Validation of Landsat Fractional Vegetation Cover Estimates from a Standardized Spectral Mixture Model

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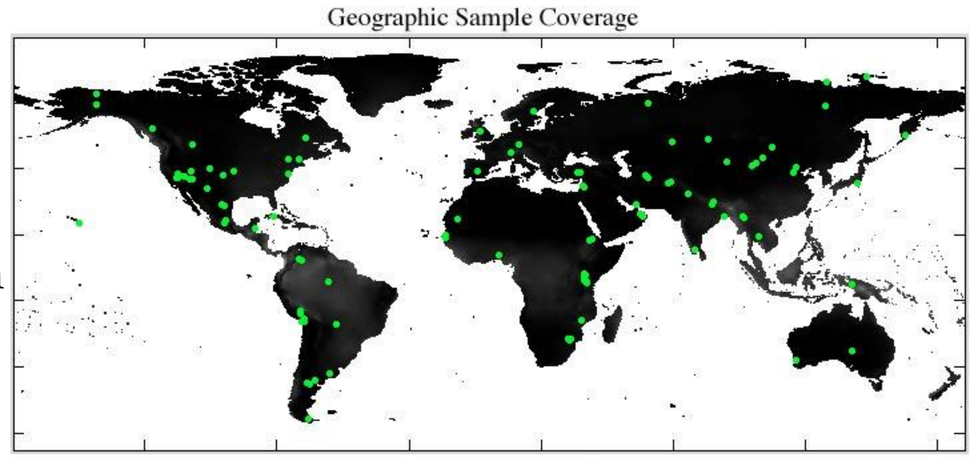
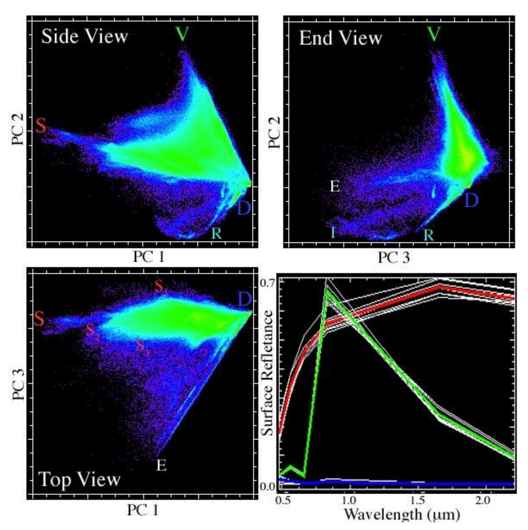
The Standardized Spectral Mixture Model



We assembled a Landsat global mixing space from a set of 100,000 Landsat spectra selected to represent the spectral diversity of the land covers across various biomes. The spectra within each biome also attempted to maximize the transitions between land covers.

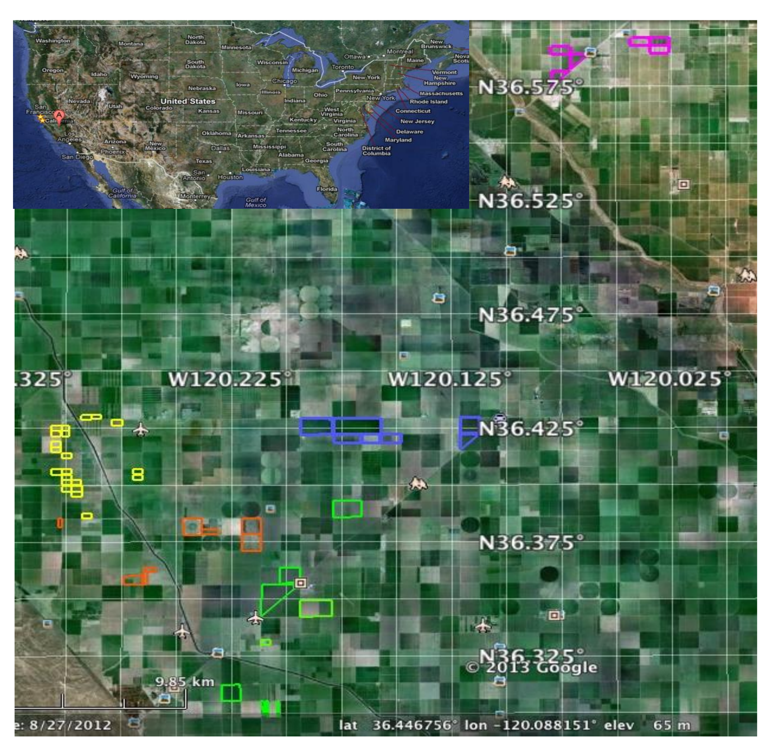
The orthogonal projections of the three low order principal components of the global Landsat mixing space contain 99% of the spectral variance of the linear mixture model

