Comparison of EO-1 Advanced Land Imager and Landsat 7 Enhanced Thematic Mapper for Crop Identification and Yield Prediction in Mexico

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Possible applications for the EO-1 Advanced Land Imager (ALI) are crop identification and crop yield prediction, both important for cropland monitoring and management. Crop identification is valuable for preparing large-scale area estimates, tracking the transport of important nutrients, and for identifying constraints on crop-specific characteristics such as the efficiency of water and light use. Crop yield estimates help identify areas with high or low yields, which can be used to determine appropriate areas for crop control and management. Yield estimates also provide valuable information to farmers and governments for marketing and trading decisions. Estimating crop yields require that crop condition be measured during the growing season, typically indicated by estimates of leaf area index (LAI).

A team of investigators carried out science validation activities relating to crop identification and crop yield prediction to determine whether the ALI could produce images directly comparable to those produced by the Enhanced Thematic Mapper Plus (ETM+) flying on Landsat 7 but at significant reductions in sensor size, mass, and cost. The validation also focused on determining the suitability of the ALI for continuity of Landsat-type remote sensing.

The science validation study took place over an agricultural region in northwest Mexico. Data was collected from the two sensors on January 14, 2002. The investigators compared the measurements obtained by the sensors, which have five similar spectral bands, a panchromatic band, and similar spatial resolutions. The ALI also has three additional bands: 1p, 4p, and 5p (Table 1).

Table 1. Band characteristics for Landsat ETM+ and EO-1 ALI sensors.

	EO-1 ALI		Landsat ETM+	
Band	Wavelength (μm)	Ground Resolution (m)	Wavelength (μm)	Ground Resolution (m)
1p	0.433 – 0.453	30	n/a	n/a
1	0.45 – 0.515	30	0.45 – 0.515	28.5
2	0.525 – 0.605	30	0.525 – 0.605	28.5
3	0.633 – 0.69	30	0.63 – 0.69	28.5
4	0.775 – 0.805	30	0.75 – 0.90	28.5
4p	0.845 – 0.89	30	n/a	n/a
5p	1.2 – 1.3	30	n/a	n/a
5	1.55 – 1.75	30	1.55 – 1.75	28.5
7	2.08 – 2.35	30	10.40 – 12.5	28.5
Pan	0.48 – 0.69	10	0.52 – 0.90	14.25

n/a = Not applicable

The researchers carried out field observations during January 2002 to identify the crops present on 115 fields (Figure 1). The three most common crops identified were two types of wheat (durum and bread wheat) and irrigated maize. The wheat fields were revisited later in the growing season when physical differences between the wheat types were more pronounced to confirm the wheat type classification.

Figure 1. An ALI panchromatic image of the Yaqui Valley study region. Fields used to compare ALI and ETM+ radiance are delineated by white lines.

In the study, Landsat ETM+ imagery was collected; one minute later ALI data was acquired for virtually identical ground scenes. ALI data was calibrated to radiance with a different calibration factor being applied to each detector in each of ALI's four sensor chip assemblies (SCAs). Some bad data was evident in ALI bands 5 and 5p, and band 3 in SCA 3 suffered from misregistration that was attributed to a "leaky" pixel correction and which required manual section of ground control points to register band 3 to the other SCA 3 bands. All datasets were geo-registered to within 1 pixel using geographic information systems (GIS) coverage of roads. A rectangular, interior portion of each field was defined for the analyses. An interior area of the field was selected to eliminate potential contamination from roads or adjacent fields in the comparison. The homogeneous fields and accurate georeferencing allowed the researchers to compare the spectral responses of the ALI and ETM+ without complications arising from spatial mismatches between the sensors.

To compare the ALI and ETM+ for crop identification, a supervised maximum likelihood classification (MLC) was performed on each image using all optical bands on the two instruments and the three major crops. Accuracy was defined in terms of the percentage of total pixels correctly classified by the MLC. For yield prediction, only the maize fields were analyzed.

This was done through the use of an identical growth model for the ALI and ETM+. There were no field measurements of grain yields available for direct field validation of yields, so while the performance of ETM+ and ALI yield predictions could be compared with each other, they could not be compared with yield predictions compiled through field measurements.

