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REINDEER RANGE INVENTORY: USE OF WINTER LANDSAT IMAGERY FOR STRATIFICATION OF DIGITAL CLASSIFICATION

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I. ABSTRACT

Range inventories using Landsat data have been conducted since 1976 on the tundra in northwest Alaska. Landsat digital classifications of large areas (>1 million hectares) were used to support collection of ground data on plant productivity and soils. This technique was effective where the inventory team had little or no previous knowledge of the area, and a very short summer field season to collect field data. Problems were encountered where resource categories differed from Landsat spectral classes across these large areas, due to regional differences in ecological condition. A means was required to break the survey area into smaller units so that resource categories could be locally described.

Winter Landsat imagery was photointerpreted to stratify the survey areas into physiographic units. Images were selected from mid-winter, when the landscape is snow covered, and low sun angles provide enhancement of subtle topographic patterns. The physiographic units derived from winter Landsat imagery were digitized to serve as boundaries for stratification of a previously classified Landsat digital image. Spectral categories were then re-identified to a resource category within each stratum. An output image was produced and used as the base for preparing the final range inventory map.

Preliminary verification results of the inventory indicate an overall accuracy of 77% ± 2.6% (.95 probability level) in comparison to a reference data set collected independently.

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II. INTRODUCTION

Reindeer herding has been practiced in northwestern Alaska since the turn of the century. For the last several decades, herds owned by Alaska Natives have been operated as a family enterprise. Recent changes in political and socio-economic conditions have resulted in motivating the herders to increase production on the ranges and provide more intensive management.(1)

In response to requests for assistance by regional native corporations, the Soil Conservation Service (SCS) initiated a program in 1976 to inventory the ranges of the Seward Peninsula. Once the inventory has been conducted, range management plans are prepared for the herders to consider ways to implement more intense management.

The University of Alaska has been involved in the program to assist with the development of techniques to use remote sensing data as an inventory tool. Machine processing of Landsat data has been the primary source of information due to the large area (∿6.5 million hectares) and the lack of aerial photography.

The inventory program has progressed in several segments, each dealing with grazing allotments between one and two million hectares in size. In this paper we will briefly describe the first survey, and examine in more detail the second survey to illustrate the technique of digital image stratification.

III. USE OF LANDSAT UNSUPERVISED CLASSIFICATION

The first range survey initiated in 1976 covered portions of four grazing allotments on the northern Seward Peninsula totaling 1.6 million hectares (Fig. 1).

Sections from three different Landsat scenes were required to provide adequate coverage. A 2% random sample was drawn from each image and clustered using ISOCLS program on the ESL IDIMS system.(2) The resulting cluster statistics were used to apply a maximum likelihood classifier to each data set. Approximately twenty spectral classes were identified per scene. These classes were evaluated using a color display system and grouped into resource categories. Color-coded images were produced using a digital image film recorder, and prints enlarged to map scale.

A crew of range and soil scientists used the color-coded classified images to locate sample areas in the field during July 1976. Plant species, productivity and soils types were recorded. This information was used by SCS to describe range sites for the survey area.

After the field season, synthesis of the ground observations led us to conclude that for the most part the Landsat classified images did a good job at delineating range sites. Patterns that were present on the images could be found in the field and described. Limitations were: 1) that not all the resource categories were spectrally separable; for example, open spruce forest, lava flows, and old tundra fire scars all have similar spectral responses 2) similar resource classes have different reflectance values for the sun lit and shadow side of the hills, and finally 3) each of the three scenes processed had slightly different classes. This resulted from differences in season between the individual images and regional changes in the plant communities across this large survey area.

In order to convert the Landsat image classification into a range inventory map, we had to describe the spectral classes locally, to circumvent the limitations listed above. This was accomplished by producing a hand-drawn map from the color products.(3)

The problem we are now attempting to solve is to derive a source of information suitable for machine processing which will allow us to locally describe Landsat spectral classes minimizing the limitations encountered during the 1976 project.

IV. USE OF WINTER LANDSAT IMAGERY FOR STRATIFICATION

The second inventory project started in 1979 and covered a 1.4 million hectare area on the northwest Seward Peninsula (Fig. 1). Early in the project, we started looking for a way to stratify the survey area into a number of smaller units which could be dealt with individually. Winter Landsat imagery provided the information needed.

