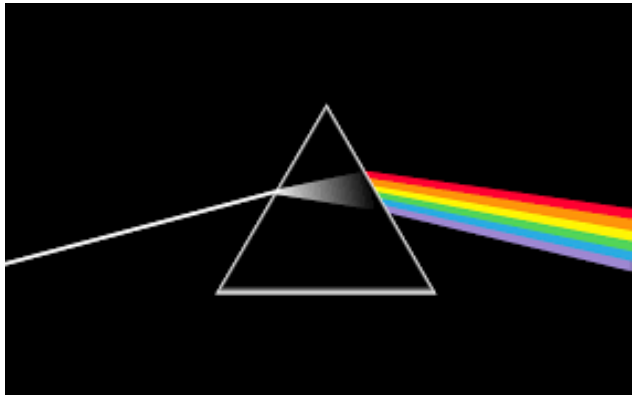
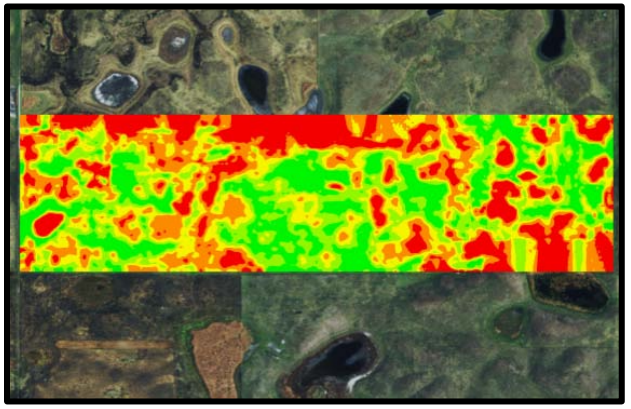
Integrated Remote Sensing Tools for Timely Predictions of Alfalfa Nutritive Value

Reagan L. Noland
M. Scott Wells
Craig C. Sheaffer

North American Alfalfa Improvement Conference
July 14, 2016

Introduction: Importance of Alfalfa

- Environmental value – ecological services
- Economic value – livestock feeding
  - Yield
  - **Nutritive value**

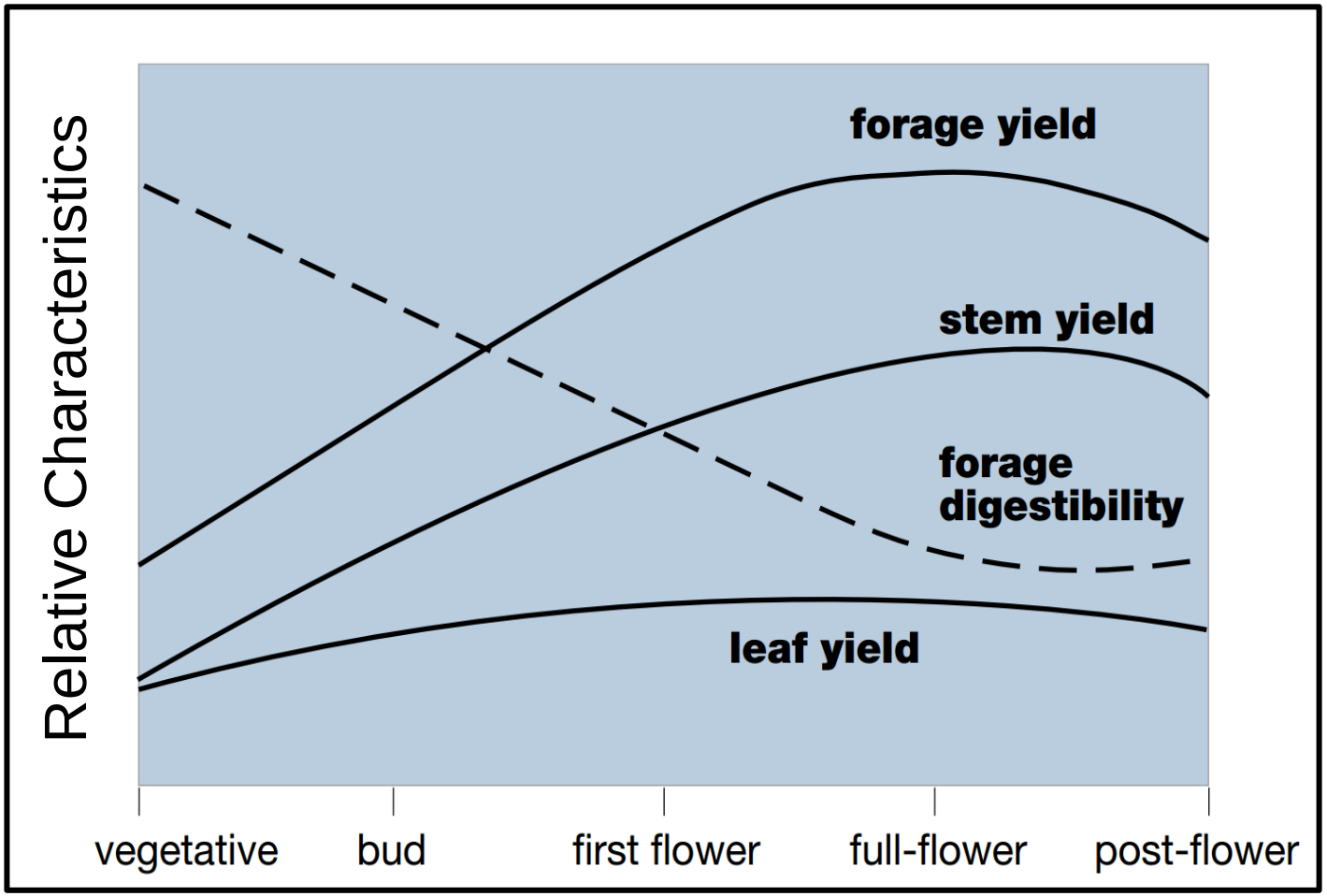
Photo credit: Scott Bauer

Introduction: Current Hay Prices

Hay Grade	Bale type	---------- Price ($/ton) ----------		
		Average	Minimum	Maximum
Prime (> 151 RFV/RFQ)	Small Square	234	125	300
	Large Square	176	150	210
	Large Round	No reported sales		
Grade 1 (125 to 150 RFV/RFQ)	Small Square	115	105	150
	Large Square	139	110	163
	Large Round	91	67	135
Grade 2 (103 to 124 RFV/RFQ)	Small Square	No reported sales		
	Large Square	101	80	123
	Large Round	66	30	120
Grade 3 (87 to 102 RFV/RFQ)	Small Square	No reported sales		
	Large Square	70	65	75
	Large Round	67	45	100

(UW-Extension, 2016)

Nutritive Value vs. Maturity

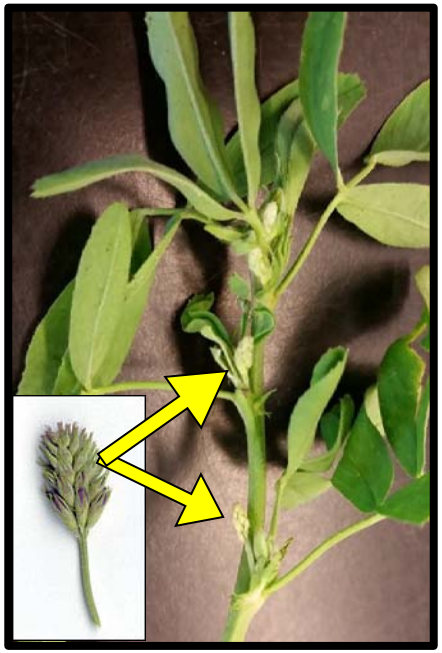


(ASA, 2011)

