

SEN 03 Remote and embedded sensing in environmental systems

SEN 03.1 Overview

This new project focuses on up-scaling the CENS embedded sensing approaches in terrestrial and aquatic systems to larger spatial scales by integrating embedded and remote sensing techniques. More specifically, we are focusing on identifying and testing remote sensing methods and algorithms for detecting changes in the environment.

Progress in this year's Sen-03 report was primarily in two areas:

- Developing and testing of a high-resolution image classification method for mapping key plant species in a wildland setting (large-scale imager-as-sensor approach).
- Exploring the use of hyperspectral reflectance to understand spatio-temporal patterns in plant-soil interactions in a wildland setting.

Specific Objectives

The specific objectives related to this year's project were as follows:

- Developing and testing of a high-resolution image classification method for mapping key plant species productivity in a wildland setting (large-scale imager-as-sensor approach).
- Exploring the use of in situ hyperspectral reflectance to understand spatio-temporal patterns in plant-soil interactions in a wildland setting.

SEN 03.2 Approach

Species Productivity Mapping Using High-Resolution Images

In this study, spatial vegetation data were collected and analyzed to quantify total swamp timothy seed mass in a pair of managed wetland ponds in the Grassland Ecological Area (GEA) in Central California. We tested the feasibility of using spectral reflectance values (red and NIR bands) to derive vegetation indices to estimate swamp timothy (*Criopsis schenoides*) seed productivity. Swamp timothy is a key forage species for migratory waterfowl on the Pacific Flyway. In addition, the capacity of an object-based classification method incorporating image textural properties was investigated as a means to improve upon the spectral band and index-based approaches. The analysis here is based on two sets of aerial imagery taken approximately 4 weeks apart after pond drawdown in the adjacent wetland units, and on manually collected plant and seed biomass samples for the units.

In Situ Hyperspectral Reflectance and Plant-Soil Interactions

In this aspect of the Sen-03 project, we looked at the potential for hyperspectral reflectance to reveal information about plant-soil interactions. Specifically, we hypothesized that, because soil properties (e.g., the combination of soluble salts, clay content, soil moisture, and soil temperature), determine soil apparent electrical conductivity (ECa) impact plant physiology, there may be a useful correlation between a plant's hyperspectral reflectance and soil ECa. We tested this hypothesis in the same wetland setting noted above, mapping soil ECa distributions using a mobile, nondestructive electromagnetic inductance sensor and then collecting reflectance spectra for the swamp timothy species mentioned above.

SEN 03.3 Systems/Experiments

Species Productivity Mapping Using High-Resolution Images

Multiband high resolution aerial photographs were taken using a Zeiss RMK® Top 15 Aerial Survey Camera System (Figure 1). Images were taken at noon, zero degrees off nadir to minimize shadow effects. Aerial images responded to green (G, 500-600 nm), red (R, 600-700 nm), and near infrared (NIR, 700-900 nm) spectral bands. The scanner produced RGB digital images with 8-bit color with pixels in each band ranging from 0 to 255.

Calculations of vegetation indices are primarily based on reflectance while the aerial photographs record the reflected radiation of ground objects as digital numbers (DNs). DN's were converted to reflectance values using ground reflectance measurements in order to calculate vegetation indices. Ground reflectance data were collected using a field spectrometer (ASD FieldSpec Pro FR) with a spectral range of 350 to 2500 nm.

Vegetation sampling to establish ground-truth was conducted after the swamp timothy seeds had matured and the entire plant was desiccated. Sample locations were randomly generated using GIS software (ArcGIS v9.3, ESRI) at a sampling rate of one sample per 0.41 ha (DSS n=73, DSN n=81). The GPS system described above was used to identify each sample plot. At each location, a 10 cm x 10 cm core representing the 1 m x 1 m area was removed from the pedon, allowing the entire aboveground biomass to be clipped and secured. Samples were oven-dried at 105°C for 24 hours. Dry masses of total biomass, total swamp timothy, and swamp timothy seeds were determined

gravimetrically for each sample.

Hyperspectral Reflectance and Plant-Soil Interactions

A conventional electromagnetic (EM) induction method was employed to determine the soil ECa across the study site. The EM device (Model EM38-MK2, Geonics Ltd. Ontario, Canada) was coupled to a GPS unit (Model Ag 114, Trimble) using a handheld computer (Allegro Model CX), and the soil ECa was logged with the investigator's walking trace using commercial software (GPS

TrackMaker®, Geomar Software Inc.). The EM38-MK2 has two receiver coils which provide a shallow reading and a deep reading, approximately 0.75 m and 1.5 m, respectively (McNeill (1980)). The ECa survey was conducted when soil moisture was at or near field capacity. The EM-38 was held 10cm above soil surface while walking transects east to west with 15 meter spacing. Samples were logged continuously on two second intervals which, at a walking pace of 2 m/s, resulted in a sampling rate of roughly one every 4 meters. A total of 1221 ECa readings were recorded for the two EM survey depths (see Figure 2). Areas of the field that had dense emergent vegetation or tall cattails were not assessed because it was difficult to hold the EM-38 in a consistent position.