Landsat imagery acquired in the Feb/March time period gave an entirely different view of this area (Fig. 3). Snow covered the landscape, entirely removing differences in vegetation type. The low sun angle (∿8°) casts shadows enhancing subtle topographic differences which are not visible on summer images. These features allowed us to evaluate regional terrain types and photointerpret the entire survey area into 29 large pieces which we called physiographic units (Fig. 2 & 4). The units were labeled with names such as coastal plain, hilly footslopes, rough mountains, etc. (Table 1) although we did not intend to imply a precise geomorphic interpretation.

We used this product to allocate field data collection efforts and to serve as a source of information for subsequent computer analysis of the summer Landsat data.

V. COMPUTER ANALYSIS WITH IMAGE STRATIFICATION

A data search for the 1979 project yielded three Landsat images acquired during a three-day period which were suitable for mosaicing prior to image classification. A cluster analysis of the raw data was performed using the ISOCLS algorithim which produced 49 spectral classes. This statistics file was used to classify the raw data into 49 spectral categories.

A preliminary attempt to group these classes into resource categories showed that similar spectral categories occurred over widely varying terrain types (Fig. 5). The resource categories that would include all the range sites contained in a given spectral class would have been too broad to be usable for range management (Table 2). Digital image stratification was used to improve the classification results.

Physiographic units, described previously were digitized from 1:250,000 scale topographic map sheets and transformed to a 50-meter Universal Transverse Mercator grid. A mask was generated from this information and used to extract portions of the classified data corresponding to different physiographic units. A total of 14 aggregated units were constructed. These areas were re-evaluated and spectral classes assigned into one of 20 resource categories (range sites). Then images were reconstructed into a single image, containing 15 classes, a graphics mask was superimposed onto the image, outlining all the physiographic unit boundaries, and tick marks imbedded to mark the corners of the 1:63,360 scale map series. A photographic negative was produced with a digital image film recorder and color prints produced (Fig. 6).

VI. DISCUSSION & RESULTS

While we have not had the opportunity to make a quantitative comparison of the stratified versus pre-stratification classification, a side by side comparison shows vast improvement after stratification (Figures 5 & 6). Range sites occurring in the wet coastal plain are noticably separated from upland range sites. Before stratification, one group of spectral classes covered both areas.

One way to assess the difference is to study the legend for the two products. Table 2 is the key for the initial classification--notice the number of range sites contained in the colors dark grey, brown, sand and orange. After stratification, a matrix (Table 3) was constructed to identify the range sites that are represented by a given color, in a particular stratum.

The stratification procedure improved this particular Landsat classification, but not without creating some problems along the way. In several instances sharp differences occur at stratification boundaries, which are too abrupt to be real. This situation is not a serious problem, and results where conditions are changing gradually over an environmental gradient. Since we are forced in the process to define a line marking the boundaries, some errors of misclassification are bound to occur. Unfortunately, where these differences exist, they tend to stand out noticably to the eye. In most cases if the stratum boundary lines were left off the image, the units would blend together undetectably.

The problem of misclassification caused by terrain aspect was not totally cured by this approach. Separating shrub from tundra classes seems to be particularly difficult in areas of moderate relief.

After examining the stratified Landsat classification and evaluating the prospective use by range managers, we elected once again to produce a hand-drawn map (Fig. 7). This process allowed us to clean up problems of misclassification remaining in the image, as well as simplify the map legend description (Table 4) into something less complicated than the matrix shown in Table 3.

During the 1980 field season we performed a small effort to assess the accuracy of our final map product. Flight lines were layed out transecting the survey area and flown in a light aircraft. Range sites were identified from the air and recorded on blank copies of the inventory map to establish a reference data set. These observations were then compared to the inventory maps yielding an overall accuracy of 77% ± 2.6% (.95 probability level) between the two. While the reference data set is certainly not error free, we feel that the results are a reasonable indication of our inventory efforts and that they will guide us to the areas that need the most improvement.

VII. CONCLUSIONS

In this project the unique features of winter Landsat data were to stratify a 1.4 million hectare survey area. This process helped gain a regional perspective of a study area which served as the base to make more detailed resource separations locally. Stratification of this nature could be used for manual photointerpretation studies as well as the machine processing application described here.