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

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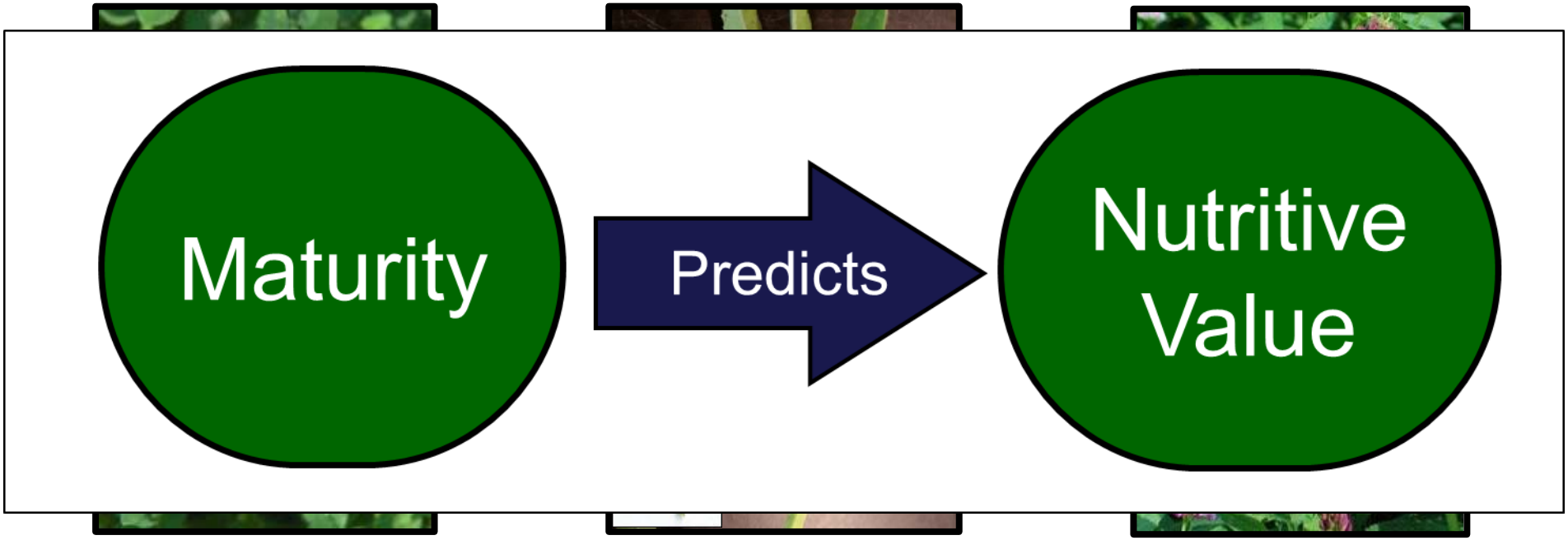

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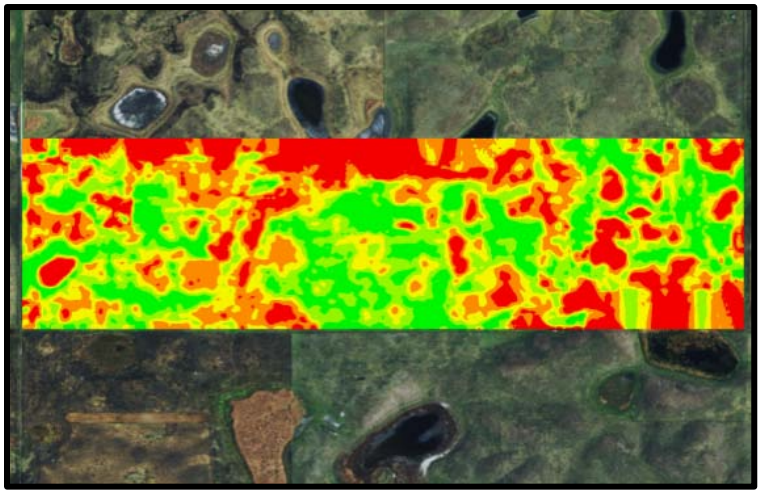
Kalu and Fick (1983)

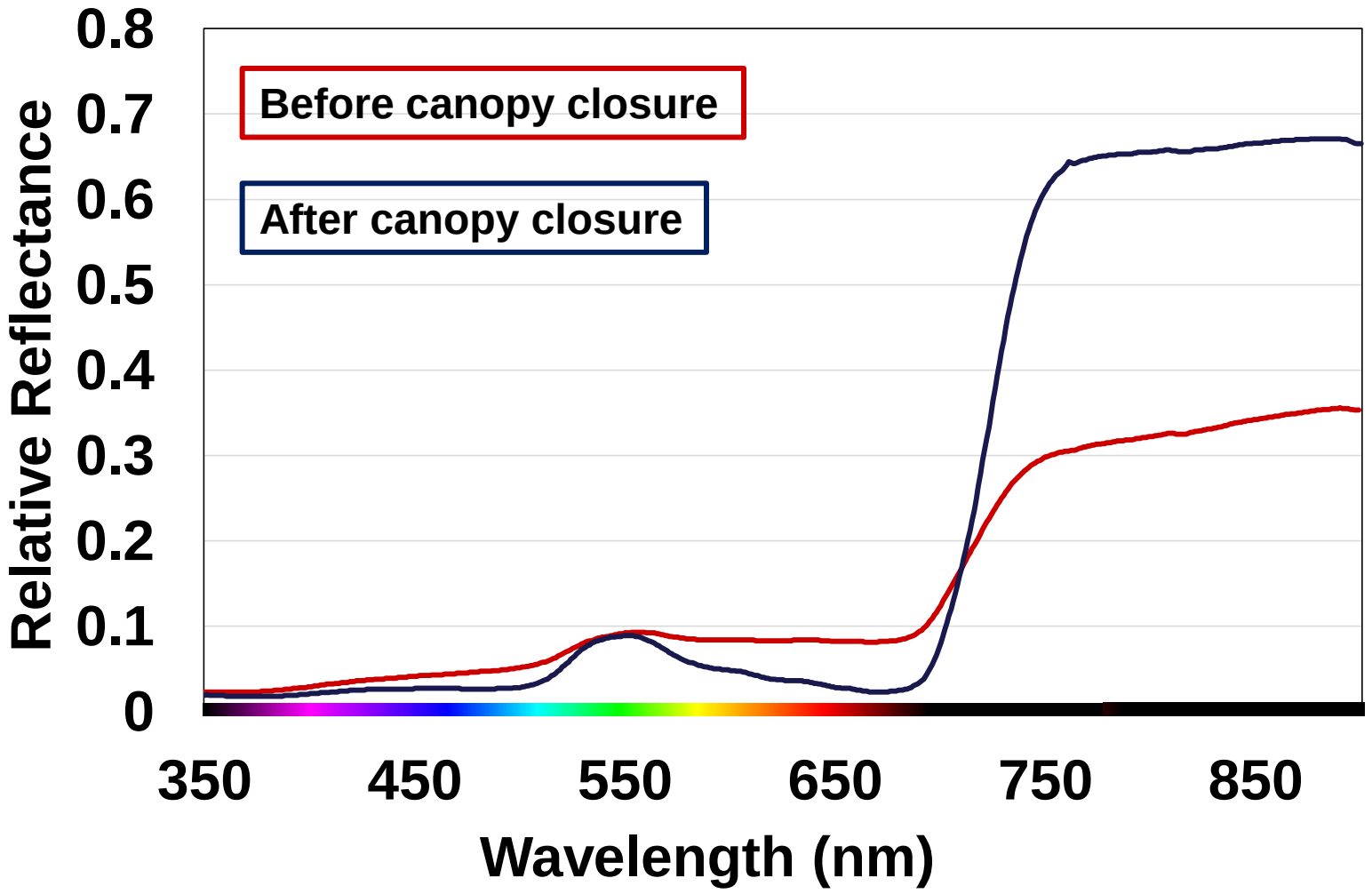
Introduction: Remote Sensing



- 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



Introduction: Remote Sensing

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

Patrick J. Starks,* Michael A. Brown, Kenneth E. Turner, and Bradley C. Venuto

ABSTRACT
Canopy reflectance (i.e., remotely sensed) data

P.J. Starks and K.E. Turner, USDA-ARS Grazinglands Research Lab., 7207 West Cheyenne Street, El Reno, OK 73036; M.A. Brown, USDA-ARS Grazinglands Research Lab., Retired; B.C. Venuto, USDA-ARS

