Evaluation of EO-1 ALI Data Through an Analysis of Land Cover and Land Use and Local Impacts of Hurricane Iris in Belize, Central America

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This investigation evaluated EO-1 Advanced Land Imager (ALI) data by classifying a diverse set of land cover/land use types, comparing the results to previously classified Landsat Thematic Mapper (TM) imagery, analyzing land cover changes associated with natural and manmade events, and evaluating its capability to resolve classification problems encountered with historical TM data. A related objective was to evaluate Hyperion data in terms of potentially improved discrimination capability relative to concurrent ALI and Landsat Enhanced Thematic Mapper Plus (ETM+) data. The research sites were located in central and southern Belize, Central America (Figure 1).

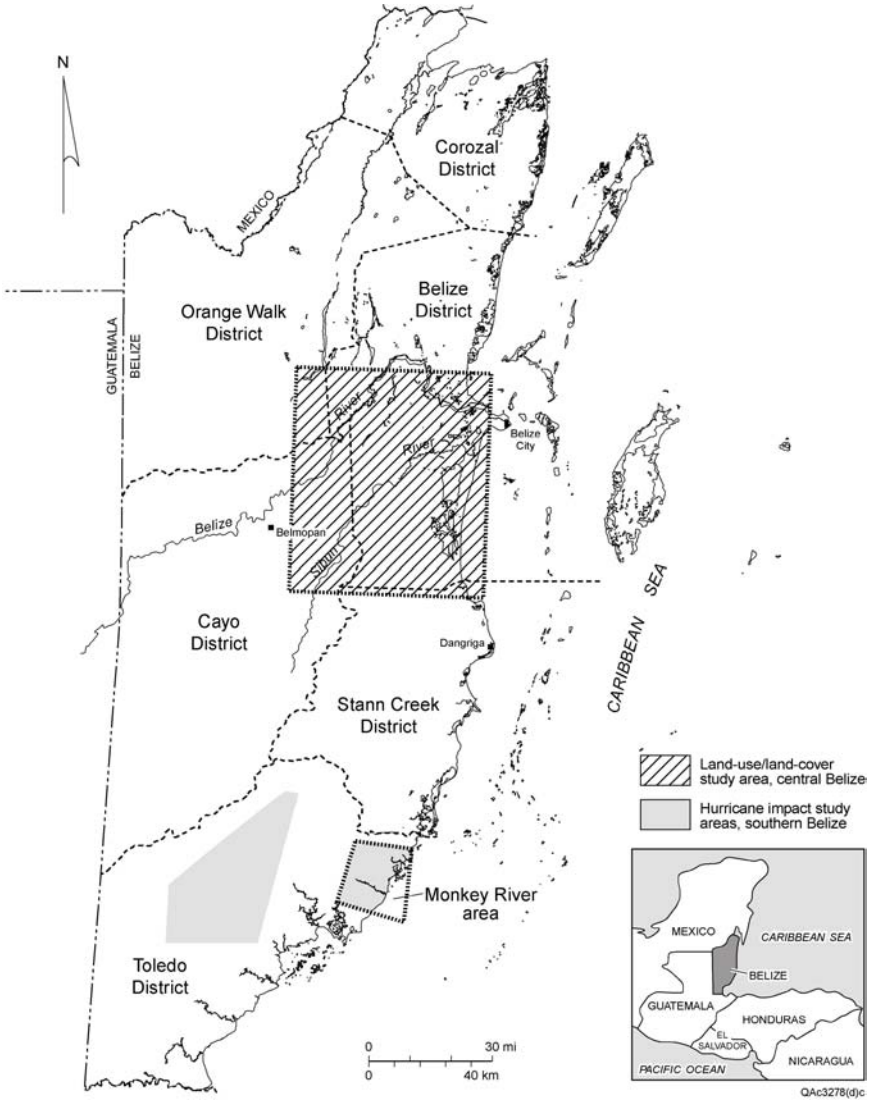

Figure 1. Index map of study areas in central and southern Belize.