Image stratification didn't solve all the problems encountered in the previous range inventory project, but did make significant improvements. We plan to examine other means such as the use of digital terrain data to refine classification results aiming toward the goal of eliminating the need to generate a hand-drawn map.

VIII. REFERENCES

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3. George, T.H., W.J. Stringer and J.N. Baldridge, "Reindeer Range Inventory in Western Alaska from Computer-Aided Digital Classification of Landsat Data", Proceedings of the Eleventh International Symposium on Remote Sensing of Environment, Vol. I, April 1977, p.671-682.

PHYSIOGRAPHIC UNITS LEGEND

Beach Dunes	BD	1-4
Hilly Footslopes	HF	1-4
Hilly to Steep Mountainous Land	HM	1-3
Low Gently Sloping Hills	LS	1
Low Undulating Hills	LU	1-5
Rough Mountainous Land	RM	1-5
Tidal Flats	TF	1-5
Wet Coastal Plain	WC	1
Wet Gently Sloping Flootslopes	WF	1
Total Units		29

TABLE I. Physiographic Unit Legend. This table lists the name and number of units photointerpreted from winter Landsat imagery (Figures 2 & 4).

KEY TO SEWARD PENINSULA RANGE SITES

COLOR	RANGE SITE
Dark Green	Tussock Tundra
Light Green	Wet Tussock Tundra
Red	Brushy Drainage
Orange	Alluvial Tall Brush & Mixed Shrub Tussock Tundra
Sand	Drained Lake (dry) & Upland Mountain Meadow
Brown	Wet Sedge Drainages & Wet Coastal Sedge
Dark Grey	Wet Coastal Sedge & Wet Sedge Meadow & Drained Lakes (wet)
Grey	Barrens (limestone) & Bald Slopes
White	Snow & Cloud & Barrens (limestone) & Alluvium
Black	Barrens (granite) & Tidal Flat
Dark Blue	Water
Medium Blue	Water
Aqua	Water

TABLE 2. Landsat Classification Legend. This key describes the resource category groupings of the Landsat classification, before image stratification, shown in Figure 5.

COLOR KEY FOR SEWARD PENINSULA RANGE SITES BY PHYSIOGRAPHIC UNITS

COLOR	(1) BD1-2-4 OCEAN	(2) BD3; WC TF1-2-3-4-5	(3) WF1	(4) LS1	(5) LU1 HF1-3-4	(6) LU2-3	(7) LU4-5	(8) HF2	(9) HM1	(10) HM2-3	(11) RM1	(12) RM2	(13) RM3-4	(14) RM5
DK GREEN	•	Tussock Tundra	Tussock Tundra	Tussock Tundra	Tussock Tundra	Tussock Tundra	Tussock Tundra	Tussock Tundra	Tussock Tundra	Tussock Tundra	•	•	•	Tussock Tundra
LT GREEN	•	Wet Tussock Tundra	•	Wet Tussock Tundra	Wet Tussock Tundra	Wet Tussock Tundra	Wet Tussock Tundra	Wet Tussock Tundra / Wet Mtn. Meadow	•	•	•	•	•	•
RED	•	Brushy Drainages	Brushy Drainages	Brushy Drainages	Brushy Drainages	Brushy Drainages	Brushy Drainages	Brushy Drainages	Brushy Drainages	Brushy Drainages	Brushy Drainages	Brushy Drainages	Brushy Drainages	Brushy Drainages
ORANGE	•	Alluvial Brush	•	•	Mixed Shrub Tussock Tundra	Alluvial Brush	Alluvial Brush	Alluvial Brush	•	Mixed Shrub Tussock Tundra	•	•	•	•
PEACH	•	•	Wet Sedge Meadow	•	•	•	•	•	Wet Sedge Meadow	•	Wet Sedge Meadow	Wet Sedge Meadow	•	•
SAND	Dry Drained Lake	Dry Drained Lake	Wet Mtn. Meadow	•	Wet Mtn. Meadow	Dry Drained Lake	Dry Drained Lake	Wet Mtn. Meadow	Wet Mtn. Meadow	Wet Mtn. Meadow	Wet Mtn. Meadow	Wet Mtn. Meadow	Wet Mtn. Meadow	Wet Mtn. Meadow
YELLOW	•	•	•	•	Dry Mtn. Meadow	•	•	Dry Mtn. Meadow	•	Dry Mtn. Meadow	•	•	Dry Mtn. Meadow	Rocky Alpine Lichen
BROWN	Wet Coastal Sedge	Patterned Ground (L.C.P.)	Wet Sedge Drainages	Patterned Ground (L.C.P.)	Patterned Ground (L.C.P.)	Patterned Ground (L.C.P.)	Patterned Ground (L.C.P.)	•	Wet Sedge Drainages	•	Wet Sedge Drainages	Wet Tundra	•	•
DK GRAY	Very Wet Coastal Sedge	Wet Sedge Marsh	•	Wet Sedge Marsh	•	Wet Sedge Marsh	Wet Sedge Marsh	Pattern Ground (L.C.P.)	•	•	•	Wet Sedge Drainages	•	•
GRAY	Wet Sand	Bare Ground	Barren or Bald Slopes	Barren	Barren or Bald Slopes	Barren	Barren	Barren or Bald Slopes	Barren or Bald Slopes	Barren or Bald Slopes	Barren	Barren or Bald Slopes	Barren or Bald Slopes	Barren or Bald Slopes
WHITE	Dry Sand	Bare Ground Snow/Ice	Barren Bald Slopes and/or Snow	Barren and/or Snow	Barren or Bald Slopes	Barren	Barren	Barren or Bald Slopes	Barren or Bald Slopes	Barren or Bald Slopes	Barren	Barren or Bald Slopes	Barren or Bald Slopes	Barren or Bald Slopes
BLACK	•	Tide Flats or Unidentified	Granite	Unidentified (Trace)	Wet Tundra (Trace)	Very Wet Tundra	Very Wet Tundra	Wet Tundra or Bare Rock	Granite	Shadow (Trace)	•	•	•	Granite
DK BLUE	Water	(1) ⋙ →												
MED BLUE	Water	(2) ⋙ →												