Estimation of Biomass and Canopy Height in Bermudagrass, Alfalfa, and Wheat Using Ultrasonic, Laser, and Spectral Sensors

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

Keenan C. McRoberts [a,*], Brent M. Benson [b], Erika L. Mudrak [c], David Parsons [d], Debbie J.R. Cherney [e]

[a] *Department of Animal Science, Cornell University, 149 Morrison Hall, Ithaca, NY 14853, USA*
[b] *203 Solutions LLC, 414 Water Street, Unit 1808, Baltimore, MD 21202, USA*
[c] *Cornell Statistical Consulting Unit, Cornell University, B09 Savage Hall, Ithaca, NY 14853, USA*
[d] *School of Land and Food, University of Tasmania, Private Bag 98, Hobart, Tasmania, Australia*
[e] *Department of Animal Science, Cornell University, 329 Morrison Hall, Ithaca, NY 14853, USA*

Starks et al., 2016
McRoberts et al., 2016
Pittman et al., 2015

Objectives

- Explore potential to use known vegetative indices to predict alfalfa maturity and nutritive status
- Develop new predictive models from spectral data

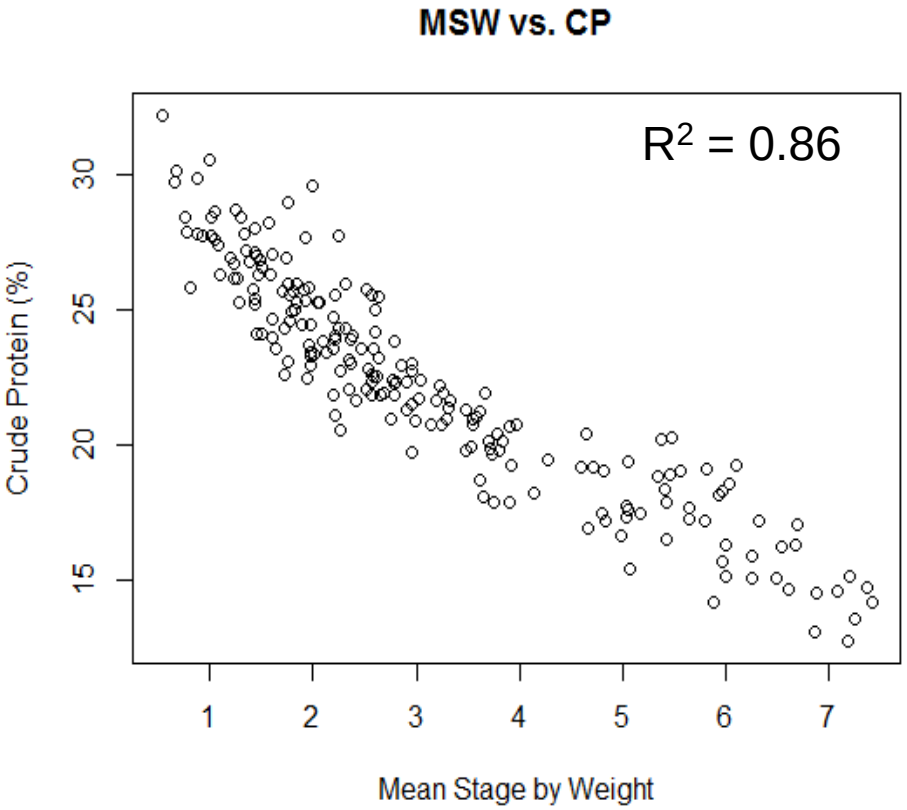
Methods: Design

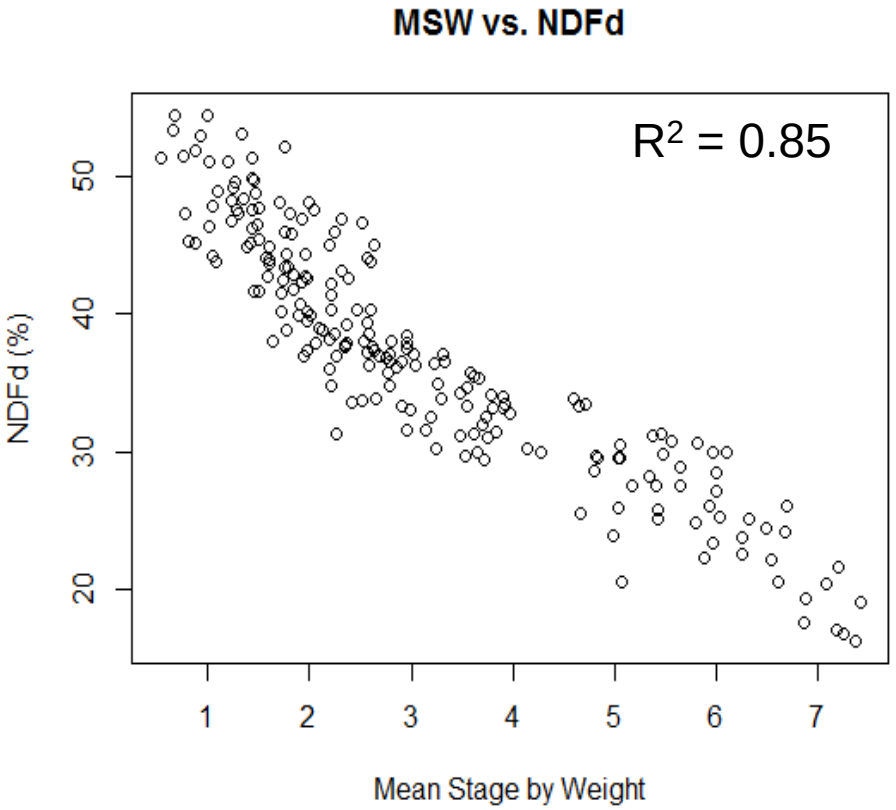
- A Randomized Complete Block Design was superimposed on a uniform stand of alfalfa at Rosemount, MN.
  - 2014: 3rd cutting (8 replications)
  - 2015: 1st and 3rd cutting (12 replications)
- Treatments: 10 varying stages of alfalfa maturity.

