Analysis of EO-1 Hyperion Imagery for Desertification Research Applications in Argentina
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Drylands (arid and semi-arid lands) cover more than 45% of the global land surface. Various practices in these regions, such as changes in fire regimens, removal of vegetation, and over-grazing by cattle and sheep, have been linked to many recognized cases of dryland degradation and desertification around the world. Although studies at the local scale have documented changes in dryland ecosystems, there has been a shortage of large-scale ecological information on drylands primarily because of the size and biological complexity of these regions with the highly varied patterns in drylands presenting major challenges to multispectral studies. Furthermore, the lack of robust observational approaches has presented a significant barrier to regional monitoring efforts.

Newer remote sensing approaches are now allowing regional studies of a range of changes in drylands. In particular, imaging spectroscopy provides a way to remotely measure land surface properties that may prove key to regional studies of desertification. For almost two decades, high-quality imaging spectroscopy has been available from a very small number of airborne instruments. Airborne instruments, such as the Airborne Visible and Infrared Imaging Spectrometer (AVIRIS), have signal-to-noise capabilities and stabilities approaching spectrometers operating under laboratory conditions. However, this information has been collected over relatively small regions and under limited ecological conditions, which limits the general applicability of the observations.

The EO-1 Hyperion, the first Earth-looking spaceborne imaging spectrometer, was launched on November 22, 2000. Hyperion provides the first space-based hyperspectral observations of terrestrial ecosystems, providing measurements in 242 spectral bands covering the 0.4-2.5-μm region at a spatial resolution of 30 meters. Hyperion is considered a "moderate fidelity" instrument when compared to AVIRIS because of its lower stability and signal-to-noise performance. Nevertheless, a comparison of the performance of AVIRIS and Hyperion is vital to demonstrating the use of spaceborne imaging spectroscopy for measuring and monitoring dryland ecosystems and for providing technical and scientific input to future orbital imaging spectrometer missions.

This study tested and compared the accuracy and precision of AVIRIS with the spaceborne moderate-fidelity EO-1 Hyperion imaging spectrometer for dryland biophysical monitoring and desertification applications. Specifically, it compared measurements of vegetation and bare soil in the study region, which encompassed the Nacunan Man-and-Biosphere Reserve and a surrounding area of unprotected land in the central part of the Monte Desert of Central Argentina (Figure 1). In doing so, the investigators demonstrated a new approach to measuring surface properties indicative of land degradation and desertification in dryland regions. The study served to (1) test the applicability of hyperspectral observations for quantifying

Figure 1. Location of Nacunan Reserve

surface cover of vegetation and bare soil across a range of dryland ecosystems in Argentina; (2) compare the performance of AVIRIS and Hyperion in identical analyses of sub-pixel vegetation and soil cover over a large dryland region; and (3) try out new approaches for determining the regional status of dryland ecosystems worldwide, focusing particularly on indicators of land degradation and desertification.

The investigation quantitatively assessed vegetation properties among four major plant communities found in the region: algarrobal (mesquite), jarillal (creosote), medanal (sand dunes), and peladal (sparse creosote) (Figure 2). Field measurements of selected areas were collected, and the proportion of green, live plant tissue, termed photosynthetic vegetation (PV); senescent, woody, or dead tissue, called non-photosynthetic vegetation (NPV); and bare soil was recorded, as were other occasional surface materials such as rock. The field data were averaged across various sampling intervals so they most closely matched the spatial resolution of the AVIRIS and Hyperion data.