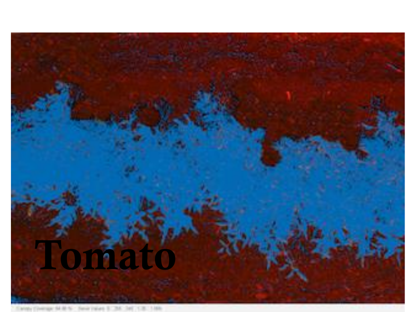
The projections were used to identify 3 endmembers, corresponding to high albedo substrate, vegetation, and dark surfaces (SVD model). The colored endmember spectra in the lower right quadrant are calculated as the average of a suite of 9 individual pixels spectra (shown in white)

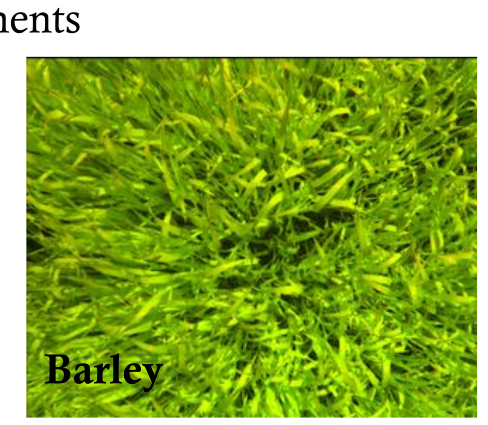


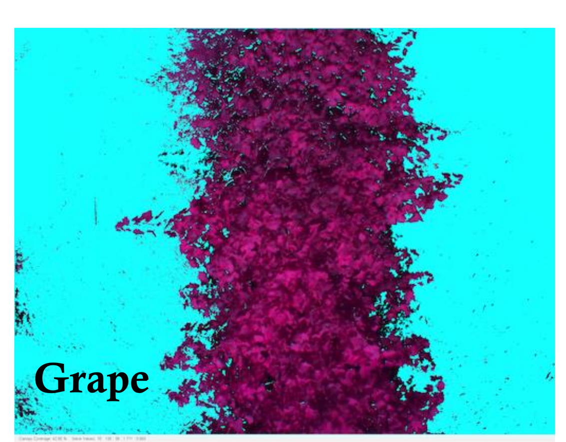
Data for Ground Validation

- We used 74 ground measurements of canopy cover (Fc) made in commercial fields of the San Joaquin Valley of California coinciding with 11 Landsat-5 overpass dates for the period April through October 2008; 17 different crops (seasonal and perennial) are represented in the dataset (details in Johnson and Trout, 2012). Fc measurements were calculated from images taken with an agricultural digital camera (TetraCam) suspended from a frame above the crop and aimed down vertically.
- The Landsat-5 images (path 43, row 35) for the dates for which Fc measurements are available were processed to surface reflectance with the Ledaps software
- Fractions and vegetation indices were calculated from the Landsat images and compared to ground measurements









List of crops for which ground measurements were available: tomato (4), safflower (5), wheat (1), onion (4), barley (1), garlic (1), sugar beet (1), grape (5), bellpepper (5), cotton (3), corn (1), almond (1), alfalfa (2), pistachio (4), cantaloupe (5), watermelon (3), and broccoli (11)