Baseline data for the investigation included 1994 and 1996 studies of land cover/land use and deforestation based on Landsat ETM+ data and numerous GPS-located field survey sites and

overflights. Although many EO-1 acquisitions were scheduled in 2001 and 2002, only one acquisition, March 7, 2001, had reasonably cloud-free concurrent ETM+, ALI, and Hyperion data. Small cloud-free areas of ALI acquired on October 1, 2001, December 4, 2001, and March 10, 2002, over southern Belize were also analyzed. A field campaign was conducted in April and May 2002, in central and southern Belize to evaluate land cover/land use classification results, to assess impacts of Hurricane Iris, and to obtain additional field data for refining training sites for supervised classifications. Field data were collected at more than 110 GPS-located sites, which when combined with previously visited sites, provided data for almost 300 field sites. Figure 2 shows an ALI swath and preliminary classification of land cover/land use in central Belize.

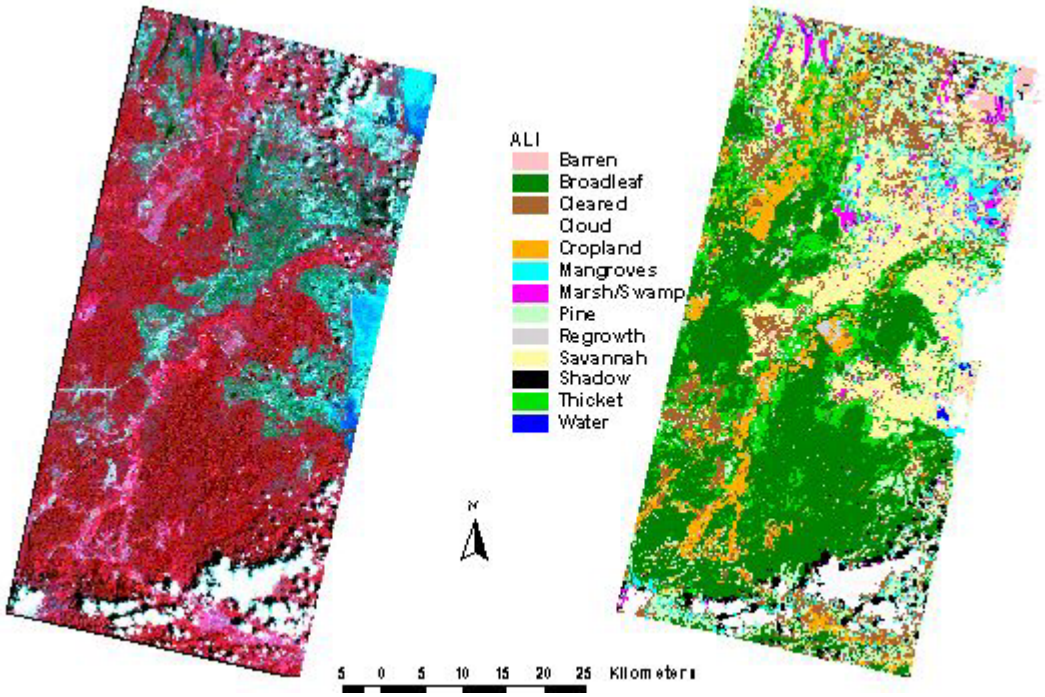

Figure 2. ALI coverage, March 7, 2001, and preliminary classification results in central Belize.

Investigators encountered several problems with the March 7 Hyperion data: no shortwave infrared (SWIR) data were collected, potential artifacts were identified in several bands, the diversity of vegetation in this particular swath was limited, and atmospheric effects were evident. Research then focused on analysis of the ALI data and on development of new statistical methods for analysis of multispectral and hyperspectral data, with the goal of applying these methods to Hyperion acquired at later dates or over other sites. ALI preprocessing included destriping, band-to-band alignment, geometric correction, and georeferencing. Work is ongoing in classifying and analyzing results of ALI and Landsat 7 data in central Belize.

The occurrence of Hurricane Iris provided the opportunity for a later investigation relating to change in forest cover. Hurricane Iris crossed southern Belize on October 8, 2001 (Figure 3). A Category 4 storm with winds exceeding 200 kph, it caused extensive wind damage including toppled and defoliated trees and major losses to the local banana industry. Among the regions affected by the storm were the Monkey River area on the coastal plain and inland mountain regions located approximately 130 km south of Belize City. In this study, investigators evaluated

the capability of ALI data to delineate land cover changes associated with destructive natural events such as hurricanes, focusing particularly on broadleaf forests.