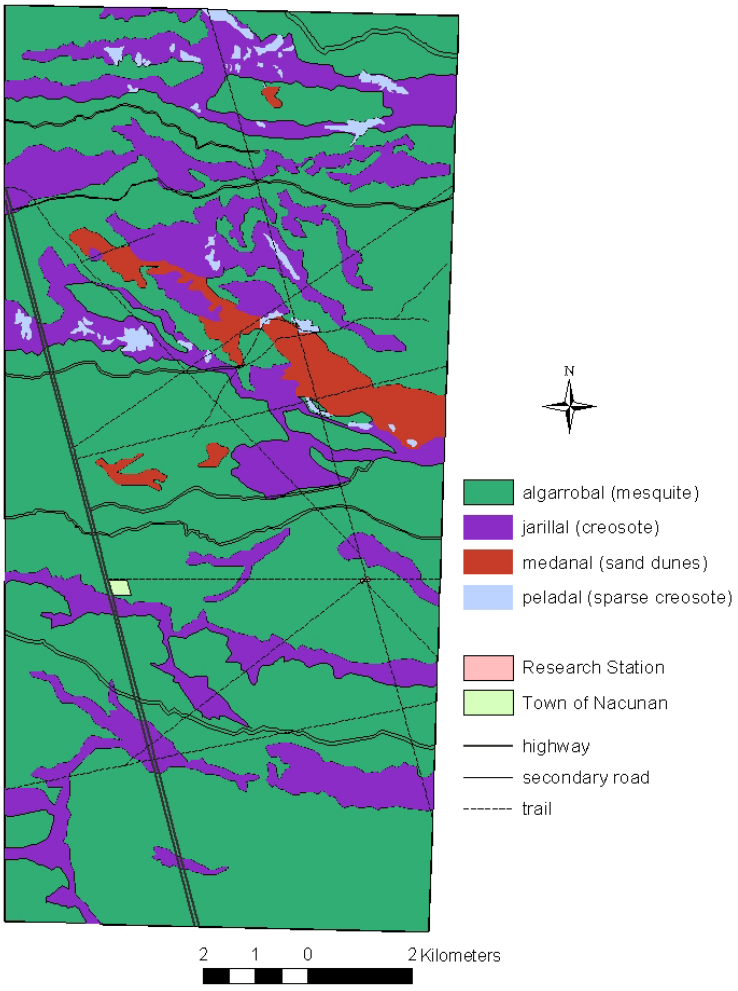

Figure 2. The Nacunan Man-and-Biosphere Reserve and four major plant communities that occur in the Monte Desert region.

Identical analyses were carried out using both AVIRIS and Hyperion imagery. AVIRIS data (at 4.5 meters resolution) and Hyperion data (at 30 meters resolution) were collected in the study area. AVIRIS data provided highly accurate estimates of PV, NPV, and bare soil when compared

with field data. The surface cover fractions indicated the unique biophysical structure of each plant community and quantitatively defined the effects of long-term grazing on these communities. Decreasing the AVIRIS spatial resolution to 30 meters decreased the certainty with which the results could be compared to field data but did not decrease the ability to quantify the presence, extent, and degree of land degradation in the region.

Hyperion provided accurate estimates of PV performance at 30-meter spatial resolution. Decreased accuracies by Hyperion for NPV and soilcover resulted from its lower signal-to-noise performance in the short wave infrared (SWIR) (2.0-2.4 μm) region. Increasing the pixel size to 60 meters slightly improved estimates of NPV and bare soil cover fractions. Spatial averaging did not enhance PV estimates, which were primarily determined by the red-edge component of the mixture analysis. NPV and bare soil estimates were accurate only when cover values exceeded ~30% (Figure 3).