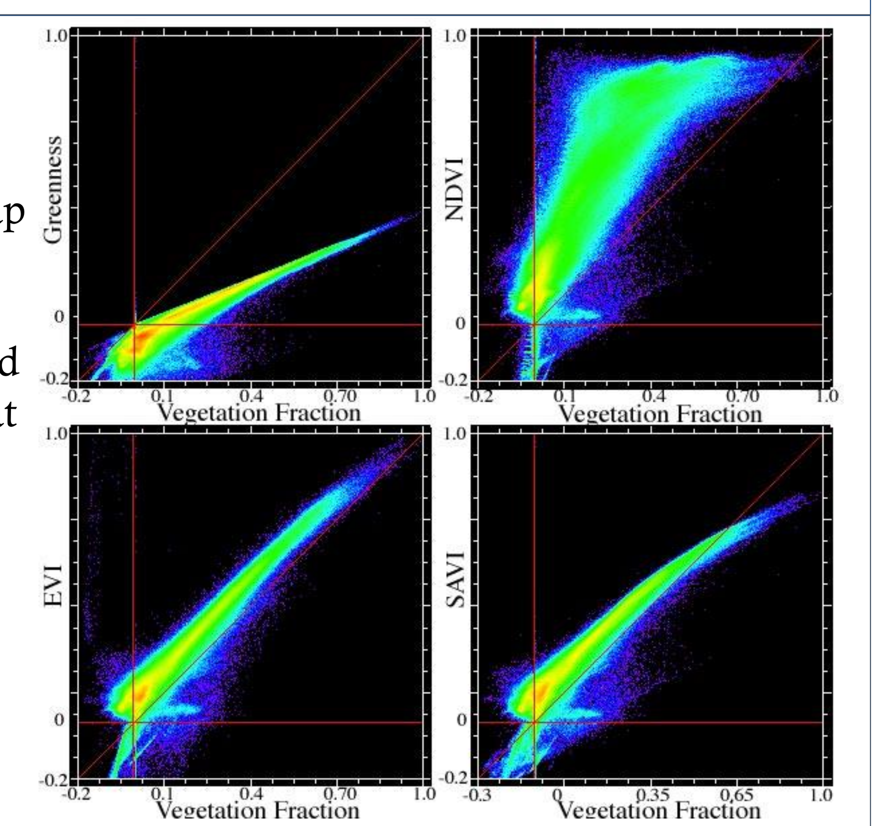
Motivation

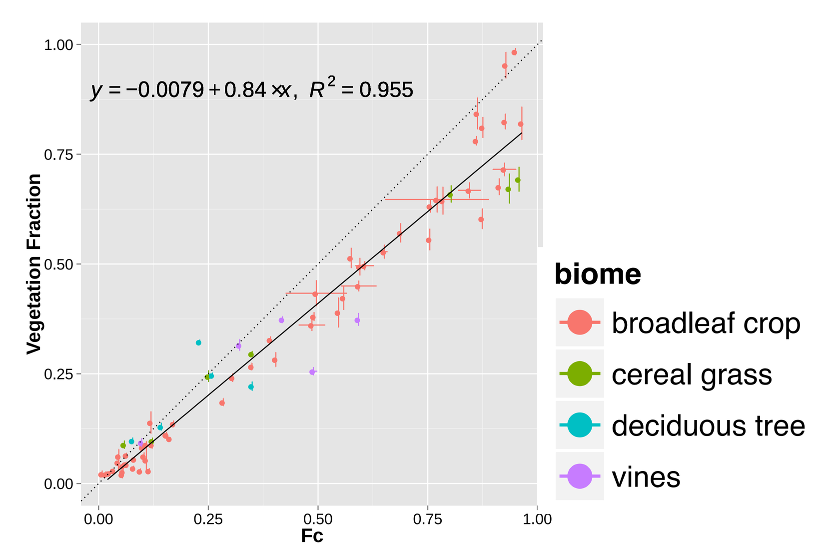
The goal of this project is to characterize urban expansion over North America since 1990 through the development of a consistent, robust, scalable, physically- based methodology using Landsat observations that represents urban land cover as continuous fractions of a limited set of different components, i.e., vegetation, high albedo substrate, and dark surfaces and shadows. To avoid making assumptions on the categorization of pixels into one of the different components, we use the technique of spectral mixture analysis. Through the funded work we seek to understand what are the aggregate physical properties (e.g. aggregate albedo, vegetation abundance, shadow fraction) associated with the diverse and heterogeneous urban landscapes relative to other major land cover classes.

The goal of this study is to understand: 1) if we can use a global standardized spectral mixture model accurately measure the surface vegetation fraction from Landsat data without the need for local calibration; 2) if there are concrete advantages of calculating vegetation fractions over vegetation indices.

