"THE UTILITY OF A GIS IN EVALUATING THE ACCURACY OF CLASSIFIED LANDSAT LAND COVER TYPE MAPS ON THE KENAI PENINSULA"

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ABSTRACT

In 1981, the U.S. Fish & Wildlife Service (USFWS) developed maps of the wetlands on the Kenai Peninsula as part of the National Wetland Inventory (NWI) Program, which was mandated by Congress. The NWI maps depict various types of wetlands according to the classification scheme developed by Cowardin, Carter, et al in 1979. The wetland types were interpreted from recent 1:60,000 scale high altitude color infrared photography and mapped at a scale of 1:63,360 to register with the USGS topographic base maps.

During the same period, another division of USFWS collected baseline environmental data to support the development of a Comprehensive Conservation Plan for the Kenai National Wildlife Refuge. The plan was developed in response to a Congressional mandate as part of the Alaska National Interest Lands Conservation Act (ANILCA). An essential part of the environmental database was land cover type. This layer of data was developed from the analysis and classification of digital LANDSAT images and digital terrain data. The classification process involved a "modified clustering technique" which employed a "maximum likelihood classifier" to generate a land cover data set of 17 unique types. Some of these types are related to wetland classes, as defined in the National Wetland Inventory.

A study area consisting of one 1:63,360 USGS quadrangle on the Kenai National Wildlife Refuge was selected for the evaluation. The NWI data was digitized and converted to a raster format at the same resolution (50M X 50M) as the land cover data, so as to exactly register the two data sets. Both raster files were loaded into the same grid cell database to facilitate manipulation and analysis. The Geographic Information System (GIS) was used to (1) selectively retrieve particular land cover types and wetland classes, (2) composite the selected data sets through spatial analysis techniques, and (3) determine the location and number of occurrences of various combinations of land cover type and wetland class. An analysis of the composition of each combination revealed occurrences which were defined as "logical mis-matches", or "errors" in classification of land cover type. The basis for this evaluation was the acceptance of the wetland class map as representative of the "real world".

The results of the evaluation demonstrated that (1) the GIS was a logical tool for making the comparison between the two data sets, (2) the GIS was efficient in determining the nature and number of classification "errors", and (3) there was a significant agreement between most land cover types and wetland classes in the study area, but there were classification "errors" to varying degrees in all the land cover types compared.

INTRODUCTION

Purpose & Scope

The purpose of this paper is to present the results of a small project designed to study a technique for quickly assessing the accuracy of land cover type maps derived from LANDSAT data. The project had as its major objective, to investigate a methodology for quickly evaluating the accuracy of LANDSAT derived landcover type maps using the analytical capabilities of a Geographic Information System (GIS) in an area for which a digital land cover type map existed. It was not intended to conduct a thorough and detailed assessment of the accuracy of the landcover type maps.

The scope of the project involved a small area on the Kenai Peninsula of Alaska which covered about 75% of one USGS 1:63,360 scale quadrangle map. The project was very limited in available time so the study was confined to a subset of the land cover types, those normally associated with wetland environments.

Background

As a background to this project, the U.S. Fish & Wildlife Service (USFWS) developed maps of the wetlands on part of the Kenai Peninsula as early as 1981 as part of the National Wetland Inventory Program (NWI). The Kenai Peninsula was chosen partly because of its importance for both wildlife and human use values and partly because of the need to provide environmental baseline data to support the comprehensive planning effort for the Kenai National Wildlife Refuge. The development of a Comprehensive Conservation Plan for the Kenai refuge was mandated by Congress in 1980 as part of the Alaska National Interest Lands Conservation Act (ANILCA). An essential element of data that was missing on the Kenai refuge was a comprehensive map of landcover types. It was a typical situation over much of the State of Alaska, especially on National Wildlife Refuges. Due to the vast expanses of land involved, the lack of extensive high altitude photography, the inaccessibility of the refuge for intensive field surveys, and the short time frame for the comprehensive planning effort, it was decided to utilize LANDSAT multispectral scanner data and automated classification techniques to produce the landcover type maps.

The USFWS has supported the development and utilization of LANDSAT derived landcover type maps on all the refuges currently in the comprehensive planning process throughout Alaska. This extensive land cover mapping effort has been a cooperative one with the USGS. The digital landcover maps have been produced by the staff of the EROS Field Office in Anchorage. EROS has produced landcover type maps for National Wildlife Refuge lands covering over 20 million acres in the last three years. Landcover type maps covering another 30 million acres of refuge lands are currently in production or planned in the near future. There is a strong commitment to the use of these digital land cover maps by the USFWS, not only in the comprehensive planning process but also in refuge management operations as well.