TABLE 3. Stratified Landsat Classification Legend. This matrix describes the color/range site relationship by physiographic unit of the image shown in Figure 6.

NORTHWEST SEWARD PENINSULA RANGE MAP LEGEND		
PHYSIOGNOMY	MAP SYMBOL	RANGE SITE
WATER	1	LAKES 40 ACRES - 160 ACRES
	2	LAKES 160 ACRES - 640 ACRES
	3	LAKES 640 ACRES +
	4	LAGOON
	5	OCEAN
TALL SHRUB	20	ALLUVIAL TALL BRUSH
	21	BRUSHY DRAINAGES
LOW SHRUB	30	WET TUSSOCK TUNDRA
	31	LOW SHRUB TUSSOCK TUNDRA
	32	MIXED SHRUB TUSSOCK TUNDRA
SHRUB-HERB	40	SPARSE SHRUB TUSSOCK TUNDRA
	41	UPLAND MOUNTAIN MEADOW
HERB	50	BEACH DUNES
	51	TIDAL MARSH
	52	WET COASTAL SEDGE
	53	WET SEDGE MEADOW
	54	WET SEDGE DRAINAGES
	55	DRAINED LAKE BORDERS
	56	DRAINED LAKES (Dry)
	57	DRAINED LAKES (Wet)
MAT and CUSHION	70	ACID ROCK DESERT
	71	ALKALINE ROCK DESERT
	72	BALD SLOPES
MISCELLANEOUS	81	BARREN

TABLE 4. Range Map Legend. This table is the legend for the final hand-drawn inventory map of the 1979 survey area (Figure 7).

