the potential impacts of petroleum activity. The coastal plain provides important habitat for a number of wildlife species, including:

- calving and insect-relief habitat for the Porcupine caribou herd,
- year-round feeding sites for muskoxen,
- staging grounds for snow geese prior to fall migration, and
- nesting areas for migratory bird species.

An accurate base map of land-cover types is needed to aid in predicting and minimizing impacts to wildlife if further oil and gas exploration or development occur on the coastal plain of the Arctic Refuge. This study assesses the accuracy of the Landsat land-cover map for this area.

STUDY AREA

The study area includes the coastal plain and foothills of northeastern Alaska between 142°W and 147°W latitude and north of 69°34′N longitude (Figure 1). It is bordered by the Brooks Range on the south, the Beaufort Sea on the north, the Aichilik River on the east, and the Canning River on the west. The study area comprises tundra vegetated with low-growing plants, including dwarf shrubs, sedges, grasses, forbs, mosses, and lichens. Shallow soils are underlain with permafrost, and the ground surface remains frozen from about mid-September to mid-May. A detailed description of the study area, including geology, climate, soils, vegetation, and wildlife can be found in Garner and Reynolds (1986).

METHODS

The 1985 land-cover map was produced using digital Landsat multispectral scanner data (MSS) and a supervised training procedure (Markon, 1986). Landsat scenes from 4 and 5 August, 1981 were obtained for the coastal plain area. The digital processing was conducted by the USGS EROS Field Office in Anchorage, using the Interactive Digital Image Manipulation System. The Landsat scenes were first radiometrically and geometrically corrected, and registered to a 50-m Universal Transverse Mercator (UTM) grid. Training blocks were selected in areas with representative land-cover types. Modified clustering techniques were used to generate initial spectral classes. These spectral classes were assigned to land-cover types based on field data from the training blocks. FWS personnel played a major role in developing the final map classes. Land-cover classes were merged with digital terrain data from 1:250,000-scale USGS topographic maps to improve class accuracy. Similar mapping procedures have been used for other refuges in Alaska (Shasby and Carneggie, 1986; Talbot and Markon, 1986).

Eighteen sites were selected for the accuracy assessment using stratified random sampling to obtain an even distribution across the coastal plain study area (Figure 1). Random samples were selected in each of six equal areas as defined by the boundaries of 1:63,360-scale topographic maps. At each site, five to ten polygons were sampled, for a total of 126 polygons. Each polygon encompassed a 10 to 100-hectare area which was mapped as one land-cover type on the 1985 map. The polygons selected at each site represented all the land-cover present at that site. Polygons were transferred from the maps to 1:63,360-scale color infrared photographs using a B&L Zoom Transfer Scope. These photos were used in the field for locating each polygon.

Two observers visited each polygon in late July 1987 using helicopter transportation. Polygons were initially viewed from the air to determine which vegetation type covered the majority

PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING,
Vol. 55, No. 4, April 1989, pp. 475–478.

0099-1112/89/5504–475$02.25/0

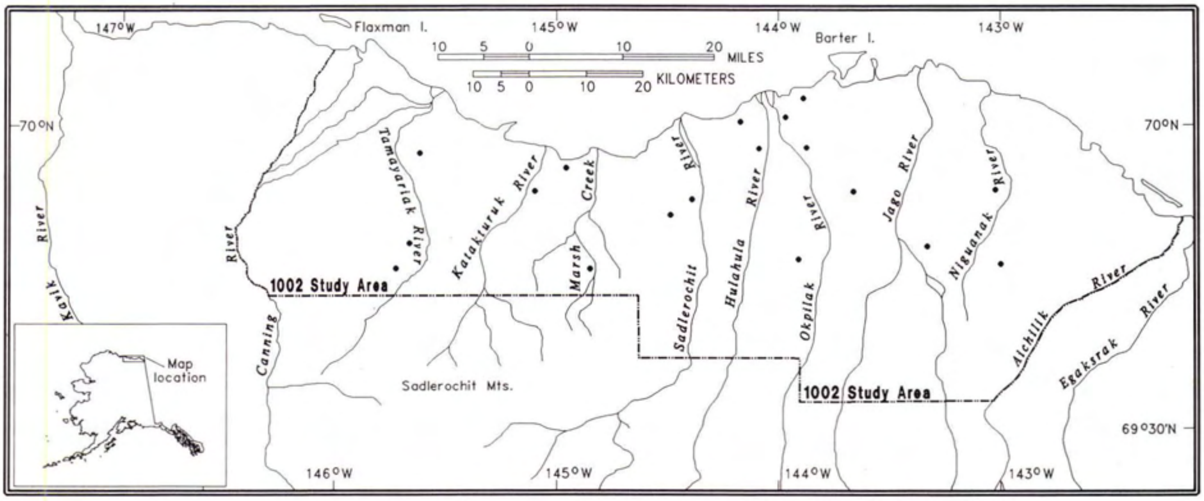

FIG. 1. Map of the study sites on the coastal plain of the Arctic National Wildlife Refuge in Alaska.