So far there have only been limited efforts to assess the accuracy of the digital landcover maps produced for the refuge lands. Plans have been made in the past to incorporate detailed accuracy assessment steps into the process of producing landcover type maps, but as of today no such steps have been completed. There exists a real need to find a reasonably quick and simple way to assess the accuracy of the land cover type maps while there is still the mechanism for utilizing the results of such an assessment.

The data management and analysis for the investigation utilized the facilities of the USFWS regional computer center in Alaska, which is part of the Office of Information Resources Management (IRM). The facilities include a Data General MV8000 minicomputer, high speed drum plotter, digitizing tables, and several interactive graphics terminals. The regional computer center currently supports two major GIS software packages, "GRID"/"PIOS" from Environmental Systems Research Institute and "MOSS/"AMS"/"COS" from Autometric, Inc. Portions of both major systems were used in the project to conduct the study of the Kenai Peninsula land cover type maps.

Location of Study Area

The Kenai Peninsula is located in Southcentral Alaska, bounded by the Gulf of Alaska to the east and south, Cook Inlet to the west, and the Chugach Mountains to the north. It extends from about 30 miles to 100 miles south of Anchorage, and covers an area of approximately 6 million acres. The Kenai National Wildlife Refuge occupies roughly the western half of the Peninsula. The project study area lies within the refuge boundary and covers about 3/4 of the Kenai C-3 USGS 1:63,360 scale quadrangle map. It is predominately flat to slightly rolling country covered with lowland conifer or mixed forest and deciduous shrubs and extensive areas of lakes and wetland habitats.

LANDCOVER MAPPING AND WETLANDS INVENTORY PROGRAMS

Landcover Mapping

A major data element required in the refuge planning process is landcover type. It forms the basis of most wildlife habitat suitability and natural resource development capability models. Maps of land cover type are generated from the analysis and classification of digital LANDSAT images, in conjunction with digital terrain data from Digital Elevation Models (DEM). The process of generating the final landcover type map is a complex process involving several tasks organized into three major phases. (Figure 1)

FIGURE 1

PHASES	TASKS
(I) Pre-Processing	(A) Select & partition LANDSAT scenes of Refuge
	(B) Correct radiometric distortion
	(C) Correct geometric distortion and register scenes with 50 Meter UTM Grid
	(D) Mosiac selected scenes or sub-scenes
	(E) Generate strata mask of refuge boundary
(II) Image Classification	(F) Select training blocks from high altitude photography
	(G) Extract raw MSS spectral data for each training block
	(H) Cluster the raw MSS spectral data in each training block and generate training statistics
	(I) Conduct field surveys; verify and evaluate training blocks
	(J) Classify and evaluate spectral data in

training blocks; revise statistics

(K) Classify spectral data for entire image using revised training statistics; generate "initial" landcover type map

(III) Post Classification

(L) Determine additional landcover types needed for refuge planning data analysis

(M) Identify and acquire ancillary data for stratification

(N) Geometrically register ancillary data and generate additional strata masks

(O) Stratify "initial" classified landcover image using appropriate strata masks; generate "final" classification

(P) Produce final landcover type map

In summary, LANDSAT digital images (scenes) selected for use in generating landcover type maps often originate from different years and/or different seasons, due to the general lack of "cloud-free" scenes for an entire refuge in any one year. Once a set of scenes is acquired for a refuge, they are geometrically registered to the USGS 1:250,000 or 1:63,360 scale topographic base maps covering the refuge. All geographic coordinates are referenced to the appropriate UTM zone.

Following registration of the scenes, "training blocks" representing areas of typical landcover types are selected on available 1:60,000 high altitude color infrared photography. A clustering operation is performed on the spectral data from the training blocks involving the use of an algorithm called "ISOCLASS" to form groups or spectral classes, where the optimum number of spectral classes is determined by minimizing the transformed scatter ratio. Each spectral class is assigned a landcover type based upon a comparison of its location in the training block image to the initial landcover types interpreted on the high altitude photography. The objective of the clustering operation is to define, to the extent possible, unique spectral classes, each of which represents no more than one landcover type. However, several spectral classes may represent the same landcover type.

Field studies in the training blocks are designed to verify the landcover types interpreted from the high altitude photography, and training statistics are developed for each training block. Using the training statistics, the spectral data in the training blocks are classified and the results evaluated with the field data and high altitude photography. Following the evaluation, appropriate revisions are made to the training statistics, and the revised statistics are used to classify the entire image. An "initial" landcover type map is the result.