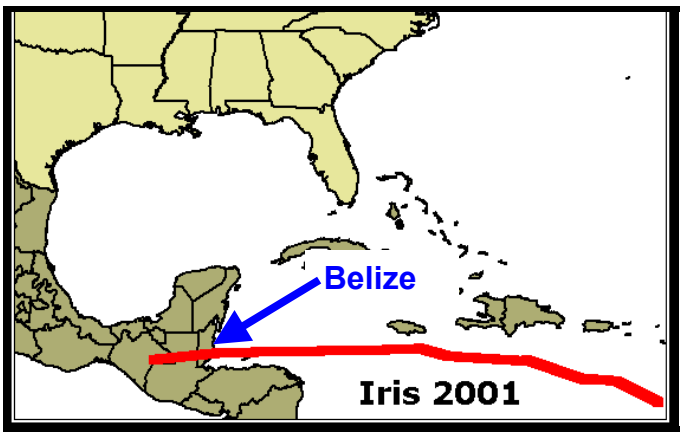

Figure 3. Path of Hurricane Iris.

The study areas spanned approximately 280 km^2 centered on the mouth of the Monkey River and an inland mountainous area more than 600 km^2 in size. Pre-hurricane classification data were acquired of the Monkey River area on March 1996 (Landsat TM) and on October 1, 2001 (Landsat 7 ETM+). Post-hurricane data were acquired on December 4, 2001 (ALI). Figure 4 shows a subset of a 1996 TM image that serves as an "index map." Figure 5 shows comparable natural color pre-hurricane 2001 ETM+ and post-hurricane ALI images.

Figure 4. Close up of 1996 TM image of Monkey River area.

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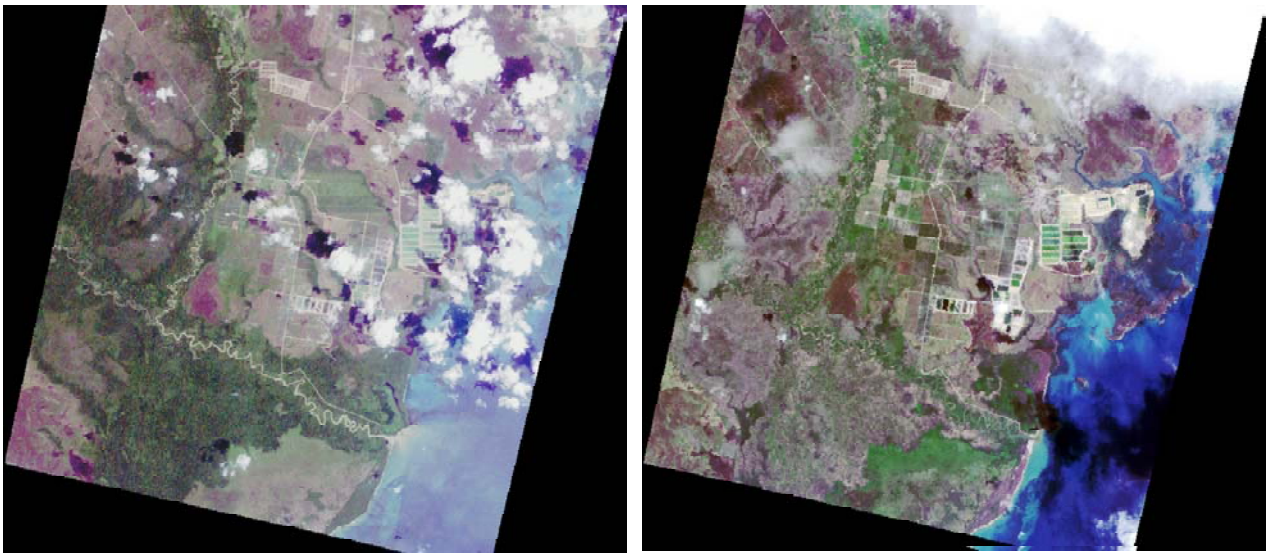

Figure 5. (Left) pre-Hurricane Iris from Landsat 7, October 1, 2001; post-Hurricane Iris from ALI, December 4, 2001. Both are natural color images.

