LAND COVER/USE CLASSIFICATION OF CAIRNS, QUEENSLAND, AUSTRALIA: A REMOTE SENSING STUDY INVOLVING THE CONJUNCTIVE USE OF THE AIRBORNE IMAGING SPECTROMETER, THE LARGE FORMAT CAMERA AND THE THEMATIC MAPPER SIMULATOR

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ABSTRACT

In an attempt to improve the land cover/use classification accuracy obtainable from remotely sensed multispectral imagery, AIS-I images have been analyzed in conjunction with TMS (NS001), LFC color infrared photography and black and white aerial photography. Specific portions of the combined data set were registered and used for classification. Following this procedure, the resulting derived data was tested using an overall accuracy assessment method.

This study is not based upon the use of precise photogrammetric 2D-3D-2D geometric modeling techniques. Instead, the discussion exposes resultant spectral findings from the image-to-image registrations. Problems associated with the AIS-I - TMS integration are considered, and useful applications of the imagery combination are presented.

More advanced methodologies for imagery integration are needed if multisystem data sets are to be utilized fully. Nevertheless, fundamental research, such as described herein, provides a formulation for future Earth Observation Station-related multisensor studies.

INTRODUCTION

Considerable technical research and development have been completed with regard to the design of remote sensing systems, and as more sophisticated imaging systems have been brought on-line, there has been greater interest directed towards the utilization of an ever increasing amount of data. In particular, as a method for realizing the full potential of remotely sensed imagery, some research has addressed the various aspects of combining complementary sensor data. In an effort to broaden the applicability of remotely sensed data, Airborne Imaging Spectrometer-I (AIS-I), Thematic Mapper Simulator (NS001 or TMS) and Large Format Camera (LFC) imagery have been analyzed conjunctively for purposes of land use/cover classification. Specifically, all data was examined to assist in the classification of Cairns, Queensland, Australia. The research objectives focused on the compatibility of an LFC, AIS-I and TMS-AIS-I imagery set.

The space-based photography was obtained by the NASA LFC during the Space Transportation System Mission 41-G, from aboard the Shuttle Challenger at an altitude of approximately 225.75 kilometers. The individual frames used for this study, 1696-1698, were taken on 11 October 1984 using Eastman Kodak SO-131 high definition aerochrome color infrared (positive) film. Without magnification, the approximate scale of the photography was 1:778,630 which, in turn, yielded an estimated spatial resolution of 20 meters (Lucas, Pearson, and Biache, 1986).

AIS-I imagery were collected aboard the NASA Ames C-130 aircraft on 22 October 1985. The altitude of the aircraft during the flight was nominally 7000 meters. Aerial black and white photography was also collected by the C-130 using a bore-sighted 35mm referencing camera along with imagery from the NS001 multispectral scanner. A second set of black and white photographs, taken on 13 August 1984 at 450 meters (provided by Northern Air Surveys under contract to the Queensland Department of Surveying and Mapping), was also included. Table 1 summarizes all data available for this land classification.

Table 1

Sensor/Camera	Spectral Range (micrometers)
Large Format Camera	
Kodak SO-131 film	0.50 - 0.90
Airborne Imaging Spectrometer-I	
128 spectral bands	
spectral sampling at 9.6 nm	1.20 - 2.40
Thematic Mapper Simulator (NS001)	
Band 1	0.448 - 0.519
Band 2	0.529 - 0.603
Band 3	0.633 - 0.697
Band 4	0.767 - 0.910
Band 5	1.00 - 1.30
Band 6	1.57 - 1.71
Band 7	2.10 - 2.38
Band 8	10.90 - 12.30
Aerial Photography (from 7 kilometers)	Black and White Aerochrome
Aerial Photography (from 450 meters)	Black and White Aerochrome

ANALYSIS TECHNIQUES

The basis for this study was the Anderson et al (1976) land use/cover classification system. This technique was deemed most suitable since the hierarchical design of the Anderson system is structured to be driven primarily by the interpretation of remote sensing data obtained at various scales and resolutions and not data collected in situ (Jensen, 1986).