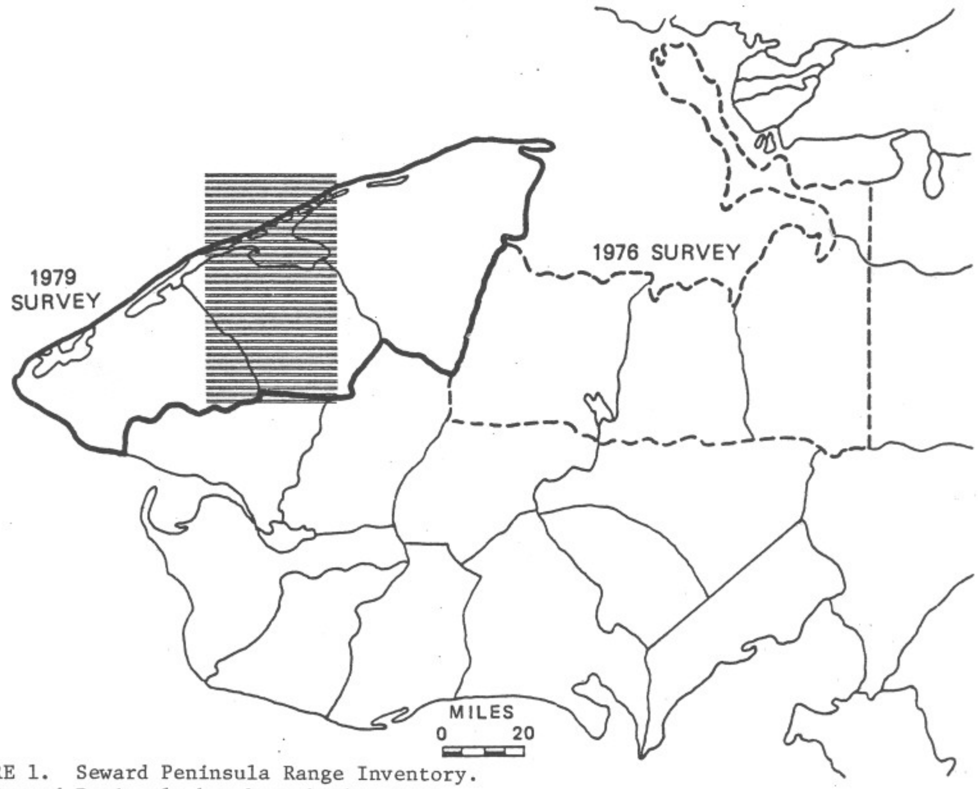

FIGURE 1. Seward Peninsula Range Inventory. The Seward Peninsula has been broken into individual grazing allotments by the Bureau of Land Management. The dashed line shows the area inventoried in 1976. A heavier line shows the perimeter of the project started in 1979. The shaded region defines the area covered by Figures 3-7, used as examples of the remote sensing products discussed in this paper.

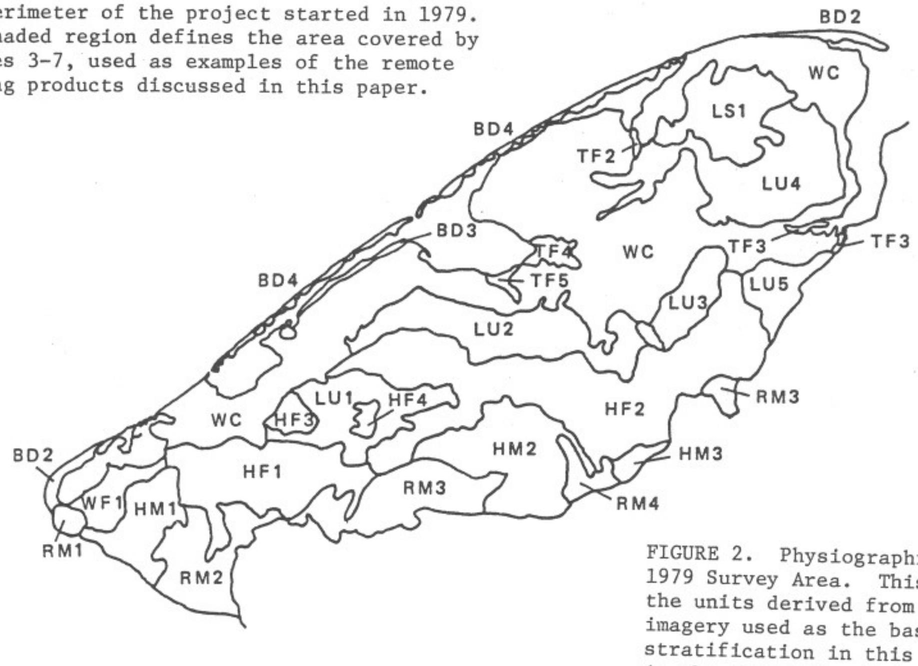

FIGURE 2. Physiographic Units of the 1979 Survey Area. This diagram shows the units derived from winter Landsat imagery used as the basis for image stratification in this project. Table 1 is the legend for this map.

FIGURE 3. Winter Landsat Image. Landsat scene 1567-22060, acquired Feb. 10, 1974, shows subtle topographic differences due to the snow cover and low sun angle.