Thirteen land cover/land use classes were identified before the hurricane, including four classes of forest and savannah, five classes of wetlands and coastal land, four classes of developed land, as well as as water, cloud, and cloud shadow. Of particular interest was the impact of the hurricane on the broadleaf forest. Figure 6 shows the pre-hurricane classes, and Figure 7 shows the post-hurricane classes that were mapped in the imagery.

Comparison of pre- and post-hurricane imagery showed substantial losses in broadleaf forests. Broadleaf forests made up approximately 40 percent of the study area in the 1996 Landsat imagery. At the Monkey River site, approximately 20 percent of the area had been classified as broadleaf forest on Landsat 7 imagery acquired pre-hurricane on October 1, 2001. Post-hurricane, ALI 2001 imagery identified less than 1 percent of the area as broadleaf forest (Table 1). Through GIS overlay analysis, the investigators found that areas that had previously been identified as broadleaf forest now had a different spectral reflectance, with more than 70 percent of the area classified as "savannah, pine/savannah, and other grasslands such as farmland." This change indicated extensive broadleaf defoliation. In the inland study area, broadleaf forests made up about 70 percent of the land cover before the hurricane and only about 12 percent after the hurricane, also indicating extensive forest damage.

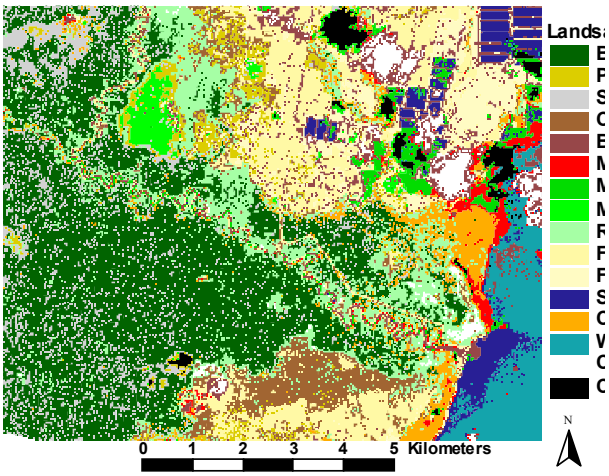

Figure 6. Pre-Hurricane Iris classes.

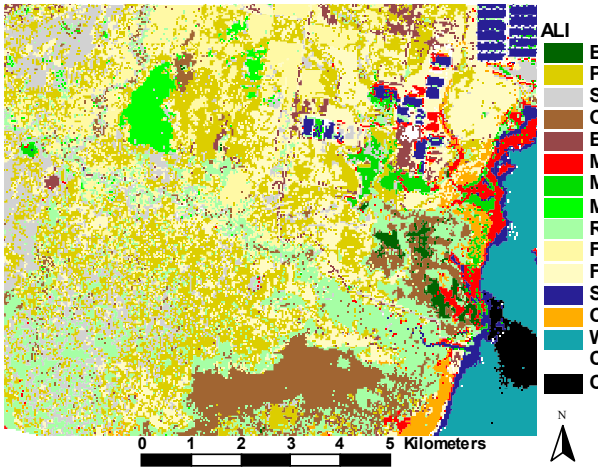

Figure 7. Post-Hurricane Iris classes.