The initial research goal was to incorporate the AIS-I imagery to the maximum extent possible in the respective phases of the classification.

Extreme amounts of distortion in the original AIS-I data, however, prohibited use of the entire flight-line. Efforts to remove this skewing problem were not employed. Hence, the first 35% and the last 12% of the imagery were not analyzed. This narrowed the choice of specific study sites considerably. Therefore, the specific study area began at Admiralty Island, continued through Smith's Creek, Trinity Inlet, various loading pier areas, and finally, ending in downtown Cairns.

Photographic analysis of the LFC hard-copy was performed using a Bausch & Lomb binocular zoom microscope. Stereo analysis was performed with a Zeiss Aerotopo stereoscope as well as with the Autometric-developed Analytical Photogrammetric Processing System (APPS-IV). AIS-I and TMS imagery were analyzed using the Earth Resources Data Analysis System (ERDAS) version 7.2, which was installed in a COMPAQ 386 micro computer. Finally, AIS-I data were also analyzed using the Spectral Analysis Manager (SPAM) and a Gould DeAnza FD5000 image processor with a VAX 11/750 computer as the host.

PHOTOGRAPHIC ANALYSIS RESULTS

From analysis of the LFC photography, a basic delineation of land use/cover was possible. For example, the vast abundance of healthy wetlands was particularly striking. The delineation of specific items, however, was difficult to ascertain with the LFC hard-copy. Most notably, definition of specific vegetation type was not attainable. Under magnification, some urban land use functions were apparent. In particular, loading piers and adjacent structural features were discriminated. One area of unknown cover type was an open field just north of the dock area. This field, larger than two Cairns city blocks, displayed an even-toned green signature over the southern half, which transitioned into a highly irregular gray-white tone in the northern half. The deep red signatures of the neighboring lush marshes and forested areas were missing from the open field. Reasons for this highly irregular site could not be defined using the LFC imagery.

In support of these initial findings, the medium and low altitude panchromatic aerial photography was analyzed in an attempt to obtain a stronger identification of the Cairns areas in question. By interpreting the photography, the industrial layout of these sites became somewhat more apparent. Indeed, the dominant structural features were devoted to the local sugar industry. In addition, the open field appeared to have some grasses, but reasons for the change in signature were still undeterminable. Generally, information regarding soil moisture and soil type is difficult to obtain using aerial photography. To address this problem and further substantiate the classification, the multispectral imagery was accessed.

AIRBORNE IMAGING SPECTROMETER-I ANALYSIS AND RESULTS

Using only the photography, preliminary classification was possible. Two major concerns however, were not met with the hard-copy: (1) the wetland vegetation could not be species determined (2) the vegetation in the aforementioned field near the loading dock could not be accurately identified. To solve these problems, a discriminate analysis of the AIS-I imagery with SPAM was employed.

The first step in this process involved creating a series of spectral library plots based on the Cairns data from areas of known composition. For example, based on the photography and topographic maps of the region, certain distinguishable areas, such as grass from urban parks, shallow water bodies and concrete/steel urban structures, were located on the AIS-I imagery. Based on these specific pixels, brightness value plots were created for the first 80 bands of the 128 band data set and saved using the SPAM SAVEPLOT command. The second step for this method involved plotting pixel brightness values from the previously charted areas in question. Thus, from within the field area, pixel brightness value plots were created and, using the LIBPLOT command, compared to the newly created library plots. Based on these and other LIBPLOT comparisons, the wetland vegetation in question was determined to be lush wetland scrub brush. With regard to the open field, the northern half was determined to be covered by an even expanse of grass with intermittent groups of herbaceous shrubs. The southern extent of the field appeared to share a similar signature. The difference in tone, however, was determined to be the presence of high soil moisture levels.