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

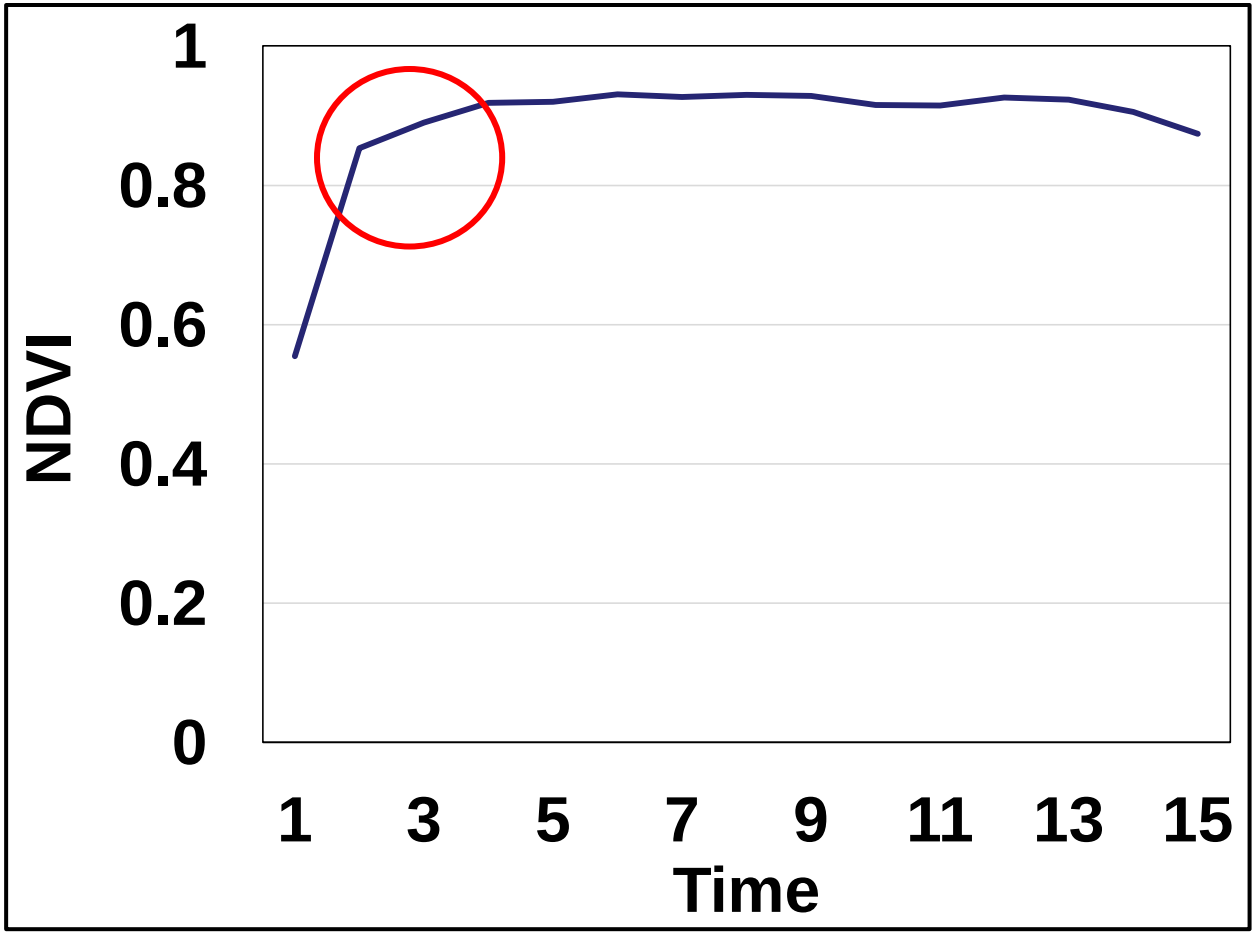




Results: Known Indices

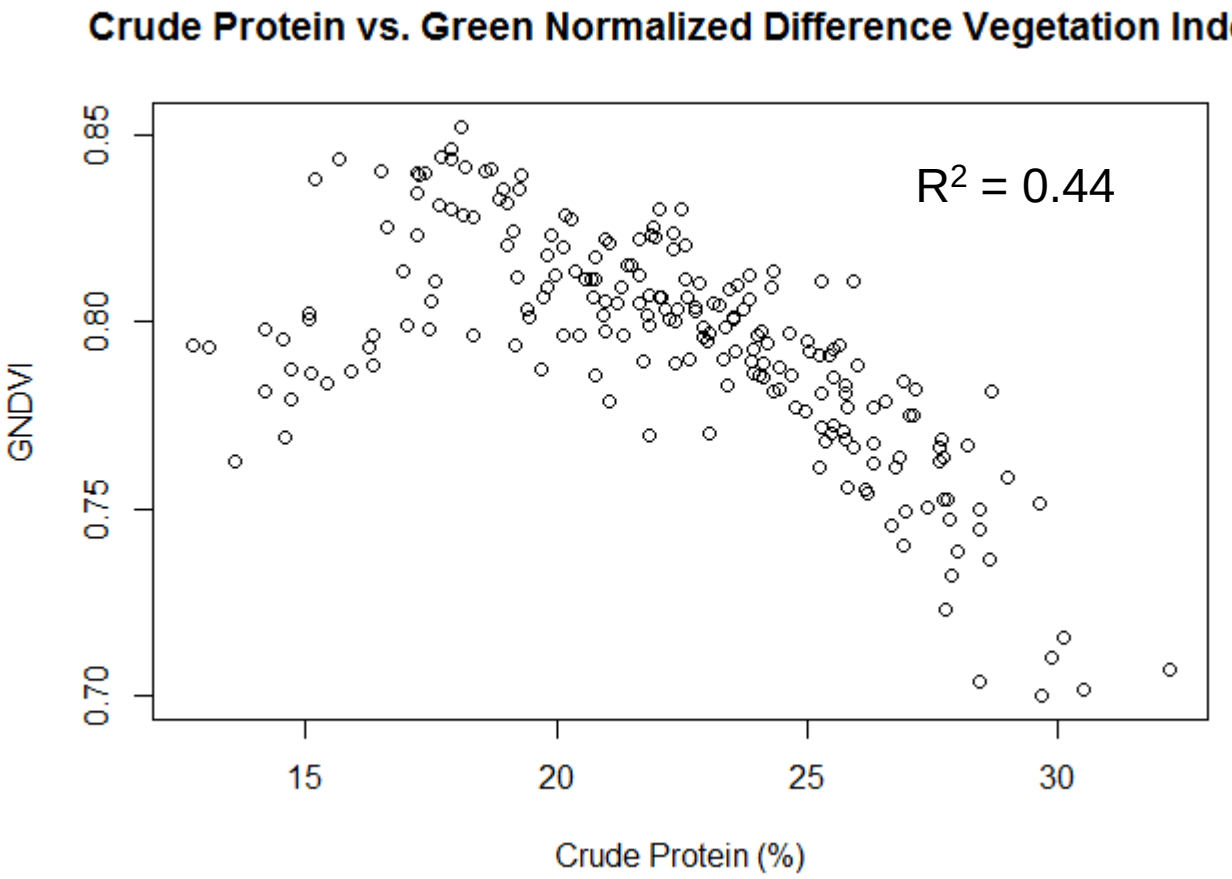
NDVI : Normalized Difference Vegetative Index

- Common spectral index used in agriculture
- Saturates with canopy closure in alfalfa.