Radiance measurements for both ALI and ETM+ in the five bands with similar wavelength ranges agreed very well in the 115 fields surveyed. These fields exhibited cover types ranging from bare soil to fully developed crop canopies, which facilitated comparisons across a wide range of values in each band. ALI fell within 3% of Landsat radiance for the five bands the two instruments had in commoon, and three of the five ALI bands were within 1% of the ETM+ radiances. Results also suggested that the "prime" ALI bands (1p, 4p, and 5p) added little spectral information over that available from ETM+ data. Overall classification accuracy did increase from 72.0% with ETM+ to 81.4% for ALI, resulting mainly from improved separation of maize from wheat. This increased distinction between maize and wheat was attributed in part to the effect of canopy water status on near IR reflectance derivatives. The additional spectral information in ALI, residuals of a regression between bands 4 and 4p, although of small magnitude, appeared significant in crop classification. The greater sensitivity of ALI in the near IR region demonstrated the usefulness of its two near IR bands (4 and 4p).

Neither sensor was able to differentiate between the two types of wheat.

Both sensors generated similar crop yield predictions, but since there were no field measurements of yield, concluding which sensor predicted more accurate yields was difficult.

The panchromatic bands resulted in the most dramatic differences between the two sensors (Figures 2 and 3). The ALI pan band revealed far more landscape detail than the ETM+. ALI could also recognize gradients within fields that were not evident in ETM+ data. The enhanced performance of the ALI pan band was attributed to ALI's 10 meter instantaneous field of view (IFOV) compared to the 18 - 21 meter IFOV for ETM+, ALI's superior signal-to-noise ratio (SNR) and greater dynamic range, and the fact that the ALI pan band was limited to visible wavelengths of 480 – 680 nm while the ETM+ pan band covered both visible and near IR wavelengths of 520 – 900 nm. This is important because multiple scattering by vegetation in the near IR region leads to greater pixel-to-pixel interactions, or adjacency effects. Further, sensitivity to both visible and near IR wavelengths, as in the ETM+, reduces the contrast between bare soil and surfaces with vegetation present.

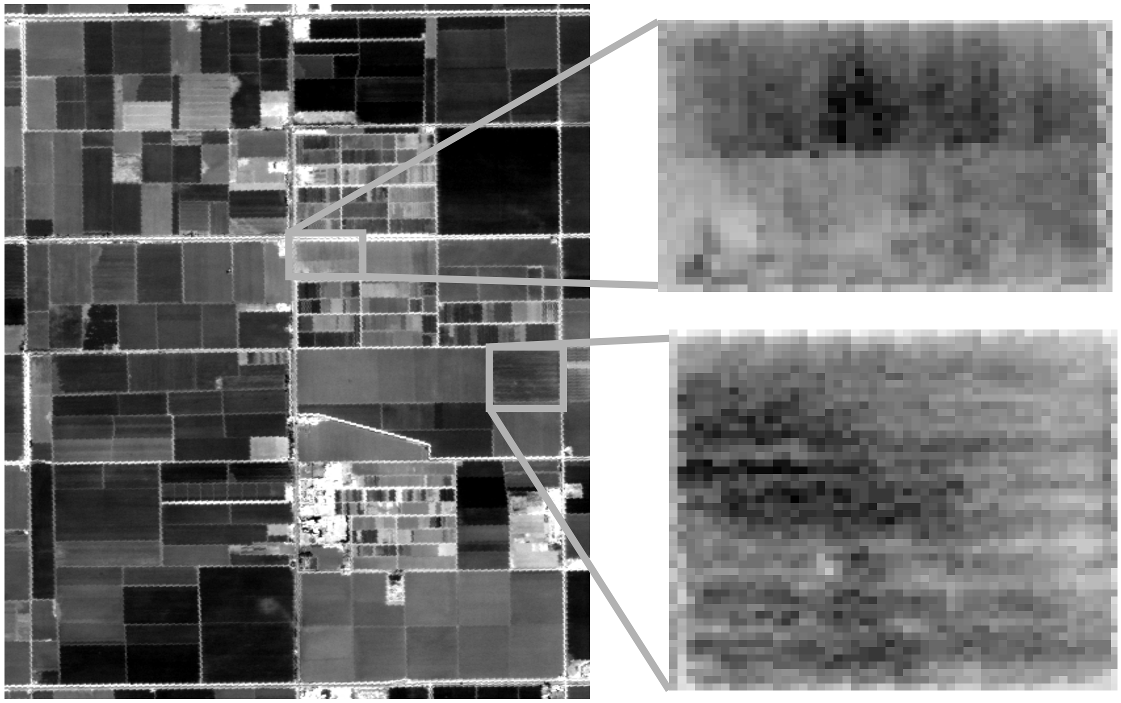

Figure 2. Panchromatic image from ALI for a 4 x 6-km area within the study region. Note the superior quality of this image when compared with the ETM+ image seen in Figure 3.