REGISTERED IMAGERY (AIS-I AND TMS) ANALYSIS AND RESULTS

The third approach to analyzing the Cairns area involved superimposing the AIS-I with the TMS imagery and performing a statistical analysis of the resultant data file. Specifically, band extraction, based on examples documented by Ustin, Rock and Woodward (1986), was employed to remove selected bands of interest from the near infrared region of the AIS-I imagery. When examined visually using SPAM, bands 9, 16 and 30 were determined to exhibit significant brightness variations and were therefore extracted. Following this, the 3-band AIS-I data set and the 7-band (band 8 was not included) TMS data were downloaded from the VAX 11/750 to the COMPAQ 386/ERDAS image processing system.

Before performing a statistical classification on the AIS-I and TMS imagery together, the two data sets had to be registered. This image registration process involved translating and rotating the imagery so that objects were positioned coincident with respect to one another and corresponding elements of the same ground appeared in the same place on the registered imagery (Jensen, 1986). In this case, the AIS-I imagery were geometrically shifted to overlay the TMS "base map" image. It should be noted, however, that this process was not based on traditional photogrammetric techniques for 2D-3D-2D geometric modeling. Instead, this procedure simply represents an image-to-image registration.

The image registration was accomplished using the ERDAS CURSES, COORD2 and RECTIFY programs. First, using CURSES, ground control points were taken from both sets of imagery. Second, the COORD2 program was used to calculate the image transformation matrix and list the resultant coefficients. Root mean square error for this routine was set at 1.5. Third, RECTIFY was accessed to perform the actual image registration. During this process, the AIS-I imagery were rectified to "fit" the TMS imagery. The brightness values of the shifted AIS-I pixels were determined via an internal nearest neighbor function. Thus,

following this series of routines, the newly created image file contained 10 bands: 7 from the TMS and 3 from the AIS-I.

The classification of the TMS-AIS-I imagery was accomplished using the ERDAS CLUSTER program. This unsupervised classification algorithm operated in a two-pass mode. The first pass through the data set built the clusters by collecting points in the image's spectral space. For each collection of points, the CLUSTER routine calculated the accompanying cluster mean vectors. The second pass through the data set separately assigned each pixel of the 11 band data set to one of the mean vectors created in pass 1.

20 clusters were created from the imagery. With regard to spectral space, axes skip factors (for the x and y directions) were set at 2. Minimum distance between clusters was also established at 2. Finally, minimum allowable cluster radius was 14 and the cluster elimination threshold percentage was 1.

Following the classification process, two-dimensional two-band plots of the mean vector values were created. These scatterplots represented the intersections of the individual mean vectors and the specific location of the 20 cluster groupings. For comparison, scatterplots from the AIS-I vs TMS as well as from the TMS vs TMS are provided in Figures 1 and 2. After plotting these mean vectors, the final process involved translating the clusters into information classes. The final land use/cover classification or "derived" map was created using ERDAS geographic information systems color assignment routines.

Accuracy for this classification process was estimated using an overall accuracy assessment method based on acceptance sampling which has been documented by Arnoff (1982). In addition, Ginevan (1979) provides a methodology for applying this procedure to classified maps. Using this technique, 92 separate pixels were plotted and labeled from the classified imagery. These were then charted on 1:100,000 Royal Australian Survey Corps topographic maps. Based on this procedure, overall accuracy was determined to be 89%. Thus, the classified imagery is above the lower limit of 85% set by Arnoff and, in turn, represents an acceptable "derived" map.

CONCLUSIONS

This three-tiered approach to land cover/use classification discusses some of the benefits from combining complementary data sets. Admittedly, this investigation was somewhat simplistic. Nevertheless, imagery from the TMS, LFC and AIS-I were used to obtain an acceptable level of derived map accuracy. By using both discriminate and statistical techniques, each data set provided unique spectral information valuable to the goal of this preliminary study. In particular, the accuracy obtained from the image-to-image registration provides incentive to develop photogrammetric models for purposes of correlating and analyzing multisensor data sets.

