Assessing Hyperion Performance Using the Coleambally Irrigation Area Calibration and Validation Site

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Introduction

The Australian CSIRO (Commonwealth Scientific and Industrial Research Organization) has conducted a number of investigations that evaluated the EO-1 Hyperion. These investigations used existing Australian calibration and validation sites and specific hyperspectral test sites with a range of existing and ongoing data collection and analysis programs. Hyperion achieved better than expected performance in a number of applications, including when applied to mineral mapping, the mapping of nitrogen for forestry and environmental applications, applications to coral reef mapping and water quality, and the provision of time series of established hyperspectral indices for agricultural applications. This summary focuses on describing techniques for the processing of Hyperion data so it can be used for agricultural applications.

Farmers and others engaged in agricultural management have used remote sensing products to acquire information potentially useful to them for at least the last 20 years. The type of information most useful to them, however, has been somewhat meager because of limitations of the technology, which have included the small number of fixed broad spectral bands, coarse spatial resolution, inadequate repeat cycles of data-gathering, and long delivery times for data. The EO-1 Hyperion hyperspectral spectrometer, launched in November 2000, may eliminate some of the limitations of remote sensing that agriculturalists have encountered. In particular, hyperspectral sensors can provide continuous spectral coverage through their ability to resolve the broader bands of currently operational systems such as Landsat into a large number of fine bands. The ability to provide continual spectral coverage had previously been limited to airborne systems, which experience other constraints that make it difficult or costly to acquire the most useful type of data. Airborne systems have problems relating to repeatability of data gathering, difficulty in covering large areas, and increased data processing.

The Coleambally Site

One of the major investigations was conducted at the Coleambally Irrigation Area (CIA) in New South Wales, Australia. This large (95,000 hectares) agricultural area that comprises more than 500 farms, is flat and consists of large, uniform fields of varying landcover types, including a number of types of rice as well as corn, soybeans, and sorghum. The area is approximately120 meters above mean sea level and is considered flat. It falls entirely within two Landsat Enhanced Thematic Mapper (ETM+) scenes that make it possible to acquire both Landsat and Hyperion imagery on an eight-day repeat cycle (Figure 1). In this study, a series of processing steps were taken to correct Hyperion data and reduce the effects of noise in order to produce measurements that would be valuable for farm management. The study also focused on a description of databases to be used for future instrument validation efforts and crop identification.

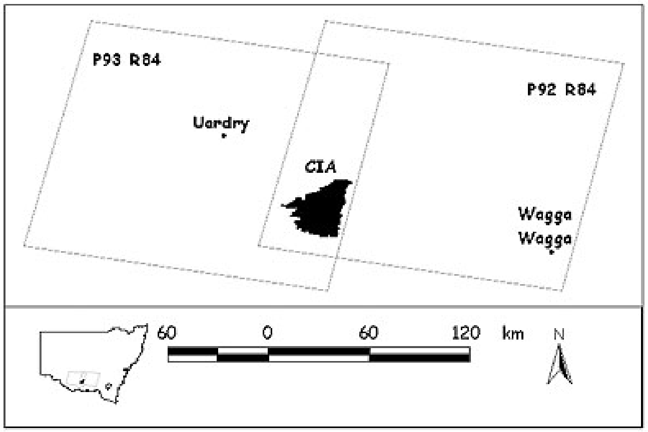


Figure 1. The CIA falls completely within two Landsat ETM+ scenes, allowing for an 8-day repeat cycle.

A time series of images was created by acquiring a series of 12 Hyperion images of the CIA during the 2001-2002 Southern Hemisphere summer growing season (Figure 2). On-site ground sampling was also performed several times during the growing season to validate the spectral signatures received from Hyperion. In addition, scanner data from the Hymap airborne hyperspectral imaging spectrometer at 5 meters spatial resolution was acquired on January 12, 2002, to provide an accurate geographic basic image (Figure 3). (A high-resolution digital air photo mosaic is acquired over the CIA every January.)

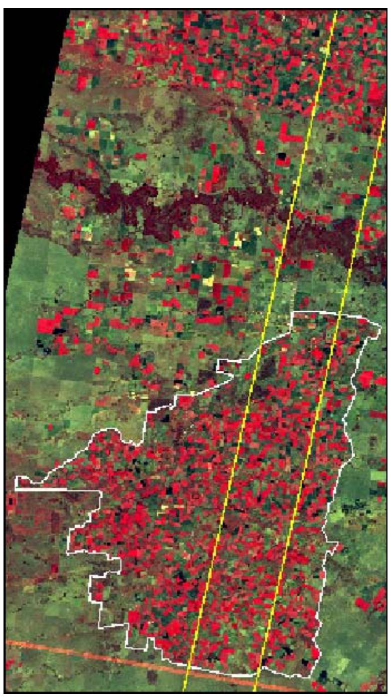


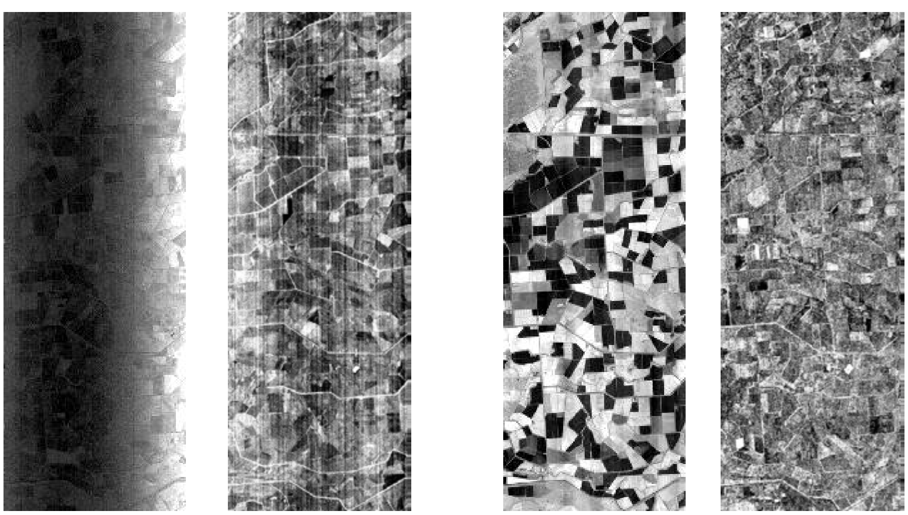
Figure 2. Site of Hyperion image acquisitions.