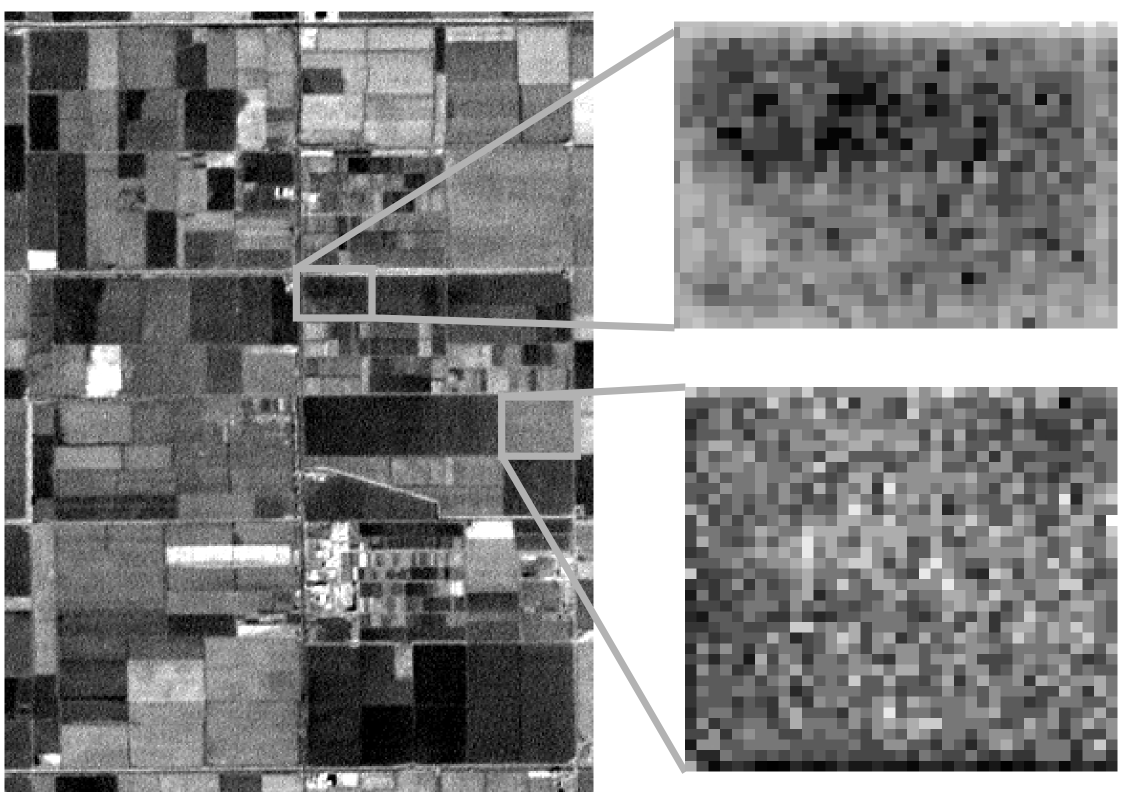

Figure 3. Panchromatic image from ETM+ for the same 4 x 6-km area as shown in Figure 2.

Conclusions:
Generally, this investigation demonstrated that ALI technology matches ETM+ performance in all areas except for problems associated with leaky pixels in ALI's band 3. ALI exceeded ETM+'s capabilities in identifying crops as a result of its additional spectral bands and produced very similar results for crop yield predictions. Further, the ALI pan band provided superior high spatial resolution images resulting from its increased SNR and dynamic range and its smaller IFOV and spectral range.

ALI's ability to capture small differences within fields is germane to precision agriculture, which aims to adjust inputs within fields to account for soil and topographic variations. ALI images would be more useful than those from the ETM+ when detecting early season deficiencies in different areas of a field, which the farmer could then address. The availability of satellite-based imagery, which is less costly than ground or airplane-based approaches, could greatly impact future precision agriculture.