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Spectral Fingerprints Predict Functional Chemistry of Native Plants Across Sagebrush-Steppe Landscapes

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Abstract

Landscapes are changing and under threat from anthropogenic activities, decreasing land cover, contaminated air and water quality, and climate change. These changes impact native communities and their functions at all spatial scales. A major functional trait being affected across these communities is nitrogen. Nitrogen supports plant nutrient cycling and growth, serves as an indicator for crude protein and productivity, and offers quality forage for wild and domestic herbivores. We need better ways to monitor nitrogen across space and time. Current monitoring is elaborate, time-consuming, and expensive. We propose drawing from agricultural methodologies to incorporate near-infrared spectroscopy as a technique in detecting and monitoring nitrogen concentrations across a threatened shrub-steppe ecosystem. We are currently developing calibration equations for nitrogen in sagebrush across four species (*Artemisia tridentata wyomingensis, A. tripartita, A. arbuscula, A. nova*), three study sites and two seasons. Preliminary results suggest that nitrogen can be accurately predicted across all sites, species, and seasons, explaining 75-90% of the variation in nitrogen. These results indicate that near infrared spectroscopy offers a rapid, noninvasive diagnostic tool for assessing nitrogen in wild systems. This advancing technology is important because it economizes the collection of ecological data in rapidly changing landscapes and provides land managers and researchers with valuable information about the health and sustainability of their lands.

Name

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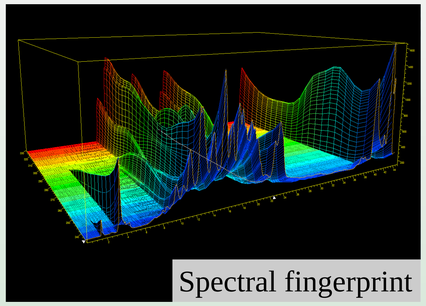
Spectral fingerprint

SPECTRAL FINGERPRINTS PREDICT FUNCTIONAL CHEMISTRY OF NATIVE PLANTS ACROSS SAGEBRUSH-STEPPE LANDSCAPES

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Sagebrush-steppe

Plant chemicals influence foraging by herbivores

Herbivores make foraging decisions, in part, due to the functional chemical traits found in plants[1,2]

Plant chemistry also provides critical ecosystem services that ensure healthy stable communities by:

- Influencing wildlife biodiversity and fecundity[3]
- Promoting food security[4]
- Providing sources for medicinal, agricultural, and technological advances[5]

How do we monitor these changing chemical traits?

Current monitoring of plant chemistry is expensive, tedious, and does not rapidly capture dynamics over space and time

Solution: Spectroscopy, in the forms of near infrared spectroscopy (NIRS, Fig 1) and hyperspectral imagery, provides rapid quantitative measurements of plant traits without contact

- Spectra produce unique fingerprints based on organic bonds that predict geophysical and chemical quantities and qualities of plants

The sagebrush-steppe is an ideal system to pioneer using spectroscopy to monitor changing plant chemistry

- Sagebrush (*Artemisia* spp) is widely distributed over 43 million hectares of land
- It is under severe threat from fire, invasive plants, and climate change
- It is rich in chemical diversity that influences specialist herbivores

Fig 1. Examples of handheld spectrometers measuring near infrared spectroscopy (NIRS)

Research Question

Can spectroscopy predict known functional chemicals in plants that explain foraging behavior of herbivores at increasing taxonomic, spatial, and temporal scales?

Methods

We developed predictive equations for phytochemical concentrations (nitrogen (Figs 2, 3, 4), coumarins (Fig 5)) using data from handheld NIRS (Fig 1) and wet chemistry.

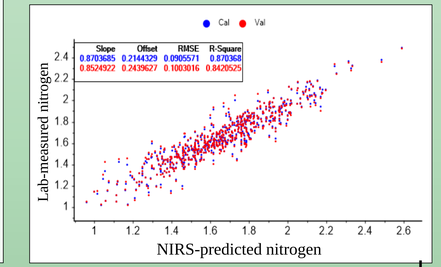


Fig 2 (above). NIRS can predict nitrogen in two species of sagebrush at one study site across two seasons (R^2 = 0.870, RMSE = 0.091).

