Spectroscopic Analysis of Temporal Live Fuel Moisture and Dry Matter Content

Yi Qi and Philip E. Dennison

Utah Remote Sensing Application Lab

Department of Geography, University of Utah

Matt Jolly and Rachel Kropp

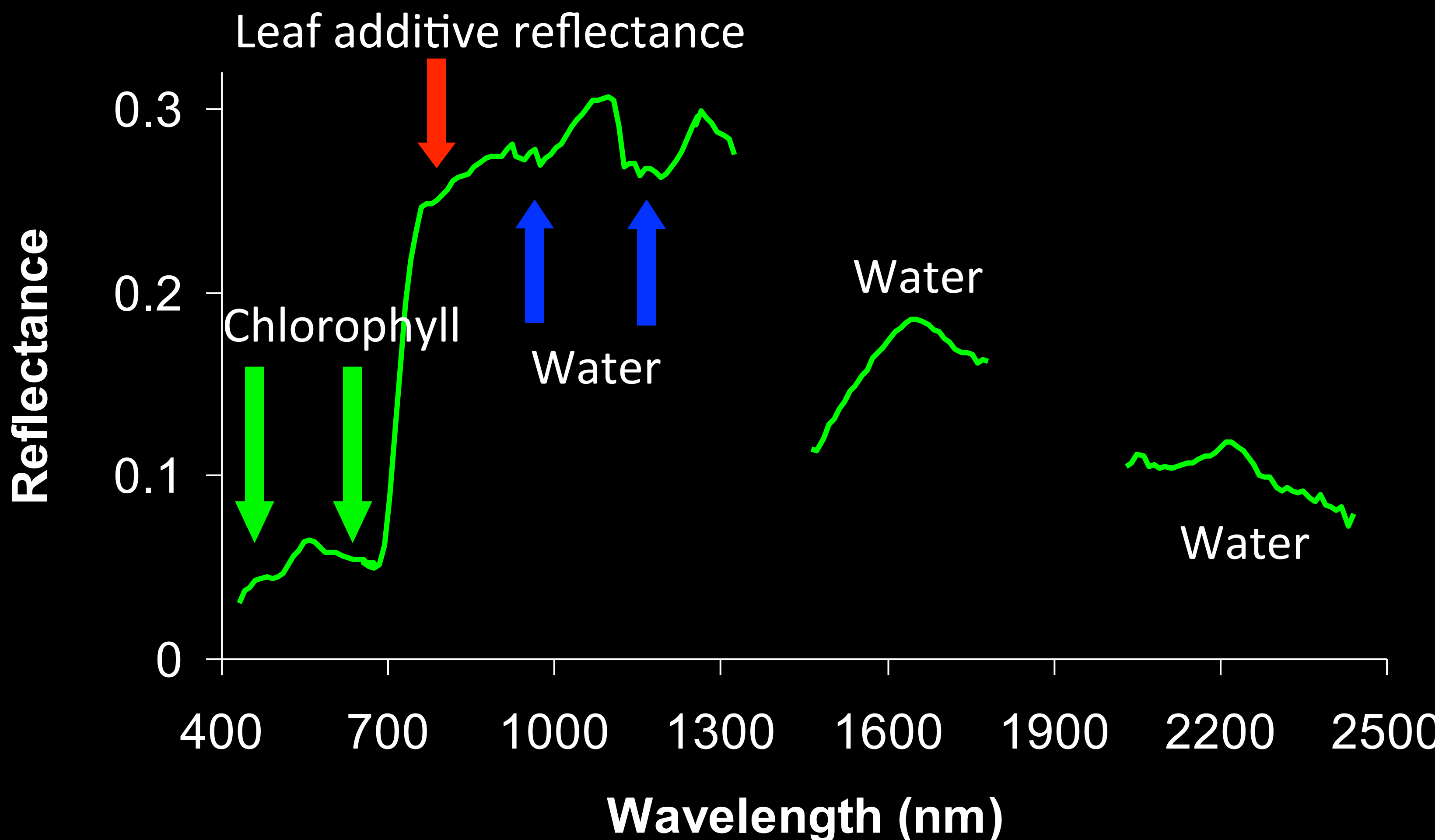
US Forest Service Missoula Fire Science Lab