The "initial" landcover type map inherently does not differentiate between certain landcover types adequately. For example, certain spectral classes are often inseparable due to a degree of "confusion", such as in areas of ice/snow, clouds, barren ground, and lichen. In addition, a few landcover types are not particularly suited to mapping by classification of spectral data, such as airfields, townsites, roads, or commercial land use. Additional ancillary data about infrastructure, physiographic provinces, hydrography, etc. are geometrically registered to the classified image and combined to stratify the initial classification. The results of the stratification yield additional landcover types and produce a "final" landcover type map for the refuge. A list of the final landcover types for the study area is located in Appendix A.

Wetlands Inventory

In 1974, the U.S. Fish & Wildlife Service was directed to conduct a new inventory of the nation's wetlands. The inventory was designed to provide basic data on the characteristics and extent of wetlands and deep-water habitats, which would facilitate the management of these areas on a sound, multiple-use basis. The Fish & Wildlife Service elected to design a new classification scheme in order to provide uniformity in concepts and terminology in mapping ecologically similiar wetland habitats throughout the country.

There are seven major steps in producing wetlands inventory maps:

(1) Preliminary field investigations
(2) Interpretation of photographs
(3) Review of existing wetlands information
(4) Quality control of interpreted photographs
(5) Production of draft maps
(6) Interagency review of draft maps
(7) Production and distribution of final maps

The inventory and mapping process begins with field investigations in which sample plots are located in several areas representing each of the major wetland habitats. Color infra-red photography at a scale of 1:60,000 is obtained from the Alaska High Altitude Photography Program for the second step. With this imagery, the photointerpreter is capable of detailed wetlands mapping to a minimum size unit of 3 acres. The photo- interpretation is accomplished with the use of a large stereoscope. The photo-interpreter identifies, maps, and classifies each wetland by analyzing vegetation, landform, slope, and drainage patterns, in conjunction with other available data, such as soil surveys, topographic maps, and the field investigations. The boundaries of each wetland are drawn on a mylar overlay to the photograph. All adjacent boundaries on other photographs are "edge-matched" to assure the accuracy of mapping between photographs.

Once all the photographs covering a complete quadrangle have been interpreted, the boundaries of the wetlands on each photo mylar overlay are transferred to a mylar overlay of the USGS 1:63,360 quadrangle map through the use of a Stereo-Zoom Transfer Scope. During this process the individual photographs are registered to the quad map prior to the cartographic transfer. It usually requires 6 - 8 photos to cover a typical 1:63,360 quad map. The result is a 1:63,360 scale mylar overlay showing the location, shape, and classification of the wetlands. It is reviewed to assure that it meets national mapping standards, and verified a second time with the field data. Following the review of the draft product, corrections are made and a final "map" generated. Copies of the final map are sent to Corps of Engineers and the appropriate resource management agencies.

Recently, the National Wetland Inventory maps for selected areas have been digitized. Several interested agencies are funding this conversion to a digital format in order to allow them to incorporate this data into existing digital databases. Once in a digital database, the wetlands data can be integrated with other environmental data for specific project objectives.

A list of the major wetland types occurring within the study area can be found in Appendix B.

METHODOLOGY

Data Preparation

At the beginning of the project, the landcover type data and the wetlands inventory data were in two radically different formats. The landcover type data came directly from the raw LANDSAT image and in a "raster" form, whereas the wetlands data was digitized as lines in a "vector" form. In order to compare the two data sets it was necessary to have them in the same form. The most efficient way to accomplish this task was to convert the wetlands data from its vector format to a raster format, since the reverse involves a much more complex and less reliable procedure. It was decided that the GRID system would be used as the GIS for the study, so the wetlands data was converted to a "Single Variable Grid" format (SVG). There are several different variations of raster formats, and the landcover type data was in one known as "Interagency Transfer Tape" format (ITT). To make the two raster data sets compatible, the landcover type data was converted from the ITT version to the SVG, a relatively simple process.

Not only did the two data sets have to be the same format, they also had to be of the same "resolution". In other words, the pixel size (size of the grid cell) had to be the same dimensions in each case. Since the pixel size of the landcover type data was already 50 meters by 50 meters, the size of the pixels for the conversion of the wetlands data was set to 50 meters square also. In terms of the area represented on the ground by that level of resolution, each pixel covered approximately .6 acres. Both data sets were previously registered to the same UTM coordinates and were therefore registered to each other automatically. This enabled a point on the ground to be referenced in both data sets by the same pixel location (row and column number). At this time the two data sets were loaded into the same grid cell database in order to facilitate the manipulation and analysis of the data simultaneously. The data was now prepared for the next phase of the study.