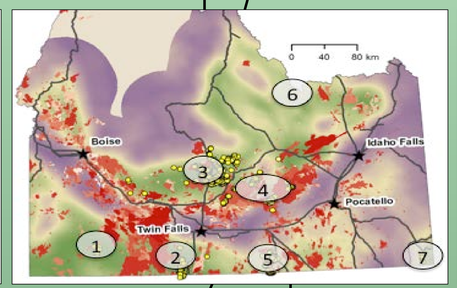
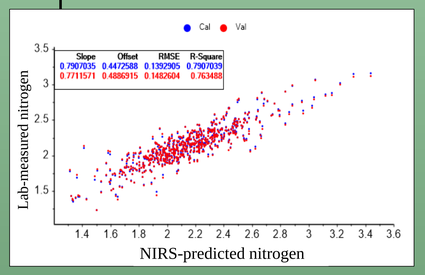


Fig 3 (below). NIRS can predict nitrogen in three species of sagebrush at one study site across two seasons (R^2 = 0.791, RMSE = 0.139).



A global equation can predict nitrogen in sagebrush

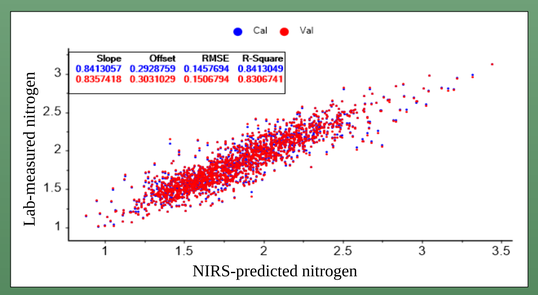
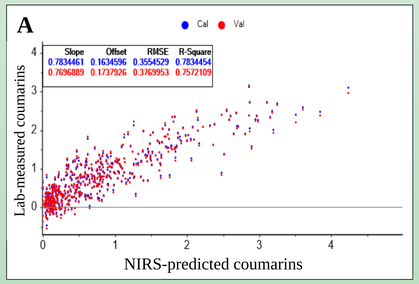


Fig 4. NIRS can predict nitrogen in five species of sagebrush at three study sites (3, 4, 6) across two seasons and multiple years (R^2 = 0.841, RMSE = 0.146).

NIRS can predict phytochemicals that explain diet selection by a specialist avian herbivore



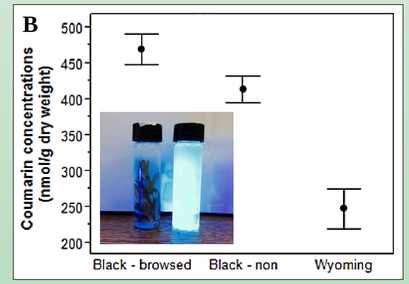


Fig 5. NIRS can predict (A) coumarins in sagebrush (R^2 = 0.783, RMSE = 0.355), which are (B) highest in browsed (*A. nova*) and lowest in non-browsed sagebrush (*A. tridentata wyomingensis*)[2].

Next Steps: Map species distribution and phytochemistry with hyperspectral imagery

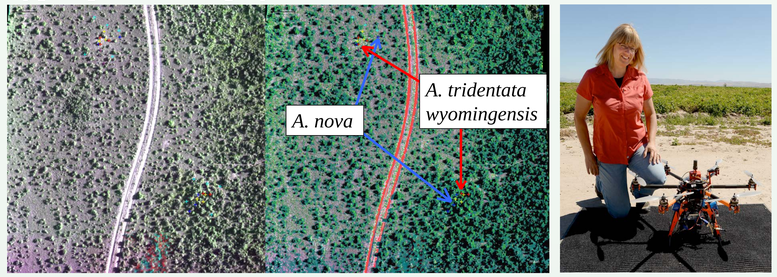


Fig 6. Hyperspectral imagery collected from an UAS[6] can differentiate plant species, with known chemical content (Fig 6B), across landscapes.

Remote sensing offers multiple advantages

- Rapid, precise, non-invasive method to map diversity of plant taxa and functional traits important to herbivores
- Spectrally-obtained taxonomic and chemical diversity can be used to predict herbivore habitat use, monitor plant communities after restoration efforts, and identify hot-spots of chemical diversity for drug discovery

References & Acknowledgements

[1]Ulappa, et al. 2014. Journal of Mammalogy.
[2]Frye, et al. 2013. Ecology.
[3]DeGabriel, et al. 2009. Ecological Society of America.
[4]Abson, et al. 2013. Agriculture & Food Security.
[5]Veeresham. 2012. Advanced Pharmaceutical Tech.
[6]Delparte, et al. 2016. Unpublished data.

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