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Comparison of Simulated HyspIRI with Two Multispectral Sensors for Invasive Species Mapping

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Abstract

This paper assesses the potential of a single HyspIRI scene to estimate cover of the non-native invasive buffelgrass (Pennisetum ciliare) in a heterogeneous Sonoran Desert scrub ecosystem. We simulated HyspIRI (60 m) along with two multispectral sensors, Thematic Mapper (TM; 30 m) and Advanced Spaceborne Thermal Emission and Reflection Spectrometer (ASTER; 15 m), from high-resolution Airborne Visible/Infrared Imaging Spectrometer (AVIRIS; 3.2 m) imagery in an area infested by buffelgrass near Tucson, Arizona. We compared classification accuracies of all simulated sensors at spatial resolutions of 15 m, 30 m, and 60 m to evaluate tradeoffs of spectral and spatial resolution across the sensors. Although spectroscopically superior to Landsat TM and ASTER, ASTER easily outperformed HyspIRI for small infestations (225 m²) on account of its spatial resolution. Shortwave-infrared bands near 2.2 µm were key indicators for both HyspIRI and ASTER, highlighting the benefit of narrow-wave SWIR for mapping invasive species in arid ecosystems.

Introduction

Invasive species pose a rising global ecosystem challenge due to impacts to ecosystem structure, function, diversity, nutrient cycling, and disturbance regimes (Mooney and Hobbs, 2000). Managers and researchers require readily available data and tools for mapping and monitoring invasive species, yet the readily available satellite data are often too coarse spatially, spectrally, temporally, or a combination thereof to effectively and consistently map invasive species (Turner *et al.,* 2003). While deca-resolution (Morisette, 2010) broadband multispectral satellite imagery with regular return intervals such as the Landsat and Satellite Pour l'Observation de la Terre (SPOT) families of sensors have been widely successful at mapping vegetation communities and land-cover change, mapping individual plant species has been limited to cases in which large continuous areas have become invaded (e.g., Peterson, 2005; Bradley and Mustard, 2006) and typically requires distinct phenological differences between natives and invaders (Huang and Asner, 2009). Many would argue that invasions that reach this scale are either already unmanageable, or their presence is already well known. Regardless, small populations can play a disproportionate role in the rate of spread and treatment efficacy of invasions (Moody and Mack, 1988; Frid and Wilmshurst, 2009). Thus, mapping small populations remains a critical need for resource managers facing plant invasions.

A key limitation of multispectral imaging in dryland ecosystems has been an inability to consistently discriminate between mineral soil and non-photosynthetic vegetation (NPV) (Olsson *et al.*, 2011). Mineral soil and NPV have distinct wavelength features in the SWIR, particularly in the 2.0 to 2.4 µm region (Asner and Lobell, 2000; Nagler *et al.*, 2003). The multispectral SWIR instrument on ASTER promised to provide this capacity, but unfortunately, it suffered a series of failures that first limited its utility (Iwasaki and Tonooka, 2005) and ultimately rendered the SWIR instrument completely inoperable (ASTER Science Office, 2009).

Invasive species mapping has been more successful when hyperspectral imagery has been used in classification or target detection. AVIRIS and Hyperion have been used to map invasions (Ustin *et al.*, 2001; Underwood *et al.*, 2003; Lass *et al.*, 2005; Pengra *et al.*, 2007; Asner *et al.*, 2008), yet both have their drawbacks. AVIRIS is an airborne sensor with 224 contiguous band channels measuring upwelling radiance at 0.01 µm intervals between 0.40 and 2.50 µm. As an airborne sensor it can be flown at varying altitudes, resulting in spatial resolutions between 2 and 20 meters. Commissioning AVIRIS requires a research experiment proposal and is effectively limited to a small number of projects and locations. Hyperion is an experimental sensor mounted on the NASA EO-1 satellite and has 220 bands measuring radiance at 0.01 µm intervals between 0.40 and 2.50 µm at a 30 m spatial resolution. While Hyperion can visit the same location on a regular basis (every five to ten days with off-nadir pointing), there is a very limited collection cycle due to its narrow swath and its limited lifetime. As such, spatial coverage and temporal resolution from either of these two sensors are limited. Also, as an experimental instrument, Hyperion has issues with cross-track calibration and low signal-to-noise ratio (SNR), particularly in the shortwave-infrared (Datt *et al.*, 2003; Kruse *et al.*, 2003). All of these issues limit the usefulness of these two national assets to contribute to any operational invasive species detection program.

HyspIRI (Hyperspectral InfraRed Imager) is one of NASA's "decadal survey" missions that aims to address these and other monitoring concerns (NAS, 2007). HyspIRI is planned to have an imaging spectrometer that measures upwelling radiance from the visible to short wave infrared (VSWIR: 0.38 µm

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Photogrammetric Engineering & Remote Sensing
Vol. 80, No. 3, March 2014, pp. 217–227.

0099-1112/14/8003–217/$3.00/0
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doi: 10.14358/PERS.80.3.217