Results: Known Indices

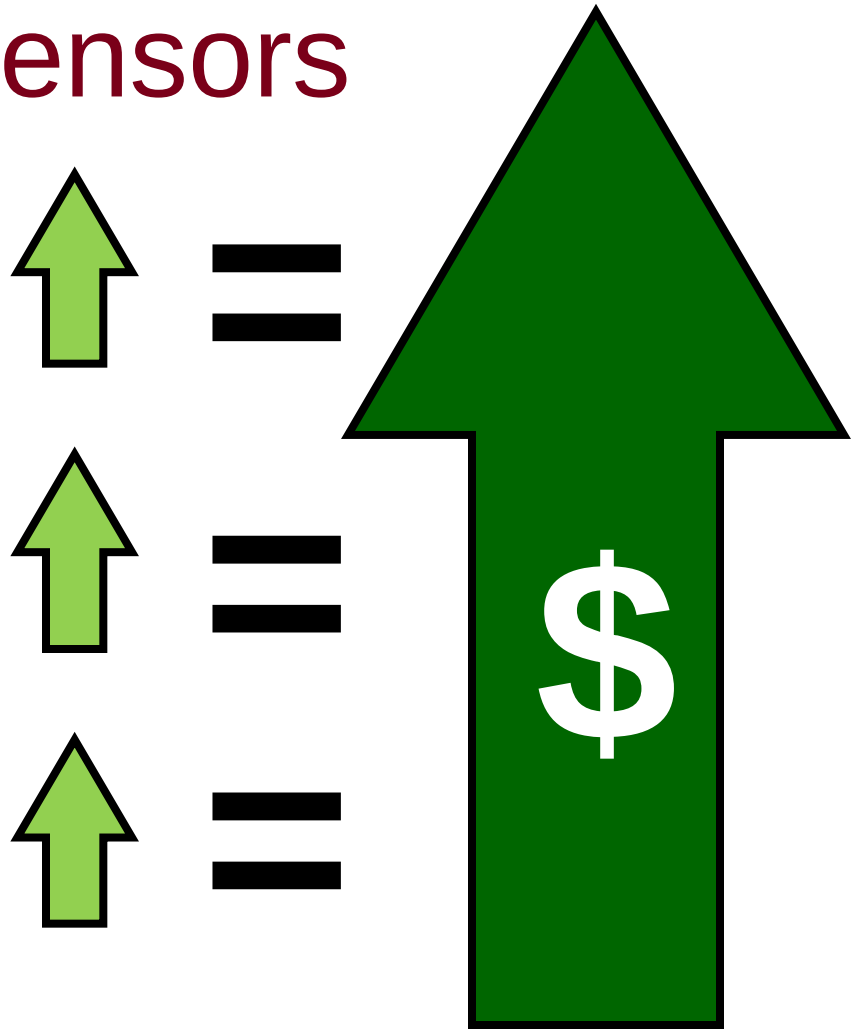
GNDVI : Green Normalized Difference Vegetative Index



*Best correlation between a published index and crude protein

Limiting economic factors for spectral sensors

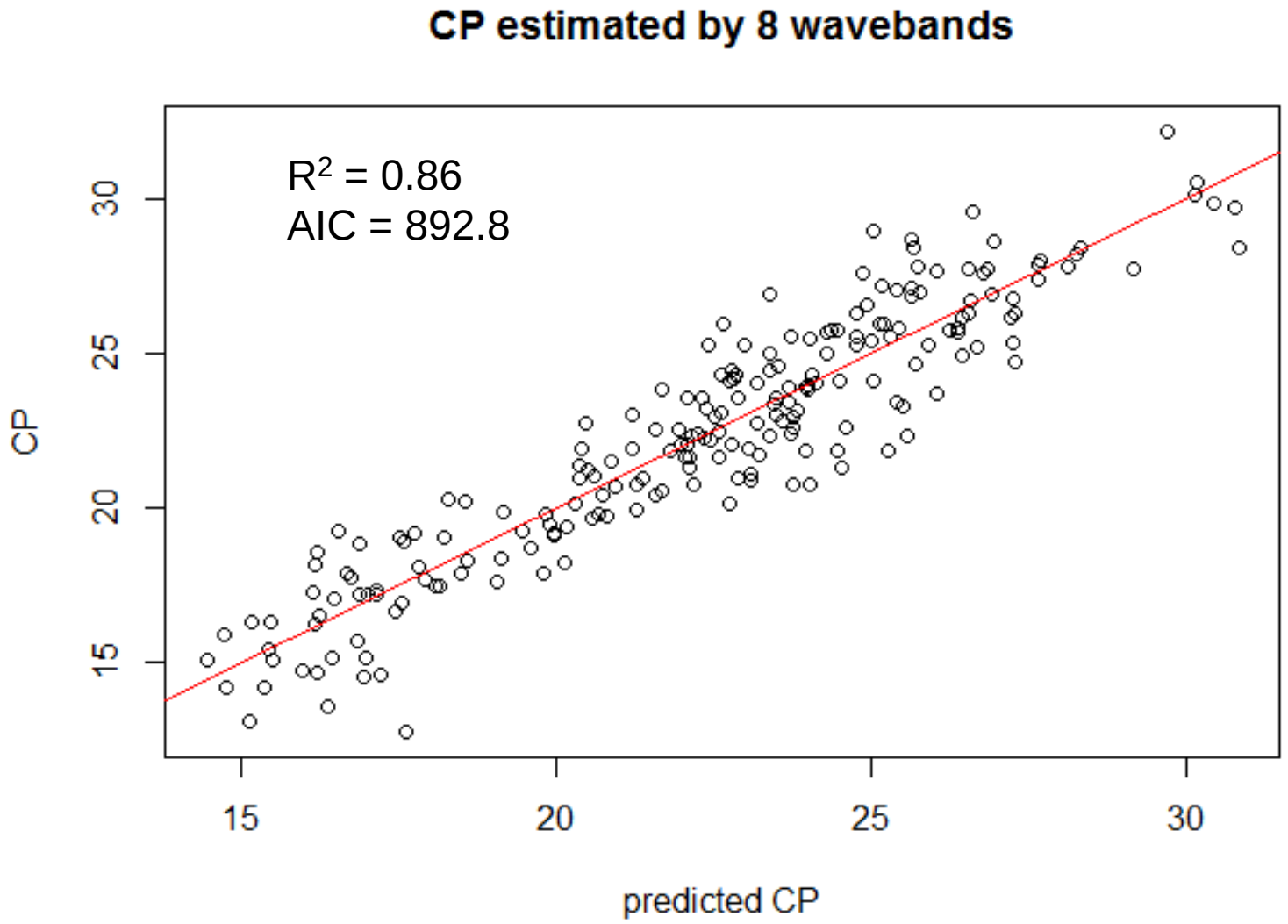
- Spectral Range
- Spectral resolution
- Number of bands