of the area. Brief data collection stops were made to record plant community descriptions, including moisture level, dominant species, and major life forms. Shrub cover and total vegetative cover were estimated, and each polygon was then classified into one of the Landsat land-cover classes described by Markon (1986). The more complete land-cover class descriptions developed by Walker *et al.* (1982) were sometimes used to supplement the 1985 descriptions, because equivalent classes occurred in the two classification schemes.

SAS Tabulate Procedure (SAS Inc., 1985) was used to produce a contingency table depicting agreements and disagreements between ground observations and Landsat map classes. The major diagonal of the table shows the number of agreements that occurred, while the off-diagonal elements of the table show how disagreements between ground observations and the map are dispersed over the different land-cover classes. The mean and standard deviation for overall accuracy was calculated using the methods of Card (1982). Overall map accuracy was calculated from the user's accuracies corrected by the proportions of each class on the land-cover map of the study area.

User's and producer's accuracies were calculated for each land-cover class (Story and Congalton, 1986). User's accuracy is the probability that a class shown on the map actually represents that class on the ground, and is calculated by dividing the number of agreements for a land-cover class by the total number of polygons classified on the map in that category. Producer's accuracy is the probability that a type on the ground will be adequately represented by the map, and is calculated by dividing the number of agreements for a land-cover class by the total number of ground observations for that category.

The ground descriptions of plant communities were used to evaluate the disagreements between ground observations and the map. Disagreements were classified into the following types of errors:

- Cutpoint – plant community observed on the ground is intermediate between two closely related land-cover classes;
- Misclassification – plant community observed on the ground clearly does not belong to map classification; and
- Description – land-cover class description needs modification.

RESULTS AND DISCUSSION

Overall, map accuracy was 37 percent (Table 1). The land-cover classes are listed such that adjacent classes are closely related. Thus, the distribution of disagreements around the major diagonal shows that many of the disagreements occurred between closely related land-cover classes. The majority of disagreements, 27 percent of all observations, were cutpoint errors (Table 2). Description errors, which could be corrected by modifying class descriptions, caused another 4 percent of the disagreements. Misclassifications accounted for only 22 percent of all observations. Therefore, 78 percent of the observations or 70 percent of the map (corrected for the proportions of vegetation types sampled) represented the general distribution of land-cover types on the coastal plain.

In terms of individual land-cover classes, clear water had the highest agreement value. Clear water had 100 percent user's accuracy, indicating that water can be accurately mapped using Landsat data (Table 1). Producer accuracy was 82 percent, as a few disagreements between water and very wet graminoid or barren floodplain occurred when the majority of a polygon was water but contained small inclusions of wet sedge of gravel bars. Water was strictly defined by the map and did not contain inclusions of any other land-cover type.

Moist/wet complex had low user's and producer's accuracies (Table 1), indicating that this class was not consistently identified by the Landsat data. Cutpoint errors frequently occurred among moist/wet complex and wet graminoid tundra or moist prostrate scrub which are related to each other along a moisture gradient (Table 2). Fourteen of the disagreements involving the moist/wet complex were cutpoint errors with wet graminoid or moist prostrate scrub. The ground observers assumed that at least 40 percent of each class must occur in a moist/wet complex site based on descriptions developed for the 1982 Landsat map (Walker *et al.*, 1982), because no quantitative cutpoint was given in the 1985 descriptions. Five out of eight polygons observed as moist/wet complex on the ground were classified as wet graminoid or moist prostrate scrub on the map. Ground descriptions at these polygons listed the map classification as the primary type, indicating that the map could distinguish between wet graminoid and moist prostrate shrub even when the ground observers determined that neither class occurred over 60 percent of the area. Deleting the moist/wet complex class from the map classification would improve accuracy.