During the same day as the ECa survey, hyperspectral measurements were collected under a cloud-free sky using a field spectrometer (ASD FieldSpec Pro FR). The spectrometer was used to acquire images of radius 0.22m (total area of image 0.15 square meters) using a 1.2 m fiber optic (25° field of view) held approximately 1m height above each sample. All spectra were taken at the nadir position. The hyperspectral data were acquired approximately every 15 meters along the same transects as the EM-38 measurements (Figure 2). At each location, groundcover was visually assessed with respect to plant species, and the results recorded in terms of primary and secondary species and percent bare soil (quantified in 10% increments). White-referencing along with instrument calibration was undertaken every 10 minutes using the RS3TM 5.5.6 spectroradiometer software provided with the instrument, data were transferred wirelessly from the spectroradiometer to a field laptop. GPS coordinates were paired with each image sample using a handheld device (Model Ag 114, Trimble).

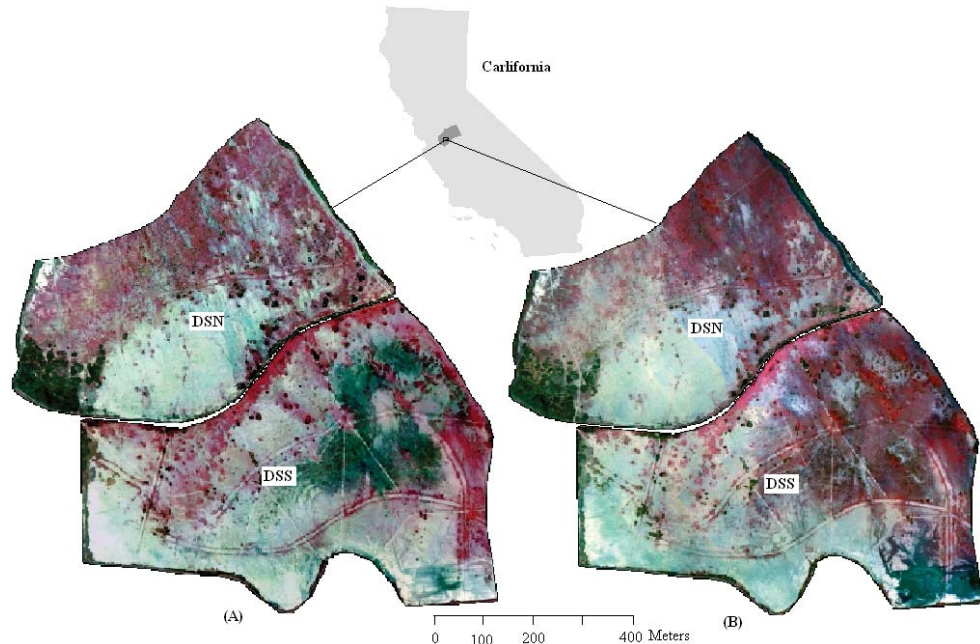


Figure 1. Wetland units Ducky Strike North (DSN) and Ducky Strike South (DSS): NIR spectral reflectance band; (A) May 11; (B) June 9.

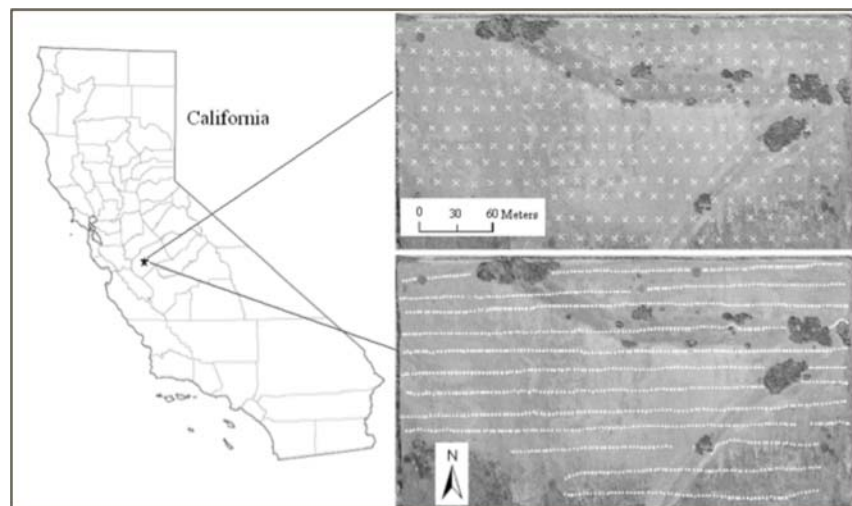


Figure 2. Site location, hyperspectral radiometer sampling locations (top) and electromagnetic survey trace (bottom).