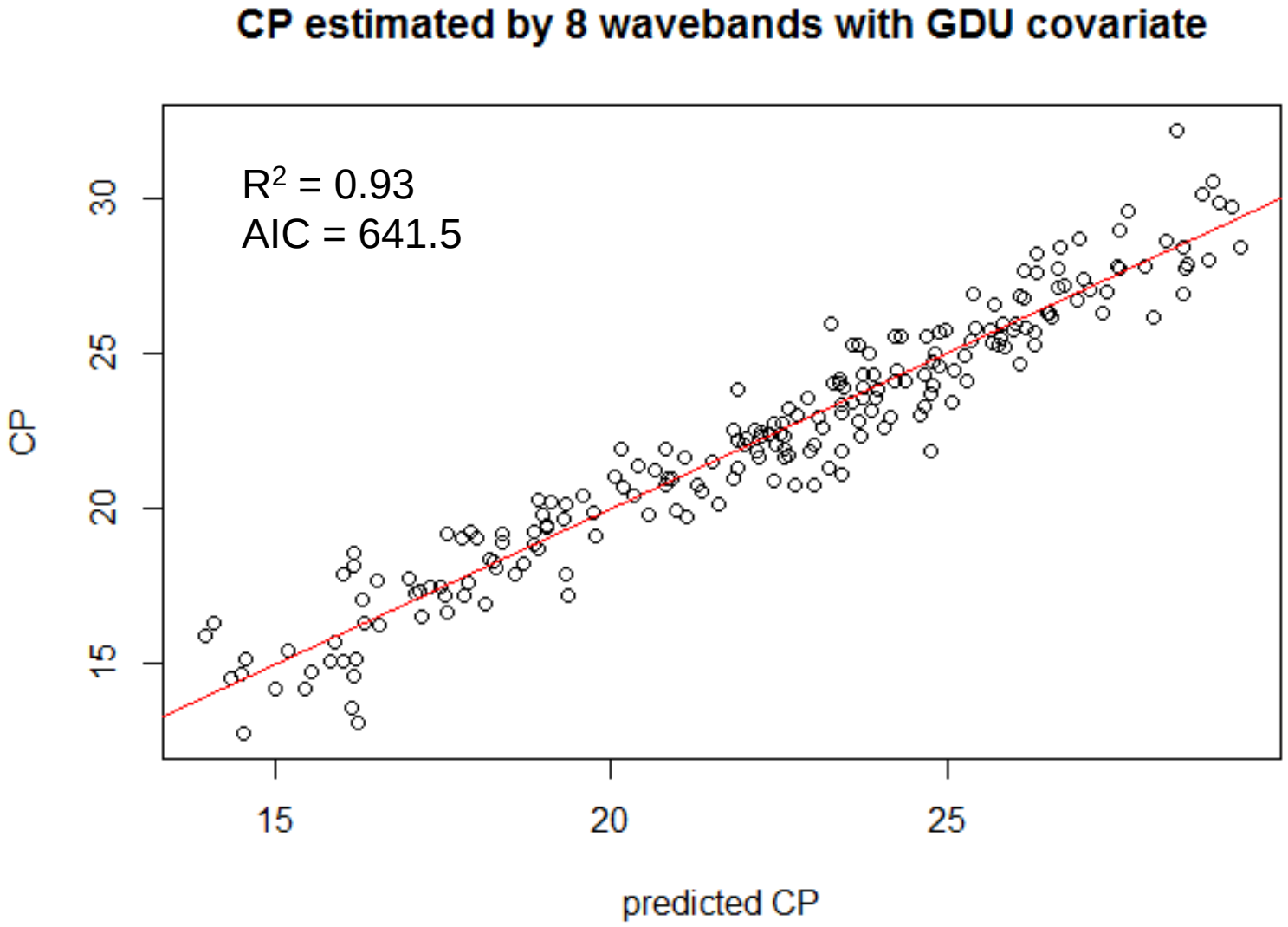
Results: New models

- **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)*

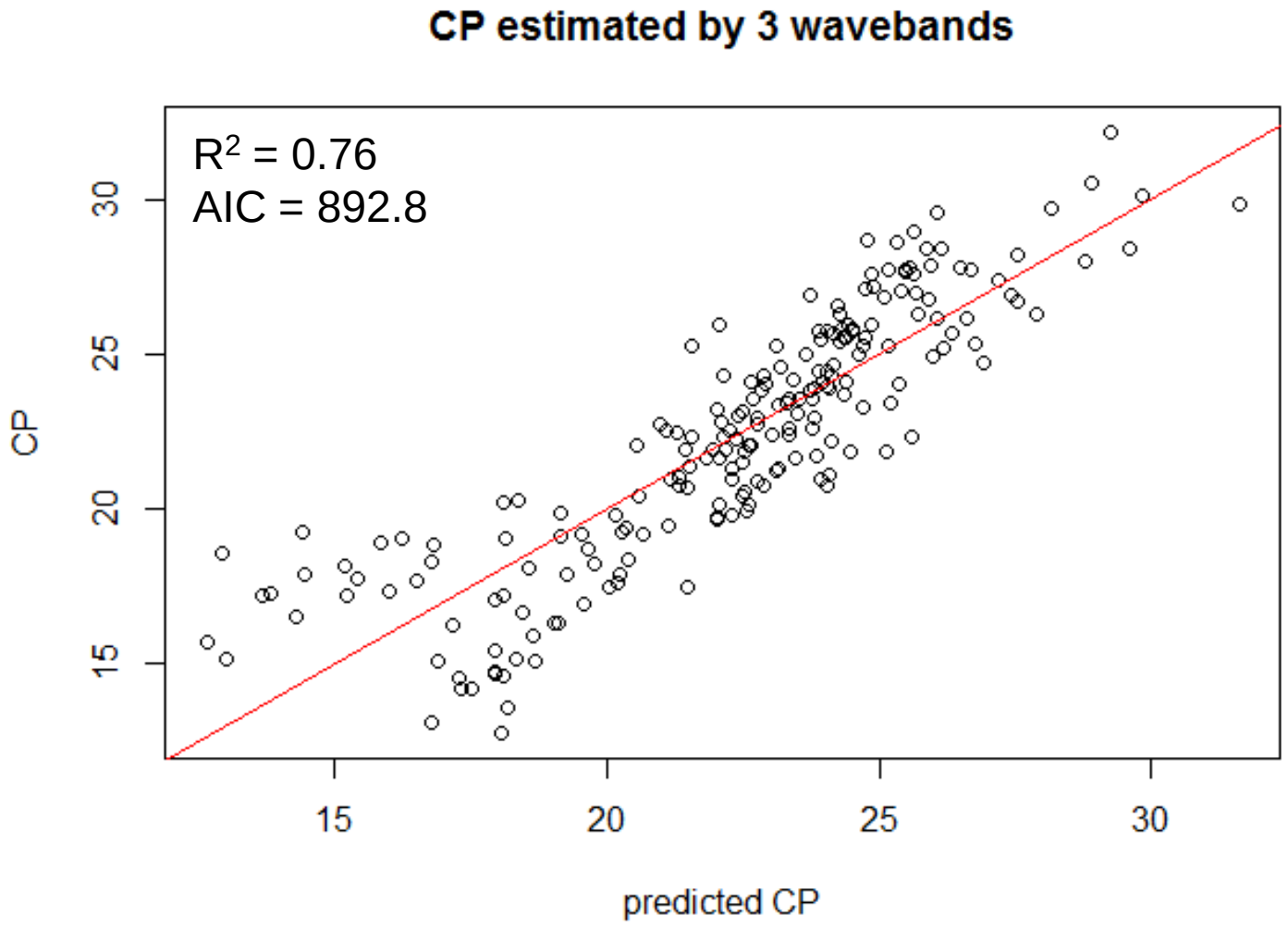
Full Model: 8 bands from 350-2500 nm



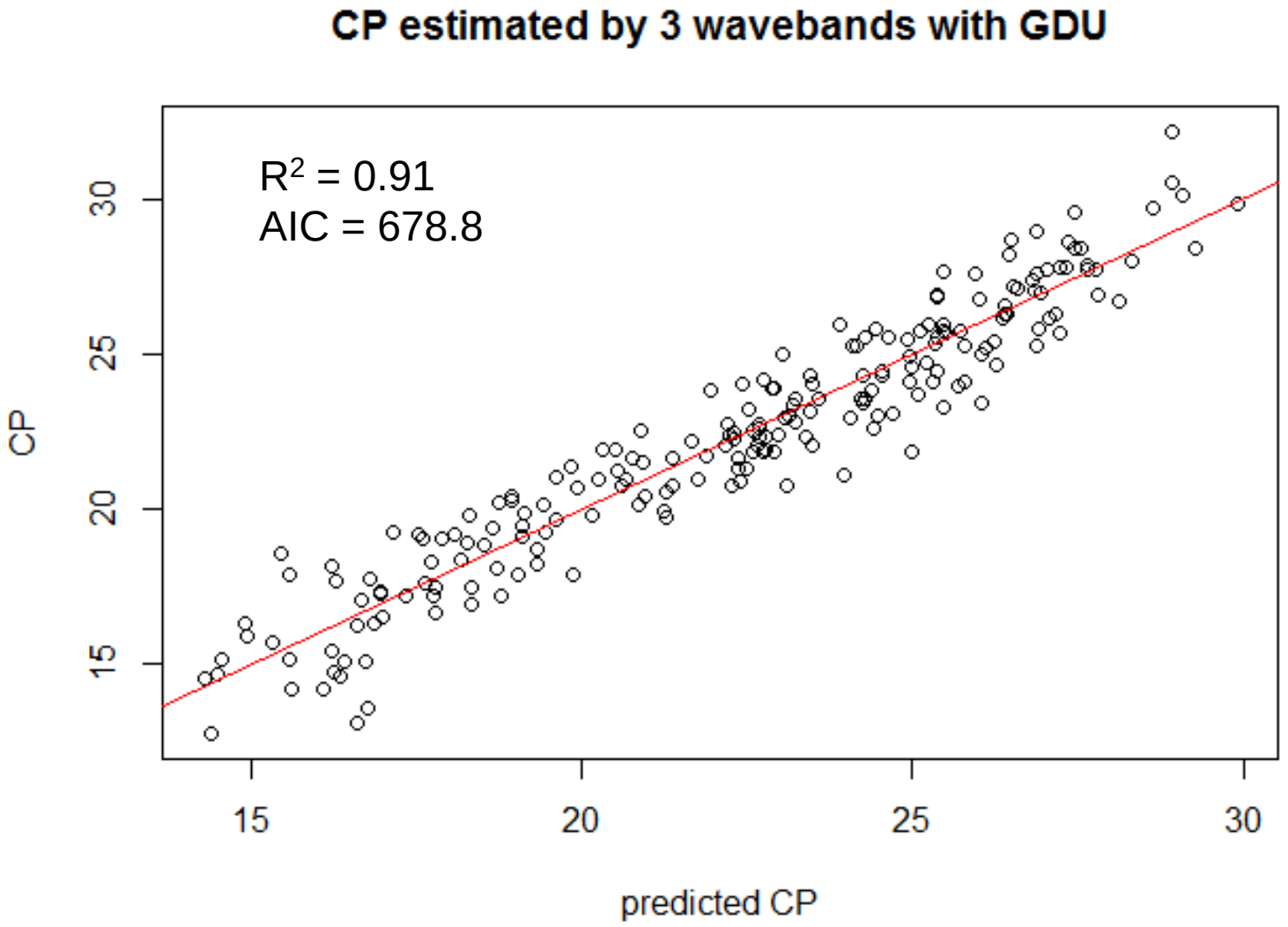
Full Model with GDU covariate



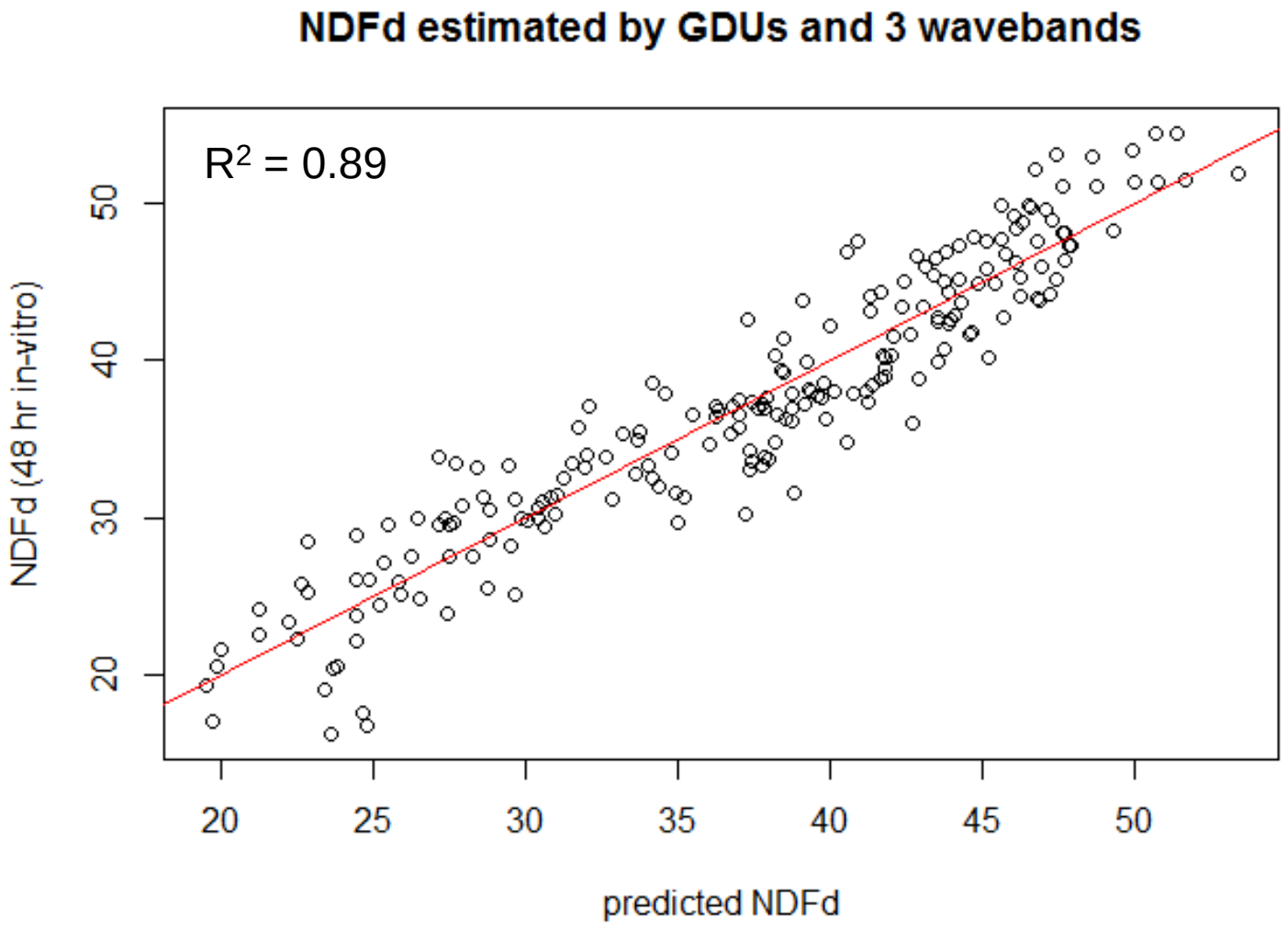
Reduced Model: 3 bands from 350-1100 nm



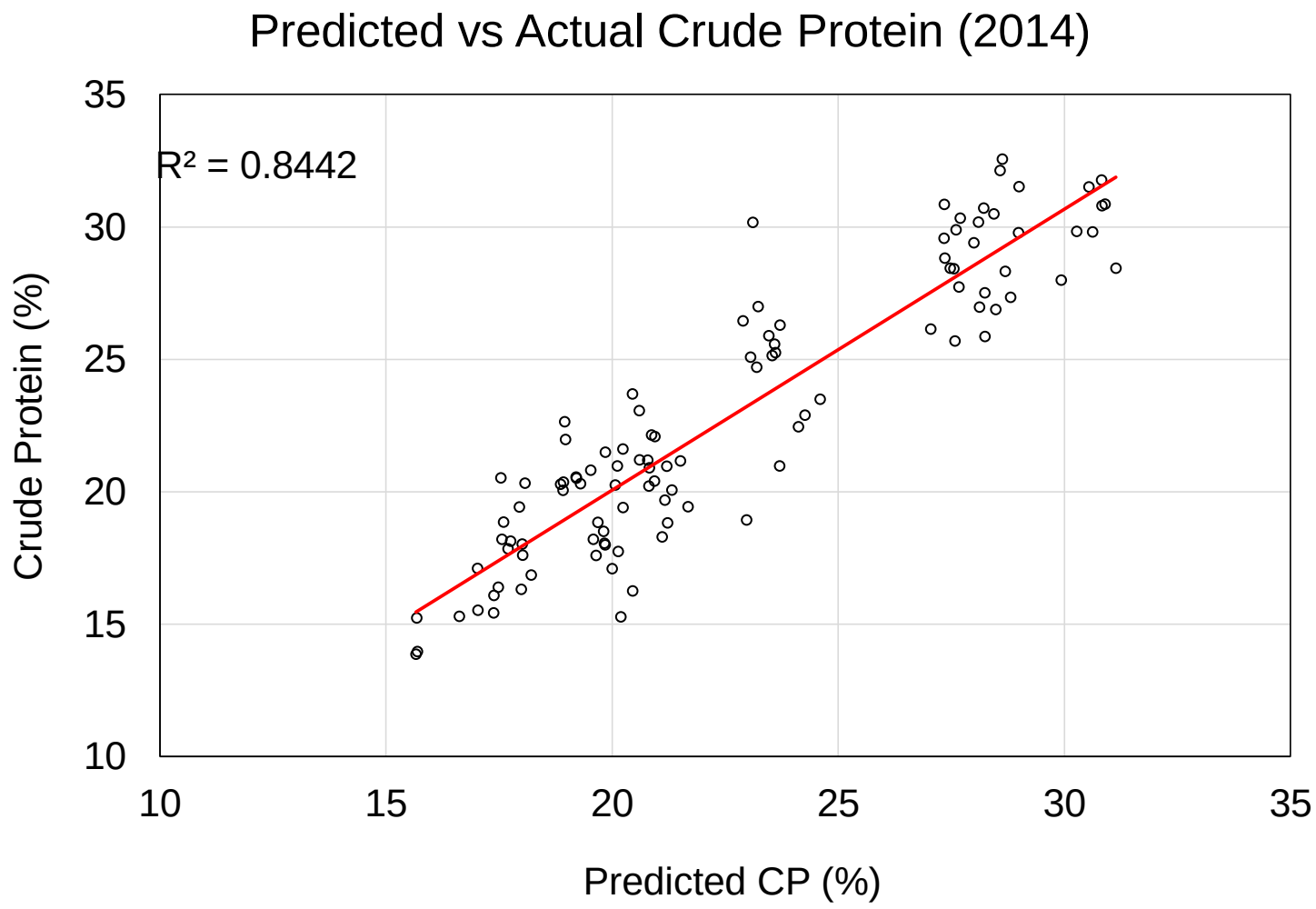
Reduced model with GDU covariate



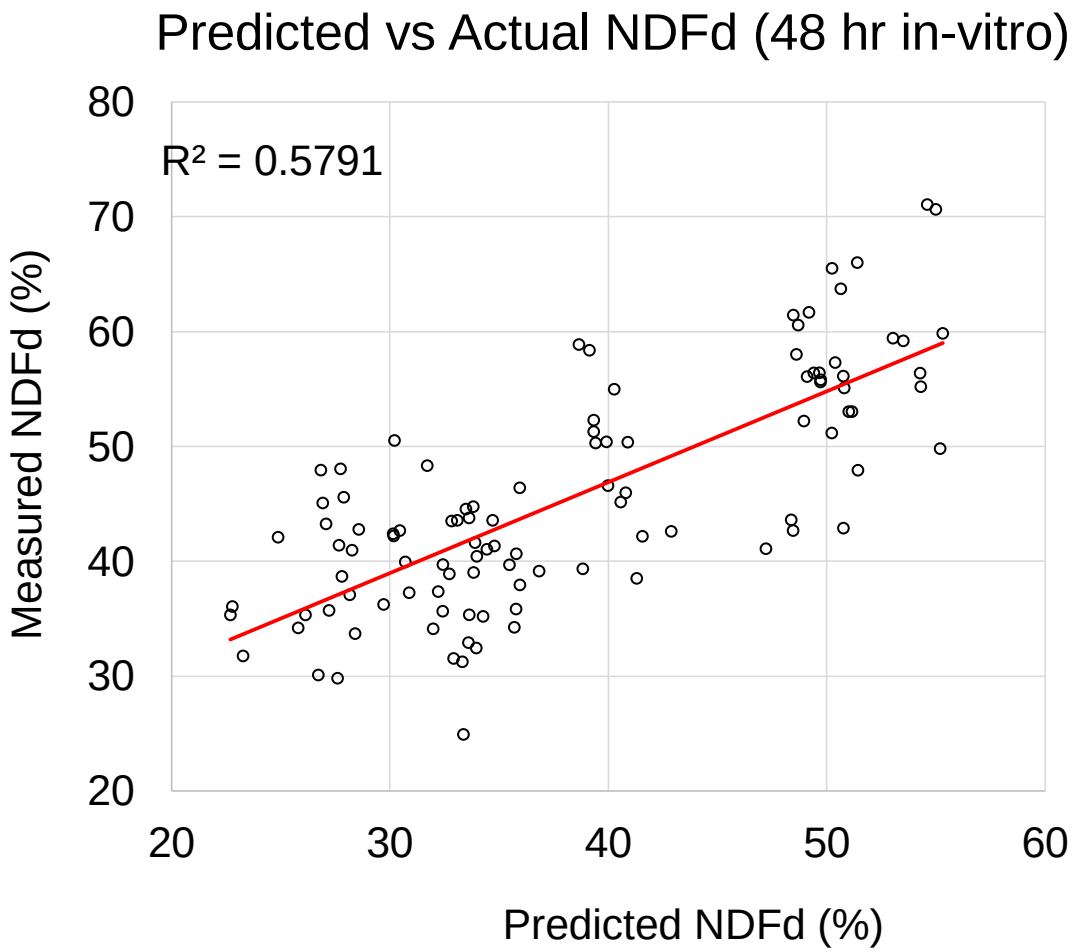
Same 3 bands applied to NDFd



2015 model applied to 2014 data



2015 model applied to 2014 data



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

- Dr. M. Scott Wells
- Dr. Craig C. Sheaffer

- Eric Ristau
- Joshua Larson

- Farm Intelligence