User's accuracies for moist graminoid tussock were extremely low, indicating that areas mapped as these types were rarely in agreement with ground observations (Table 1). Seventeen polygons were classified as moist graminoid tussock on the map, but only two polygons were determined to be in this class on the ground. Much confusion occurred between moist graminoid tussock and moist prostrate scrub or mesic erect scrub. Eight

TABLE 1. CONTINGENCY TABLE COMPARING LANDSAT-DERIVED MAP CLASSIFICATIONS TO GROUND OBSERVATIONS

Ground observations Landsat land-cover class		Map classification Landsat land-cover class														
		CW	OW	SW	VW	WG	MW	MP	TT	ME	ADS	DP	SF	BF	Totals	Producer's accuracy (%)
Clear water	(CW)	**14**	·	·	1	·	·	·	·	·	·	·	·	2	17	82
Offshore water	(OW)	·	**1**	·	·	·	·	·	·	·	·	·	·	·	1	100
Shallow water	(SW)	·	·	·	1	1	·	·	·	·	·	·	·	1	3	0
Very wet graminoid	(VW)	·	·	·	**4**	1	·	·	·	·	·	·	·	·	5	80
Wet graminoid	(WG)	·	·	·	1	**11**	5	·	·	·	·	·	·	·	17	65
Moist/wet tundra complex	(MW)	·	·	·	·	3	**3**	2	·	·	·	·	·	·	8	38
Moist prostrate dwarf scrub	(MP)	·	·	·	·	2	5	**10**	11	3	·	·	·	1	32	31
Moist graminoid tussock	(TT)	·	·	·	·	·	·	1	**1**	·	·	·	·	·	2	50
Mesic erect dwarf scrub	(ME)	·	·	·	·	1	5	2	5	**4**	·	·	·	·	17	24
Alluvial deciduous scrub	(ADS)	·	·	·	·	1	1	·	·	·	·	·	1	·	3	0
Dry prostrate dwarf scrub	(DP)	·	·	·	·	·	1	2	·	·	·	**2**	4	·	9	22
Scarcely veg. floodplain	(SF)	·	·	·	1	·	·	·	·	·	·	·	**4**	1	6	67
Barren floodplain	(BF)	·	·	·	·	·	·	·	·	·	·	·	·	**6**	6	100
Totals		14	1	·	8	20	20	17	17	7	·	2	9	11	**126**	
User's Accuracy (%)		100	100	·	50	58	15	59	6	57	·	100	44	55		
Map area (%)		1.1	2.6	<0.1	0.3	13.7	15.4	25.2	30.1	7.3	0	0.7	1.4	2.0		
Overall map accuracy = 37%																
S.D. = 4%																

TABLE 2. NUMBER OF DISAGREEMENTS BETWEEN GROUND OBSERVATIONS AND MAP CLASSES ATTRIBUTED TO EACH ERROR TYPE

Ground observation	Map class	Error types[a]		
		Cutpoint	Misclassification	Description
Water	Very wet graminoid	1	·	·
	Barren floodplain	·	·	2
Shallow water	Very wet graminoid	1	·	·
	Wet graminoid	·	1	·
	Barren floodplain	·	·	1
Very wet graminoid	Wet graminoid	1	·	·
Wet graminoid	Very wet graminoid	1	·	·
	Moist/wet tundra	5	·	·
Moist/wet tundra complex	Wet graminoid	3	·	·
	Moist prostrate scrub	2	·	·
Moist prostrate scrub	Wet graminoid	·	2	·
	Moist/wet tundra	4	1	·
	Moist graminoid tussock	4	7	·
	Mesic erect scrub	·	3	·
	Barren floodplain	·	1	·
Most graminoid tussock	Moist prostrate scrub	·	1	·
Mesic erect scrub	Wet graminoid	·	1	·
	Moist/wet tundra	·	3	2
	Moist prostrate scrub	·	2	·
	Moist graminoid tussock	4	1	·
Alluvial deciduous shrub	Wet graminoid	·	1	·
	Moist/wet tundra	·	1	·
	Scarcely vegetated	1	·	·
Dry prostrate scrub	Moist/wet	·	1	·
	Moist prostrate scrub	2	·	·
	Scarcely vegetated	4	·	·
Scarcely vegetated	Very wet graminoid	·	1	·
	Barren floodplain	1	·	·
Errors (Total)		34	27	5
Percentage of all observations[b]		27%	22%	4%

[a]Error type: cutpoint - plant community observed on the ground is intermediate between two closely related types; misclassification - plant community clearly does not belong to map classification; description - class descriptions need modification.