FIGURE 4. Physiographic Units. The units are shown here on the winter Landsat image from which they were interpreted. Table 1 is the key for these units. Figure 2 shows the physiographic unit map derived for the entire project area.

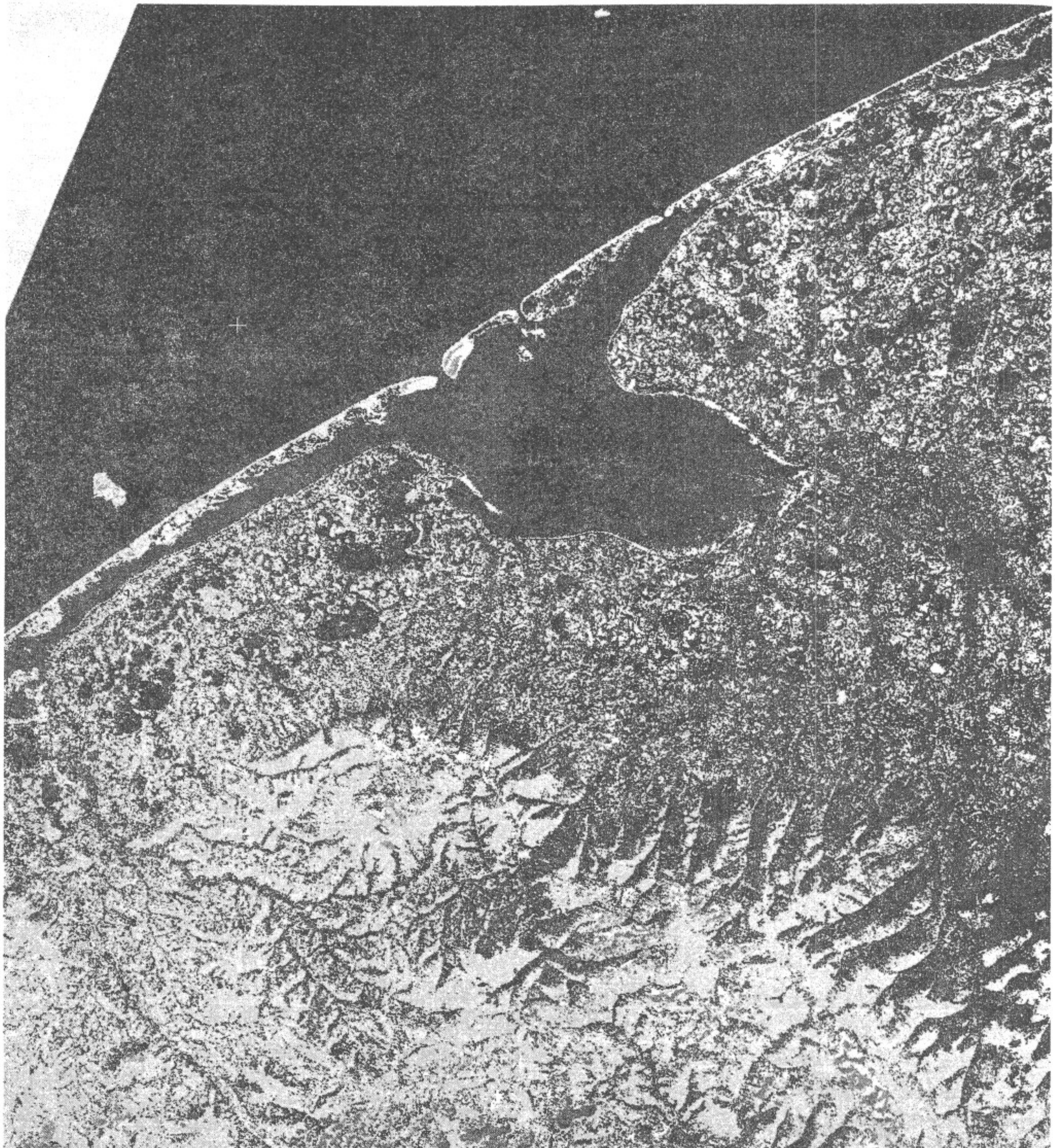

FIGURE 5. Initial Landsat Classification. This is a black-and-white rendition of the color classified image produced prior to image stratification. Note the broad extent of some of the grey tones. Table 2 is the key to the color version of this product.