SEN 03.3 Accomplishments

Species Productivity Mapping Using High-Resolution Images

The best swamp timothy dry seed mass predictions were obtained using the June aerial image, with the best performance achieved using the simple ratio index (SR) ($R^2=0.565$, Std. Err. = 29.3 g m⁻²), transformed soil-adjusted vegetation index (TSAVI) ($R^2=0.561$, Std. Err. = 29.9 g m⁻²) and normalized difference vegetation index (NDVI) ($R^2=0.554$, Std. Err. = 30.0 g m⁻²) in univariate linear models. The SR results are plotted in Figure 3. In general, the June image produced better results than the May image because the weather conditions were such that the May vegetation cover was inadequate for this approach.

Using the SR index for the June image, we created an algorithm for transforming the high resolution image to a map of swamp timothy productivity (Figure 4).

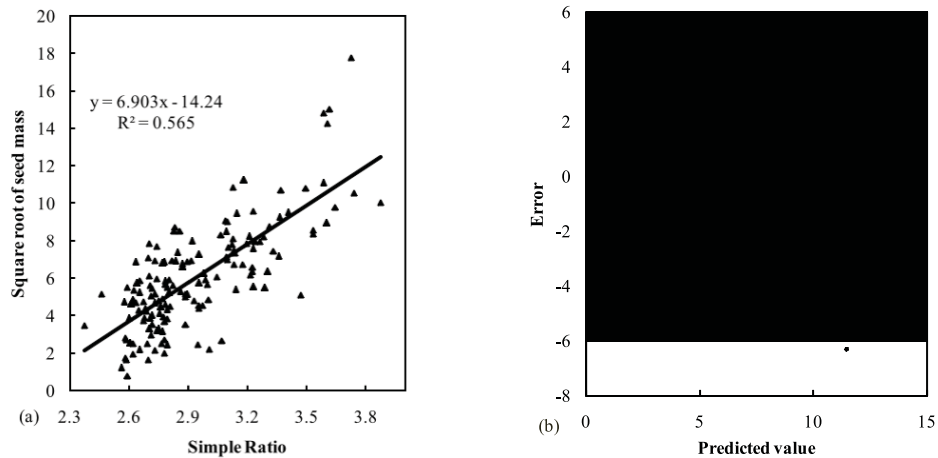


Figure 3. (a) Positive root square of observed swamp timothy seed mass (g m⁻²) plotted to the best correlated vegetation indices (Simple Ratio) in Ducky Strike from aerial images taken on June 9, 2006, and (b) the error distribution of the model.

In Situ Hyperspectral Reflectance and Plant-Soil Interactions

Results from our experiment indicate that the reflectance spectra of the ground sampling plots clearly differed with varying soil ECa (Figure 5), demonstrating that the potential for using spectral features to distinguish soil ECa. The most obviously sensitive spectral bands were among the visible band (350 to 680 nm), short wavelength NIR bands (1430 to 1800 nm and 1930 to 2500 nm). The plot in Figure 6 summarizes the best band combinations in terms of their correlation (R-squared).

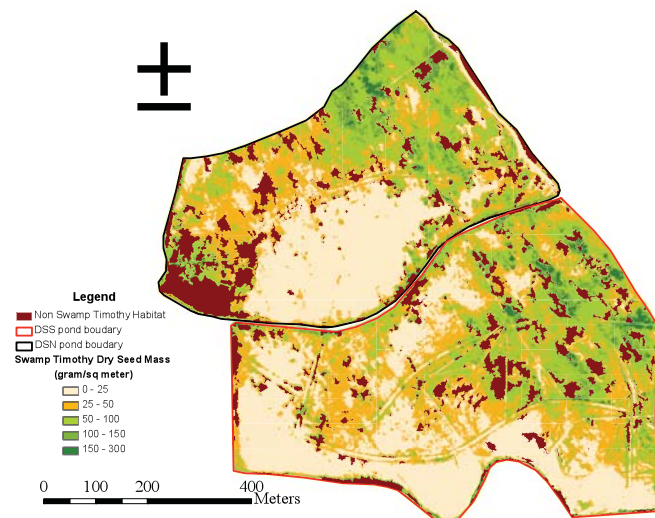


Figure 4. Interpolated swamp timothy seed mass (g m⁻²) prediction based on best correlated vegetation index (Simple Ratio) based on Ducky Strike wetland pond June aerial imagery.