[b]Total of all observations including agreements equals 126.

disagreements between these types were due to cutpoint errors and nine were due to misclassification errors (Table 2). The cutpoint errors may have resulted from the authors using a stricter definition of the moist graminoid tussock class and broader definitions of moist prostrate scrub and mesic erect scrub than that used for the map. The authors assumed that up to 20 percent cover of cottongrass tussocks could be included in moist prostrate scrub based on descriptions for the 1982 map (Walker *et al.*, 1982), but this percentage may be lower for the 1985 map. The cutpoint between mesic erect scrub and moist graminoid tussock was defined as 25 percent shrub cover, but this may not have been consistent on the map. More ground data is needed to quantify these cutpoints, and to determine how consistently the Landsat MSS data can distinguish between these types.

Producer's accuracies for moist prostrate scrub and mesic erect scrub were very low, indicating that these types were not accurately represented by the map (Table 1). Five misclassification errors occurred between these types in addition to the eight misclassification errors between these types and moist graminoid tussock (Table 2). The large number of misclassification errors indicates that the map did not clearly identify these vegetation types.

Scarcely vegetated floodplain and barren floodplain had high producer's accuracies, but low user's accuracies (Table 1). These classes had a high probability of being classified correctly on the map when they were found on the ground, but the map also included other types within these classes. The reverse was true for dry prostrate dwarf scrub which had a higher user's accuracy or probability of being correct on the map. Cutpoint and misclassification errors were the main sources of disagreement in these land-cover classes of floodplain areas (Table 2). Cutpoint errors occurred among dry prostrate scrub, scarcely vegetated floodplain, and barren floodplain which have decreasing amounts of vegetative cover. Barren floodplain and scarcely vegetated floodplain classes on the map were described as having less than 5 percent and 5 to 20 percent vegetative cover, respectively. Ground descriptions indicated that these percentages are low.

Misclassification errors occurred between the floodplain classes and very wet graminoid, wet graminoid, and moist/wet complex tundra. Floodplain habitats include braided stream beds with water in river channels surrounded by narrow islands of barren gravel or vegetation. The spectral reflectances of these different components were apparently averaged together in the 50-m^2 Landsat pixels, and were similar to the spectral signatures of the wetland classes. Alluvial deciduous shrubs were not mapped on the coastal plain and, therefore, had a producer's accuracy of 0 percent. The resolution of the Landsat MSS data was not fine enough to be able to distinguish this vegetation type which occurs in narrow bands along rivers.

CONCLUSIONS

We conclude that the Landsat-assisted vegetation map shows the general distribution of land-cover classes present on the coastal plain of the Arctic Refuge. Although the overall map accuracy was low, the majority of errors were cutpoint errors where the plant community on the ground was intermediate between two closely related classes.

In order to correct cutpoint problems, further mapping efforts must include detailed vegetation sampling to allow quantification of the cutpoints. The ground-truthing data used to develop the map was inadequate for defining the differences between closely related types. Many of the land-cover class descriptions did not specify quantitative cutpoints, and those cutpoints that were included often seemed inconsistent or inaccurate when comparing map classes to ground data. Trained botanists utilizing the present land-cover descriptions frequently disagree with each other (Larry Pank, U.S. Fish and Wildlife Service, pers. comm.) as these closely related classes are difficult to distinguish on the ground.

More quantitative ground data are needed to determine whether maps based on satellite data can consistently separate closely related types. The large number of cutpoint errors may indicate that the level of classification detail was too great to be separated using Landsat MSS data (George, 1986). Higher accuracy may have been obtained by defining fewer classes.

Description errors, although comprising only a small portion of all errors, illustrate the need to develop detailed ground descriptions of vegetation classifications, which will allow accurate interpretation of map information.

Large numbers of misclassification errors occurred in the moist prostrate scrub and mesic erect scrub categories, indicating that these classes were not adequately defined on the Landsat map. Misclassified polygons were also found on river floodplains where the map classification was unable to distinguish between braided floodplain communities with river channels and wet or moist plant communities. Higher resolution Thematic Mapper or SPOT data may produce a more accurate classification of floodplain communities which occur in narrow bands on the coastal plain.

In conclusion, the general distributions of land-cover classes shown on the Landsat-assisted map provides basic information for wildlife habitat studies and regional conservation planning (Talbot and Markon, 1986). Wildlife studies designed to predict or minimize the impacts of oil and gas exploration and development will require more detailed, site-specific vegetation maps. Future mapping efforts must include higher resolution data and adequate ground-truthing to quantify cutpoints between closely related classes.

ACKNOWLEDGMENTS

Marta McWhorter and Lorna M. Koestner assisted in collection of field data. Dave Douglas produced enlarged maps of the study sites from the classified Landsat data, and Cathy Curby provided assistance with data analysis. The U.S. Fish and Wildlife Service provided funding for this project.

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(Received 29 July 1988; revised and accepted 6 December 1988)