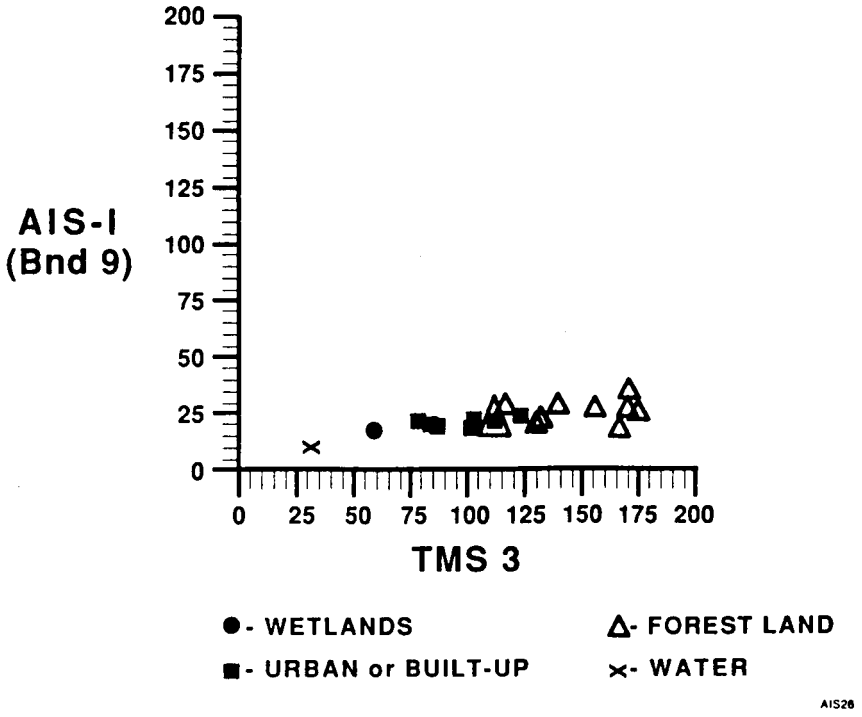

FIGURE 1. RESULTS FROM CLUSTERING ON THE REGISTERED AIRBORNE IMAGING SPECTROMETER-I - THEMATIC MAPPER SIMULATOR DIGITAL IMAGERY.

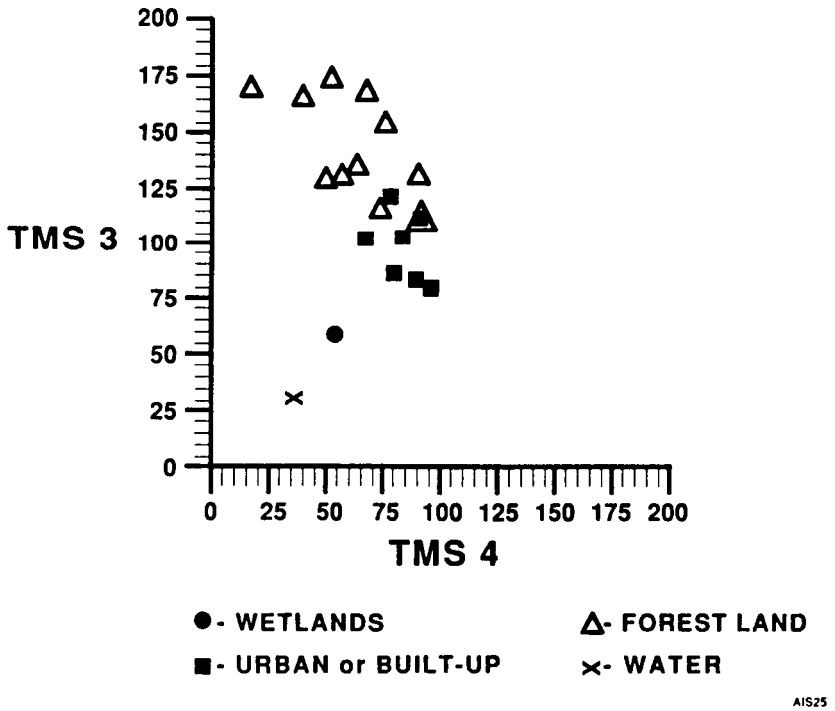

FIGURE 2. RESULTS FROM CLUSTERING ON THE REGISTERED AIRBORNE IMAGING SPECTROMETER-I - THEMATIC MAPPER SIMULATOR DIGITAL IMAGERY.

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