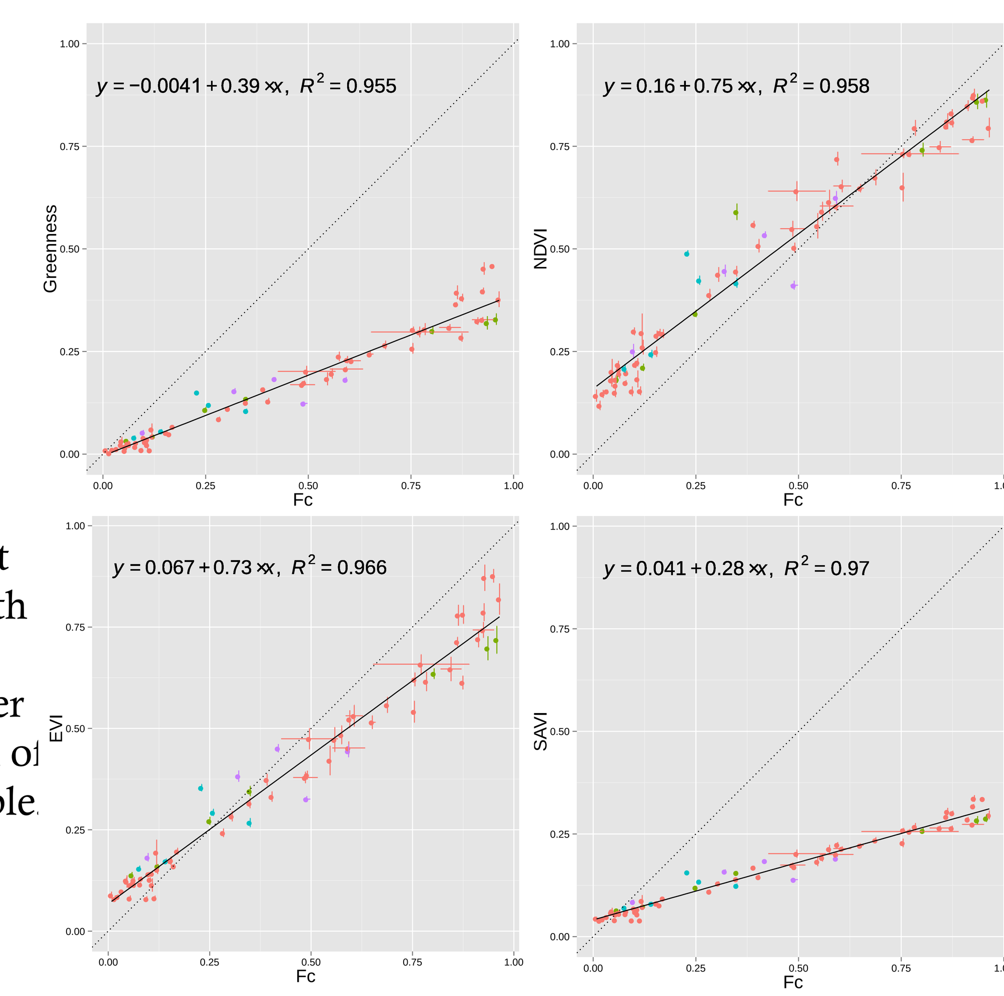
Results

The comparison of the Vegetation Fraction from the global set of 100,000 Landsat spectra with vegetation indices shows a strong linear relations with Tasseled cap Greenness, EVI, and SAVI. Tasseled cap Greenness is strongly linear and tightly correlated to vegetation fraction, but reaches a maximum value of 0.5. EVI and SAVI show both a positive bias, with SAVI saturating at vegetation fractions > 0.6. NDVI shows a strong saturation at less than 05 vegetation fraction, with a wide range of responses across all fractions.





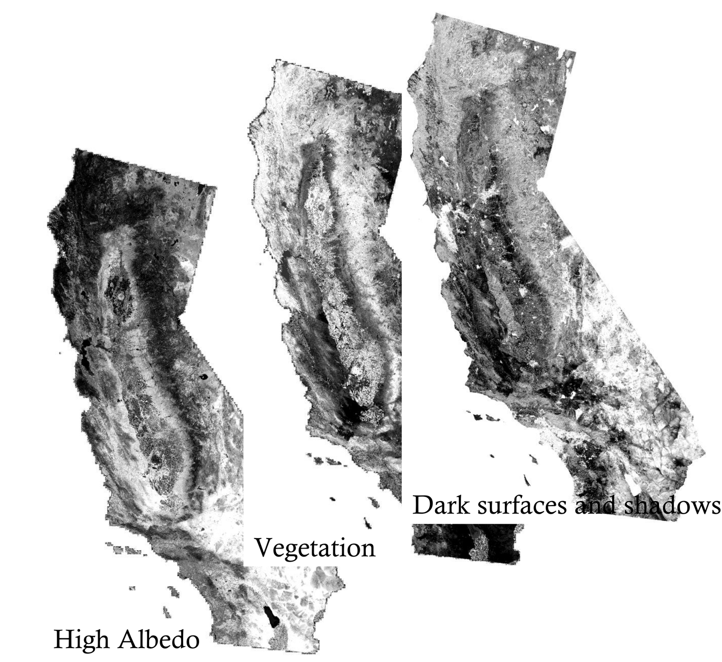
The vegetation fraction derived from the Standardized Spectral Mixture Model shows a very strong relationship with Fc, with a zero intercept, and closest agreement with the Fc (slope closer to unity). Up to fractions of about 30%, the Vegetation fractions match the Fc with relationship near the 1:1 line. The Vegetation Fraction underestimates Fc by 10-15% at higher values of canopy cover, though overestimation of Fc in the ground measurements are also possible