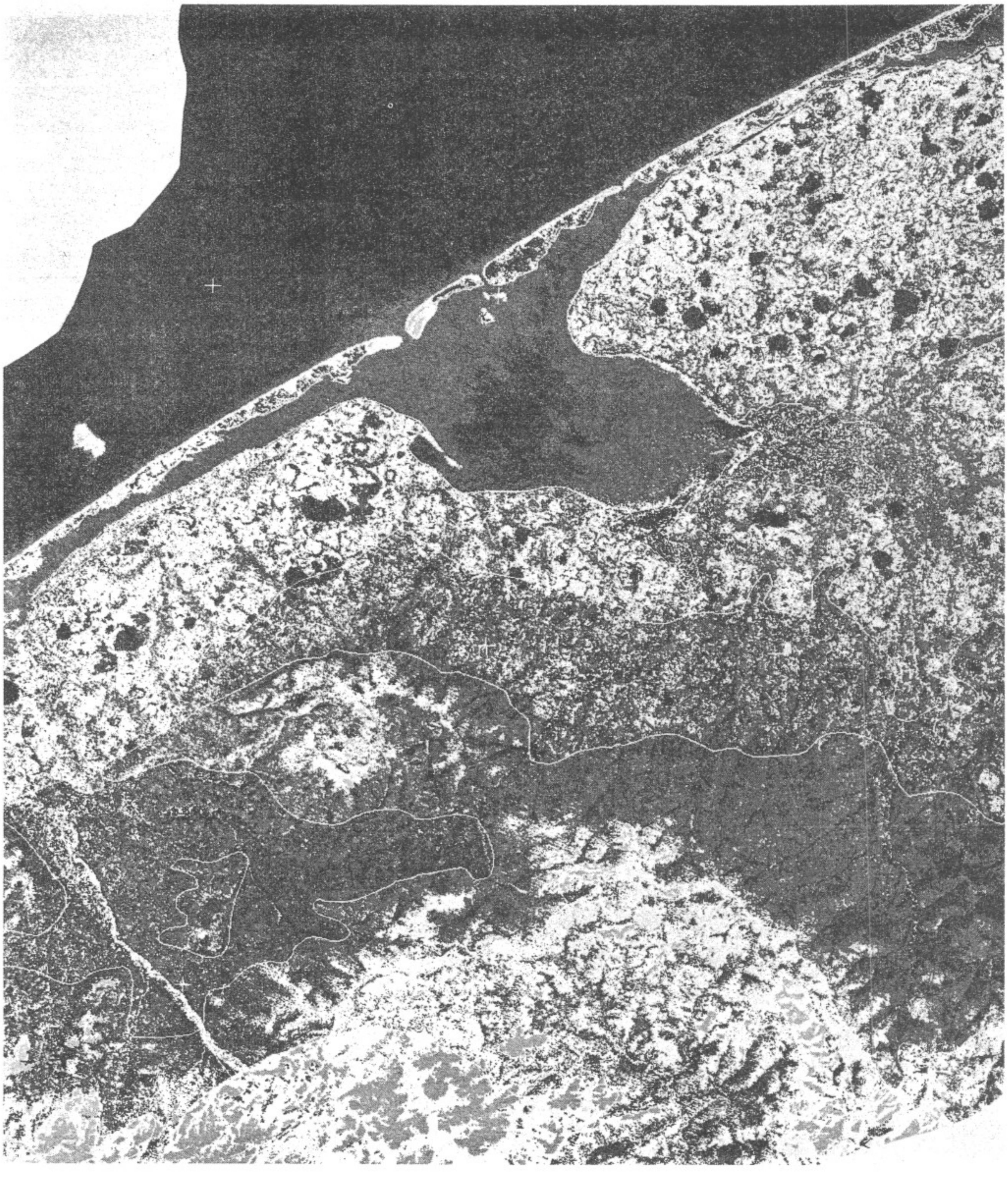

FIGURE 6. Stratified Landsat Classification. This image was produced in color after digital image stratification. Compare it to the initial classification in Figure 5. Table 3 is the legend for this product.

FIGURE 7. Range Map. The line-drawn map is the final inventory product derived from the stratified Landsat classification (Figure 6). The legend for this map is Table 4.

AUTHOR BIOGRAPHICAL DATA

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