- Farm Nutrients

References

- American Society of Agronomy. 2011. Alfalfa management guide.
- Kalu, B.A., and G.W. Fick. 1981. Quantifying Morphological Development of Alfalfa for Studies of Herbage Quality1. Crop Sci. 21(2): 267.
- Kalu, B.A., and G.W. Fick. 1983. Morphological Stage of Development as a Predictor of Alfalfa Herbage Quality1. Crop Sci. 23(6): 1167.
- McRoberts, K.C., B.M. Benson, E.L. Mudrak, D. Parsons, and D.J.R. Cherney. 2016. Application of local binary patterns in digital images to estimate botanical composition in mixed alfalfa–grass fields. Comput. Electron. Agric. 123: 95–103.
- Pittman, J.J., D.B. Arnall, S.M. Interrante, C.A. Moffet, and T.J. Butler. 2015. Estimation of biomass and canopy height in bermudagrass, alfalfa, and wheat using ultrasonic, laser, and spectral sensors. Sensors (Basel). 15(2): 2920–43.
- Starks, P.J., M.A. Brown, K.E. Turner, and B.C. Venuto. 2016. Canopy Visible and Near-infrared Reflectance Data to Estimate Alfalfa Nutritive Attributes Before Harvest. Crop Sci. 56(1): 484.
- Starks, P.J., D. Zhao, W.A. Phillips, and S.W. Coleman. 2006. Development of canopy reflectance algorithms for real-time prediction of bermudagrass pasture biomass and nutritive values. Crop Sci. 46(2): 927–934.
- University of Wisconsin Extension. 2016. Hay Market Demand and Price Report for the Upper Midwest As of May 23, 2016. Retrieved from: https://fyi.uwex.edu/forage/files/2016/05/05-23-16.pdf

Questions?