Figure 3. High resolution digital air photo acquired in January 2000 to support the 2000/2001 summer (Southern Hemisphere) growing season

Geometric correction was undertaken using Hyperion images acquired in the previous growing season. The study showed that Hyperion geometry was stable. Further, two bands (Band 57 and Band 78) were compared, and results indicated that processing to Level 1B_1 had excellent VNIR and SWIR co-registration. On the basis of this study, the complete time series has been registered to less than half a pixel accuracy between every image.

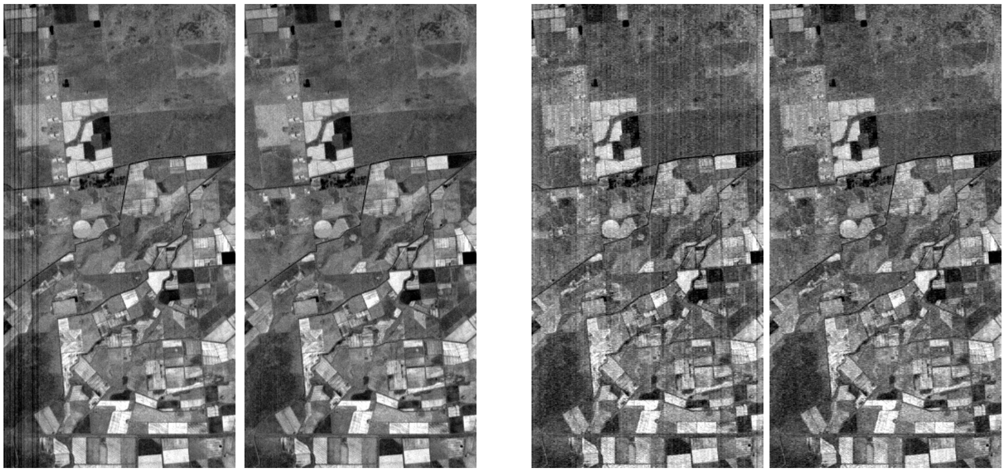
Hyperion data requires atmospheric correction, particularly in regard to atmospheric water vapor. HATCH, FLAASH, and ACORN atmospheric correction programs were used to measure the amount of water vapor. It was found that most methods of normalizing time series data were effective, but that some residual noise remained. This required that extra data cleaning and feature selection be performed. Also, a subset of 150 bands was selected from the total number of Hyperion bands in order to develop measurements from those bands considered "stable."

Another source of noise particularly visible and most pronounced in the SWIR bands was vertical streaking. Excellent noise reduction was obtained by equalizing column means and variances. Figure 4 shows MNF (Minimum Noise Fraction) Bands 1 and 15 before and after de-streaking. Figure 5 shows the visual impact of de-streaking.



MNF 1 Radiance Original Data **MNF 15 Radiance** **MNF 1 Radiance De-streaked Data** **MNF 15 Radiance**

Figure 4. MNF Bands 1 and 15 before and after de-streaking.



Original Data **De-Streaked Data** **Original Data** **De-Streaked Data**

VNIR **SWIR**

Figure 5. Visual impact of de-streaking.

The time series of images produced a large volume of data that would need processing before it could be used to measure soil and crop constituents. One way to organize this data is to "bin" the 150 spectral bands into synthetic Advanced Land Imager (ALI) bands and process the data into major land cover types. Atmospheric correction would already have been applied at the fine spectral level and the final data would exhibit a high SNR. This stratification into synthetic ALI bands should allow the most effective selection of indices.

Indices for agricultural performance

The work being undertaken has made use of a range of indices that have been applied at other sites and in other work at Coleambally to measure yield, stress, crop health, crop condition (such as nitrogen content), water content, and cover. The value of these indices is well established from airborne platforms and through the use of handheld spectrometers and in laboratory studies. The capacity for Hyperion data to be used to map these conditions from space has been assessed and it has been found that many of the indices can be successfully extracted from Hyperion data if the data are pre-processed using the kind of methods outlined above. If the data are effectively pre-processed and atmospherically corrected, then data series consistent with what can be obtained from airborne instruments can be derived (albeit with lower SNR) from the space data. However, an extensive time series such as that obtained from EO-1 would be too costly and could not be afforded through airborne data acquisition.

Conclusion:

This investigation demonstrated a way to process a time series of hyperspectral images to noise-reduce and normalize them so that they can be used to provide land use and other relevant spatial data. It has shown how time series of space data for regions anywhere in the world can be put together and how the proven benefits of hyperspectral data processing for agriculture can be applied in many cases at a broad scale and for regional surveys. Satellite data does not replace the kind of information that can be acquired from the air or on the ground, but it can provide complementary worldwide regional scale information at affordable costs.

In general, it was found that Hyperion performance exceeded expectations and demonstrated the value of developing and implementing a future mission. However, as an experiment, it has also demonstrated the need for improved SNR in a future space hyperspectral instrument as well as the value of developing and implementing such a future mission.