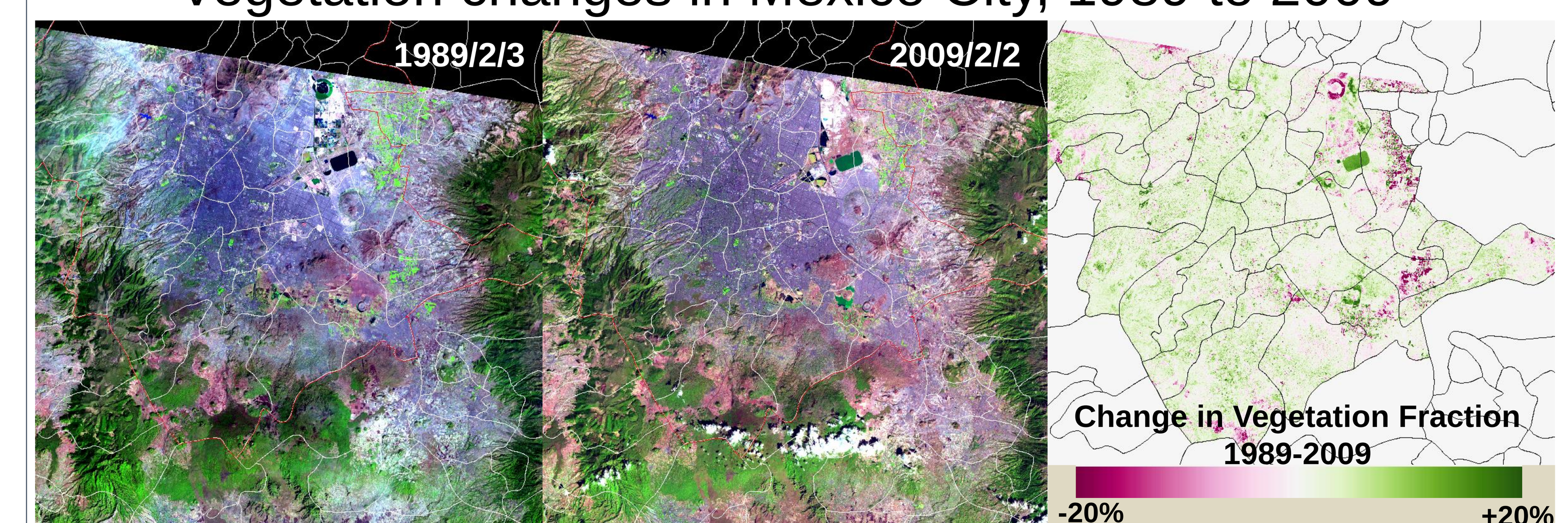
The vegetation indices also show a very strong correlation with Fc, but with a stronger bias and, except for the Tasseled Cap Greenness, a non-zero intercept. The best fit is by EVI and SAVI, reflecting the patterns shown in the global spectra.

Applications

The inversion of a constrained standardized spectral mixture model can be applied to any scene from the Landsat archive to obtain reliable measures of substrate, dark surfaces and vegetation fractions. Here on the left we show continuous surfaces of high albedo substrates, dark surfaces and shadows and vegetation over for the 2005 peak growing season of California.



Vegetation changes in Mexico City, 1989 to 2009



The vegetation fractions from Landsat measure the progress of the million tree campaign started in the early 1990s in Mexico City. Small but measurable increases in vegetation cover can be quantified over most of this sprawling megalopolis.

Conclusions and Future Work

With a standardized spectral mixture model we can obtain reliable physical measures of vegetation fractions from Landsat data while bypassing the need for ground calibration that is required when using vegetation indices.

The limited requirements of this approach make it suitable for the calculation of vegetation fractions globally.

Future work will explore how to best combine the fractions from the high albedo substrate and dark surfaces and shadows to measure the expansion of the built environment.

References

- Johnson, L.F.; Trout, T.J. Satellite NDVI Assisted Monitoring of Vegetable Crop Evapotranspiration in California's San Joaquin Valley. Remote Sens. 2012, 4, 439-455
- Small, C.; Milesi C. Standardized Spectral Mixture Models. Remote Sens. Env. 2013, In review.

Acknowledgments

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