Integrated Remote Sensing Tools for Timely Predictions of Alfalfa Nutritive Value

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Introduction: Importance of Alfalfa

– Environmental value – ecological services

– Economic value – livestock feeding
  • Yield
  • Nutritive value

Photo credit: Scott Bauer
# Introduction: Current Hay Prices

<table>
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<tr>
<th>Hay Grade</th>
<th>Bale type</th>
<th>Price ($/ton)</th>
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<td></td>
<td></td>
<td>Average</td>
<td>Minimum</td>
<td>Maximum</td>
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<tr>
<td>Prime (&gt; 151 RFV/RFQ)</td>
<td>Small Square</td>
<td>234</td>
<td>125</td>
<td>300</td>
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<tr>
<td></td>
<td>Large Round</td>
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(UW-Extension, 2016)
Nutritive Value vs. Maturity

Relative Characteristics

- forage yield
- stem yield
- forage digestibility
- leaf yield

Maturity stage
- vegetative
- bud
- first flower
- full-flower
- post-flower

(ASA, 2011)
Quantifying Alfalfa Maturity

Mean Stage by Weight (MSW) and Mean Stage by Count (MSC)

Vegetative
growth stages 0-2

Bud
growth stages 3-4

Flower
growth stages 5-6

Kalu and Fick (1981)
Quantifying Alfalfa Maturity

Mean Stage by Weight (MSW) and Mean Stage by Count (MSC)

Maturity Predicts Nutritive Value

Vegetative growth stages 0-2
Bud growth stages 3-4
Flower growth stages 5-6

Kalu and Fick (1983)
Introduction: Remote Sensing

- Quick, non-destructive assessment
- Information at the field scale
- Optimize timing of harvest
  - (as well as other field operations)

Left photo credit: Don McCullough
Introduction: Canopy Reflectance

Before canopy closure

After canopy closure

Relative Reflectance

Wavelength (nm)

350 450 550 650 750 850

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8

University of Minnesota
Driven to Discover™
Introduction: Remote Sensing

Canopy Visible and Near-infrared Reflectance Data to Estimate Alfalfa Nutritive Attributes Before Harvest

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Jeremy Joshua Pittman 1,2,*, Daryl Brian Arnall 2, Sindy M. Interrante 1, Corey A. Moffet 1 and Twain J. Butler 1

Application of local binary patterns in digital images to estimate botanical composition in mixed alfalfa–grass fields

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Objectives

• Explore potential to use known vegetative indices to predict alfalfa maturity and nutritive status

• Develop new predictive models from spectral data
Methods: Design

- A Randomized Complete Block Design was superimposed on a uniform stand of alfalfa at Rosemount, MN.
  - 2014: 3rd cutting (8 replications)
  - 2015: 1st and 3rd cutting (12 replications)
- Treatments: 10 varying stages of alfalfa maturity.
Methods: Data Collection

- Collect canopy reflectance data prior to destructive sampling
  - FieldSpec 4 (ASD Inc.) measured raw reflectance (350-2500 nm)
- Harvest all plots for yield, nutritive status, and maturity assessment
- Nutritive analysis performed with a Perten NIRS system
- Select wavebands correlated to response variables based on AIC (Akaike Information Criterion)
- Fit linear models to the selected predictors.
Results: Growth Staging Still Works

\[ R^2 = 0.86 \]

\[ R^2 = 0.85 \]
Results: Known Indices

NDVI: Normalized Difference Vegetative Index

- Common spectral index used in agriculture
- Saturates with canopy closure in alfalfa.
Results: Known Indices

GNDVI: Green Normalized Difference Vegetative Index

*Best correlation between a published index and crude protein

\[ R^2 = 0.44 \]
Limiting economic factors for spectral sensors

• Spectral Range
• Spectral resolution
• Number of bands
Results: New models

• From the full range of spectral data

• Identified 8 wavebands that best predicted crude protein and minimized AIC

• Checked effects of adding environmental covariates
  • Growing Degree Units (GDUs) since cut

• Reduced model to improve utility
  • Lower spectral range (VIS/NIR)
  • Lower resolution (10 nm bands)
Full Model: 8 bands from 350-2500 nm

CP estimated by 8 wavebands

$R^2 = 0.86$

$AIC = 892.8$
Full Model with GDU covariate

CP estimated by 8 wavebands with GDU covariate

$R^2 = 0.93$

$AIC = 641.5$
Reduced Model: 3 bands from 350-1100 nm

CP estimated by 3 wavebands

$R^2 = 0.76$

AIC = 892.8
Reduced model with GDU covariate

$R^2 = 0.91$

$AIC = 678.8$
Same 3 bands applied to NDFd

NDFd estimated by GDUs and 3 wavebands

$R^2 = 0.89$
2015 model applied to 2014 data

Predicted vs Actual Crude Protein (2014)

Predicted vs Actual Crude Protein (2014)

$R^2 = 0.8442$
2015 model applied to 2014 data

Predicted vs Actual NDFd (48 hr in-vitro)

R² = 0.5791
Conclusions

- Canopy reflectance, integrated with climate information, can inform predictions of alfalfa nutritive value.

- New models using 3 wavebands in the VIS/NIR regions with GDUs as covariate maintained strong predictability and near-optimum model fit.

- The accuracy of passive reflectance measurements is affected by light conditions. Active sensors developed from these results would avoid this issue.
Acknowledgements

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• Joshua Larson

• Farm Intelligence
• Farm Nutrients
References

Questions?