Data Selection and Comparison

Once the two data sets were in the GRID system database, individual landcover types and wetland classes were selectively retrieved for the study area, using the extraction function of the GIS system (ie. all gramminod marsh landcover type and all persistent emergent marshes wetland class). As stated earlier, the study was confined to landcover types that were correlated with wetland environments. After the selected data were extracted from the database, they were combined through boolean logic to form categories representing various possible combinations. For example, a simple extraction might be that of gramminoid marsh landcover and persistent emergent marsh wetland. The possible combinations would be (1) gramminoid marsh + persistent emergent marsh, (2) gramminoid marsh alone, (3) persistent emergent marsh alone, and (4) neither. As the number of landcover types and/or wetland classes increases, the number of possible combinations increases considerably, though usually not all of the possible combinations will occur, and not all the combinations that occur will be logical ones. The extraction and combination procedure (compositing) is an analysis technique to determine the degree to which the two selected data sets spatially correspond. In other words, for each landcover type in the study area, the compositing procedure determined which wetland classes occurred in the same location and the amount of area they covered. As an example, there might be 300 acres of landcover type A in the study area. Within the area covered by type A there might be 40 acres of wetland class 1, 10 acres of wetland class 2, and 250 acres of wetland class 3, or three combinations that occur.

The compositing procedure was accomplished in the GRID system by programming a "model", which extracted the appropriate landcover types and wetland classes and combined them into new data categories whose values reflected the particular combination that occurred. The modelling program then calculated the number of pixels (grid cells) for each combination that occurred. The final result of the compositing procedure consisted of two items. First, a tabular report showing the combinations of landcover type and wetland class with the number of acres that occurred. Second, a Single Variable Grid cell file (SVG) in which the value stored for each pixel was a unique number representing each particular combination. The SVG was used later as the input file to a raster plotting routine, which generated a plot file for graphic output on a high speed drum plotter.

Accuracy Assessment

In assessing the accuracy of the landcover type map for the study area a fundemental assumption was made concerning the criteria for assessment. It was assumed that the wetlands inventory data was the most accurate representation of the actual landcover on the ground, with respect to the wetland environment. In other words, the wetland data was the standard by which the landcover type map was to be measured or compared. It was felt that this assumption was valid, considering the greater level of detail in the classification and mapping of the wetland classes, as well as the higher incidence of field verification and accuracy assessment performed on the wetlands data.

The accuracy assessment procedure for the landcover type map consisted of identifying combinations of landcover types and wetland classes according to their degree of logical correspondence or "match". Combinations were then grouped into one of three assessment categories based on their degree of match.

Category 1 : High probability of error in classification (logically mis-matched)

Category 2 : Potential error in classification (possible match under certain conditions or assumptions)

Category 3 : High probability of correct classification (logical match under most conditions and assumptions)

In the first category were combinations such as a landcover type of "soil/rock/sediment" and a wetland class of "persistent emergent marsh". The second category included combinations where the landcover type could conceivably contain small, isolated occurrences of the particular wetland class or was so broadly defined as to allow for the occurrence of several, more detailed wetland classes. An example of the second category would be a combination of "dwarf shrub - lichen tundra" landcover type and "saturated shrub bog" wetland class. The last category contained all the combinations in which it was very likely the two data sets were in close agreement, such as "string bog - wetlands" landcover type and "saturated, emergent, bog-type marsh" wetland class.

Once the combinations were identified and grouped into one of the three categories, the total area of each combination and its assessment category were summarized by the landcover type. By comparing the totals in each assessment category, a relative measure of accuracy was determined for each landcover type. A ranking among landcover types was made based upon comparing their relative accuracies. The results of both comparisons were summarized in tabular display. Limited time prevented any further work with the results, such as more sophisticated statistical analysis between landcover types.

RESULTS AND CONCLUSIONS

To reiterate, the purpose of this study was to investigate a methodology for quickly evaluating the accuracy of LANDSAT dervived landcover type maps, and not to conduct a thorough and detailed assessment of the classification accuracy of the Kenai Peninsula landcover type maps. In view of the limited scope of the study, the results of testing the methodology on the Kenai Peninsula landcover type maps are very preliminary. A summary of the initial results of the comparison between the landcover types and wetland classes is included in Appendix C.

The comparison of the landcover type map and the wetland inventory for the Kenai C-3 quadrangle yielded three conclusions with respect to the task of assessing the classification accuracy.

(1) The use of the GIS provided the capability to determine where the two data sets were logically "mis-matched", the nature of the possible classification errors, and the extent of the conditions.