Table 1. Pre- and post-hurricane land cover/land use percentages at Monkey River (Total area ~24,750 ha)

Class	ETM+	ALI
Broadleaf	19.0	0.3
Pine/Savannah	7.3	18.2
Savannah	5.4	9.5
Coastal Savannah	3.1	3.1
Barren/Residential/Cloud	6.3	7.2
Mangroves	2.6	3.7
Marsh 1 & 2	5.7	2.6
Riparian	6.3	7.5
Farmland 1 & 2	17.6	17.5
Coastal Strand	1.9	2.4
Shrimp Farm	2.7	3.5
Water	12.9	12.3
Cloud	6.6	10.6
Shadow	2.5	1.7

Accuracy of the classification using ETM+ October 1 data and ALI December 4 data was also evaluated in using imagery from the two sensors (Figure 8). For all experiments, although classification results were similar, ALI exhibited the highest degree of accuracy in discriminating several difficult class pairs in test data (Table 2). Striping artifacts in ALI were limited and could usually be removed effectively for classification purposes. Accuracy was determined by use of ground truth from field surveys taken in 1996-98. It should be noted that some classes defined in these surveys may have changed in the interim, and additional ground truth is being used to verify the results.

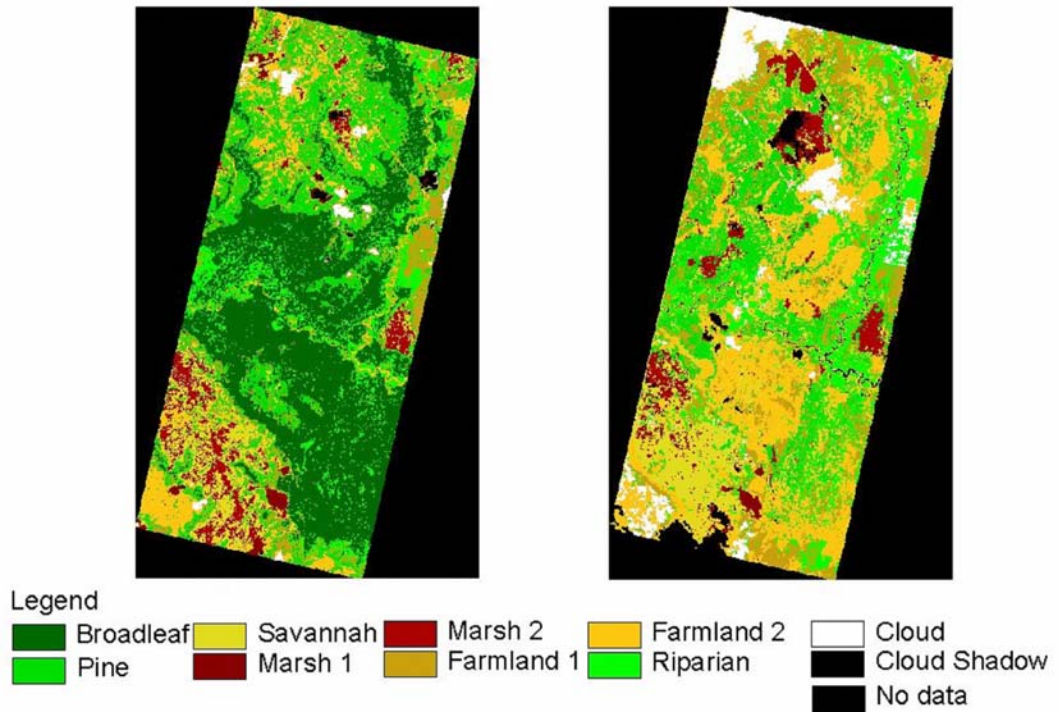

Figure 8. Monkey River area classification results. Landsat results are on the left and ALI on the right.

Table 2. Classification accuracies.

Experiment No.	ETM+ October 1, 2001	ALI December 4, 2001
1	86.29	97.14
2	86.18	98.18
3	86.74	97.66
4	86.74	97.40
5	85.62	97.66
Overall Accuracies	**86.31**	**97.61**
Std. Deviation	**0.47**	**0.39**

Conclusion:

Comparison of ALI and Landsat ETM+ classification results indicated overall that ALI is superior for discriminating several difficult classes such as thicket, regrowth, cropland, and cleared land. In addition, ALI appeared to be superior to Landsat TM data in delineating some coastal land cover classes such as mangrove. Additional ground truth data collected during a field campaign in May 2002, helped verify preliminary classification results, particularly for the mangrove class.

ALI data was also used effectively to determine the impacts of Hurricane Iris on broadleaf forests and possibly on other land-cover types. Changes in spectral signatures and texture were clearly delineated.