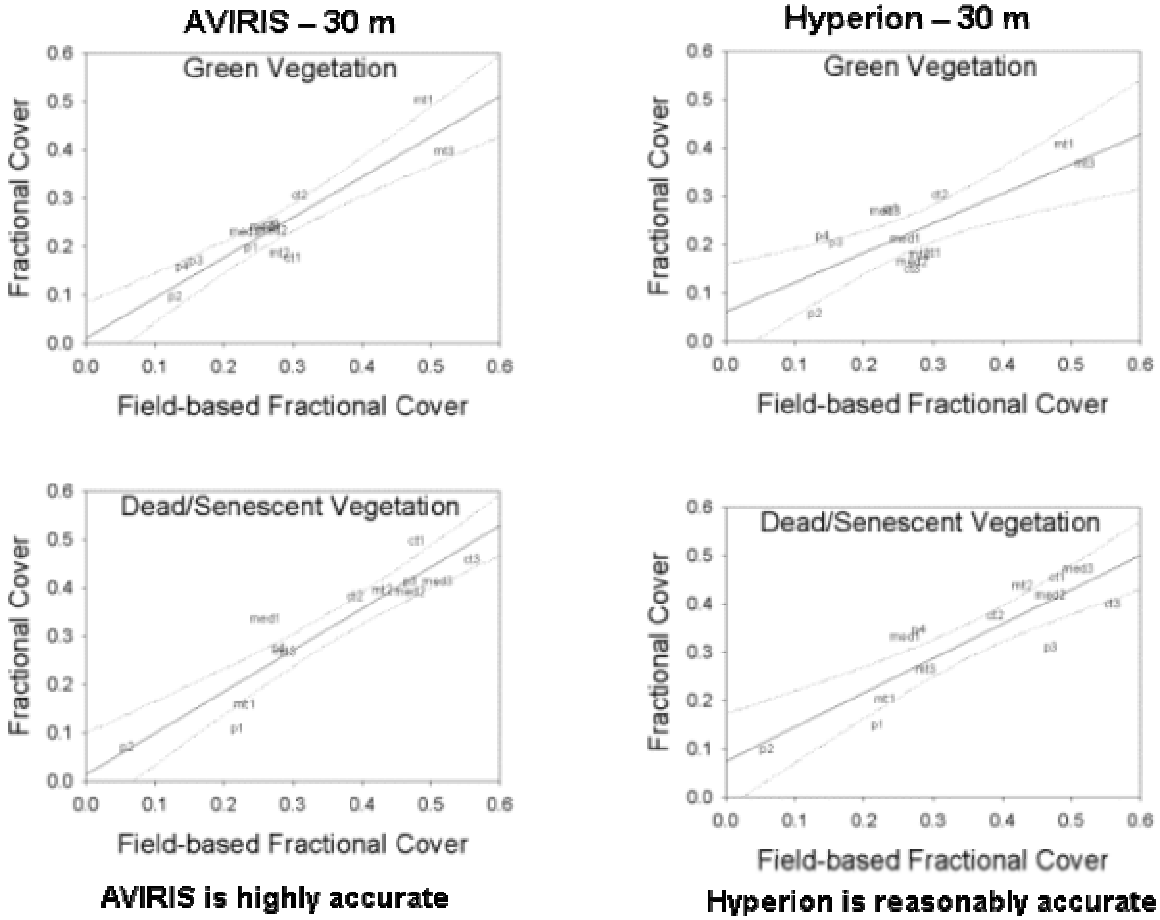

Figure 3. Comparison of field (ground) and spectral mixture analysis results using AVIRIS 30-m (left) and Hyperion 30-m data for green vegetation and dead/senescent vegetation.

In the Monte Desert region near the Nacunan Reserve, some areas have undergone a degree of woody vegetation encroachment indicative of rangeland degradation, but the spatial patterns are

localized and variable. In particular, a widespread NPV decrease and bare soil increase were common outside of the reserve. Both airborne (AVIRIS) and spaceborne (Hyperion) imaging spectroscopy indicated this situation.

Conclusions:
In general, the study demonstrated that high-fidelity airborne instruments such as AVIRIS perform exceptionally well, while moderate-fidelity instruments like Hyperion also provide adequate information to track broad changes in the proportion of PV, NPV, and bare soil.

The investigators concluded that imaging spectroscopy holds great promise for monitoring land use, land degradation, and desertification in dryland regions of the world. Hyperion represents a major step forward in the effort to use spaceborne imaging spectroscopy for environmental research and policy development issues anywhere in the world on a regular basis. Only a space-based instrument can provide this service, and the need for this technology is clearly defined for arid and semi-arid regional studies.