(2) The GIS performed the assessment functions relatively quickly and in an efficient manner, particularly in view of the fact that the study area covered over 180 square miles, at a resolution of about 1/2 acre.

(3) The preliminary results of the testing of the methodology showed a significant agreement between many of the landcover types and the wetland classes. In addition, there were classification errors to varying degrees for all landcover types. It should be noted that this conclusion is preliminary and is not supported by a rigorous statistical analysis of the results yet.

Although the project seemed to demonstrate the utility of a GIS to facilitate an accuracy assessment of LANDSAT derived landcover type maps, there remains a great deal of work yet to be accomplished. In particular, a need exists to develop specific techniques for assessing accuracy, specific criteria for measuring accuracy, and strategies for utilizing the results. A GIS is a valuable tool in such a task.

APPENDIX A

KENAI C-3 LANDCOVER TYPES

Code	Description
1	Conifer Forest
2	Conifer Woodland
3	Mixed Deciduous / Conifer Forest
4	Deciduous Scrub - Sub-Alpine
5	Deciduous Scrub - Lowland & Montane
6	Dwarf Shrub - Low Shrub Peatland
7	String Bogs & Wetlands
8	Dwarf Shrub - Tundra
9	Dwarf Shrub - Lichen Tundra
10	Lichen Tundra
11	Gramminoid & Disturbed Areas
12	Snow & Ice
13	Water - High Sediment
14	Water - Moderate Sediment
15	Water - Clear
16	Soil/Rock/Sediment

APPENDIX B

KENAI C-3 WETLAND INVENTORY

Code	Description
PSS4/1B	Saturated, Open Canopy Black Spruce Bog
PSS1/EM5B	Saturated Shrub Bog
PSS4B	Saturated Black Spruce Bog
PEM5B	Saturated, Emergent, Bog-type Marshes
PEM5C	Seasonally Flooded, Persistent Emergents
PSS1/EM5F	String Bogs and Reticulate Bogs
POWH	Permanently Flooded, Small Open Ponds
PEM5F	Semi-Permanently Flooded, Emergent Marshes
PSS1B	Saturated Shrub Bog (70% Canopy)
PSS1C	Seasonally Flooded, Dense Shrub
PF04/EM5B	Saturated, Black Spruce Bog - Emergent Layer
PEM5H	Permanently Flooded, Emergent Marshes
PAB4H	Permanently Flooded, Floating Aquatics
PSS/EM5B	Saturated Shrub Bog (30% canopy)
PSS1/4B	Saturated Deciduous Shrub Mixed Black Spruce
PEM5/OH	Permanently Flooded Open Water, Emergent Marsh
PSS4/EM5B	Saturated Black Spruce Bog W/ Emergent Layer
PSS4/EM5C	Seasonally Flooded Areas W/ Black Spruce
PF04B	Saturated Black Spruce Bogs
PSS1/EM5C	Seasonally Flooded Areas W/ Deciduous Shrub
L1OWH	Permanently Flooded, Open Water Areas of Lakes
L2AB4H	Permanently Flooded, Shallow Lakes - Aquatics

APPENDIX C

SUMMARY OF COMPARISON RESULTS

Landcover Type	5	6	7	8	11	14	15	16
Total Acres	13955	15674	3414	636	2231	131	4333	103
Wetland Class	Acres by Landcover Type							
PSS4B	* 33	? 890	+ 60	? 1	* 27		* 9	
PSS1/EM5B	? 3284	? 3394	+1069	? 6	* 219		* 138	* 1
PSS4B	* 10	? 23	? 14				* 3	
PEM5B	* 97	? 164	+ 42	? 4	? 5		* 22	
PEM5C	* 232	? 269	+ 9	? 2	? 3			
PSS1/EM5F	* 198	? 290	+ 722		* 17		? 36	
POWH	? 258	? 126	? 139	? 4	? 6		+ 223	
PEM5F	* 132	? 158	+ 247	? 1	* 16		? 19	
PSS1B		? 3	+ 1		* 1			
PSS/EM5B					? 1			
PEM5/OH		* 7	+ 17					
PSS4/EM5B	* 77	? 48						
PSS4/EM5C	* 214	? 49			? 27			
L1OWH	* 124	* 109	* 372	* 3	* 35	+ 114	+ 3039	* 16
L2AB4H	* 13		* 22		* 6	+ 6	+ 147	* 6

Category 1 : * (High Probability of Error in Classification)

Category 2 : ? (Potential Error in Classification)

Category 3 : + (High Probability of Correct Classification)