Live Fuel Moisture (LFM)

- Water content of living plant material
- LFM

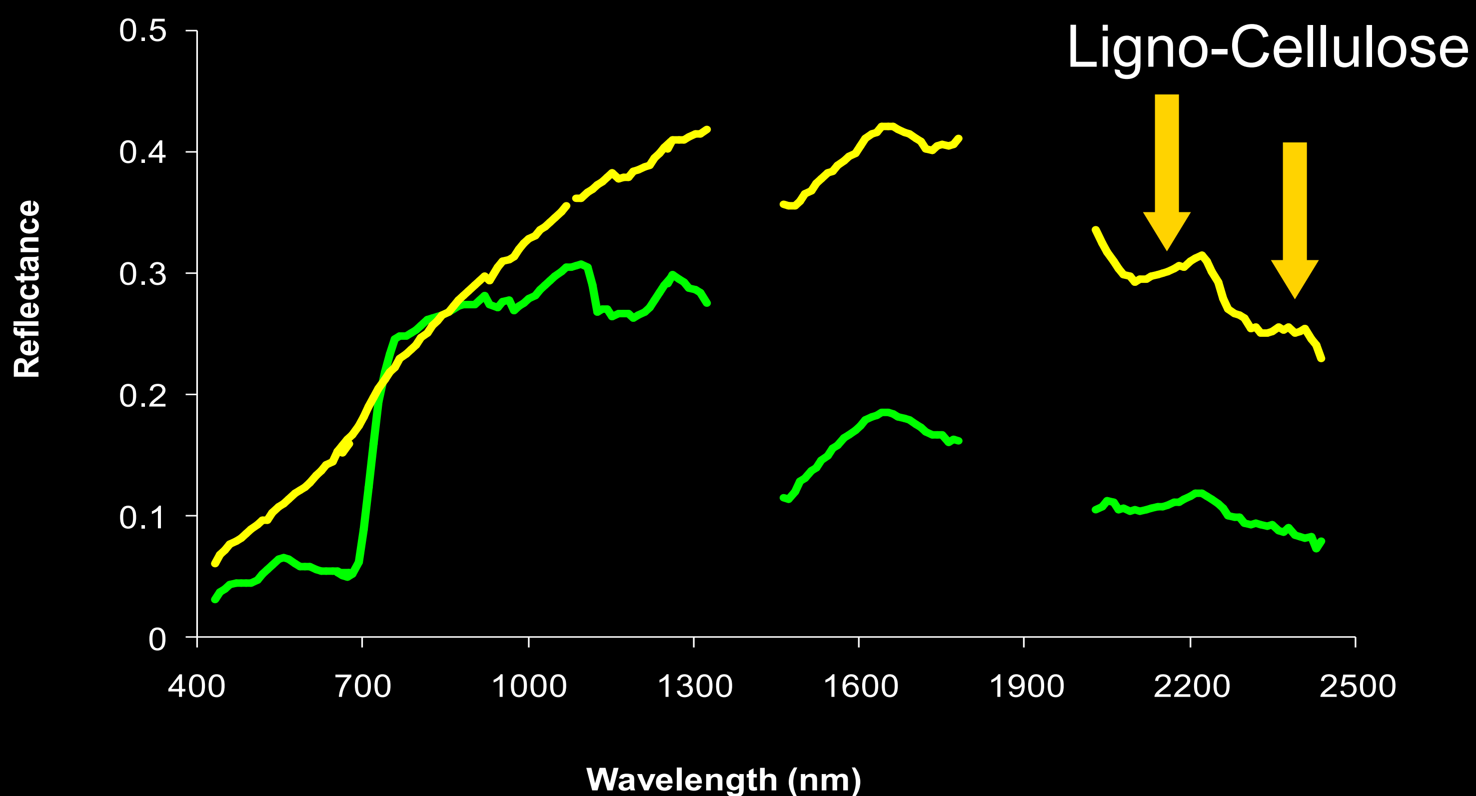
- Water acts as a heat sink for combustion and heat transfer
- High LFM reduces probability of live fuel ignition and fire rate of spread through live fuels

Vegetation Spectral Signature

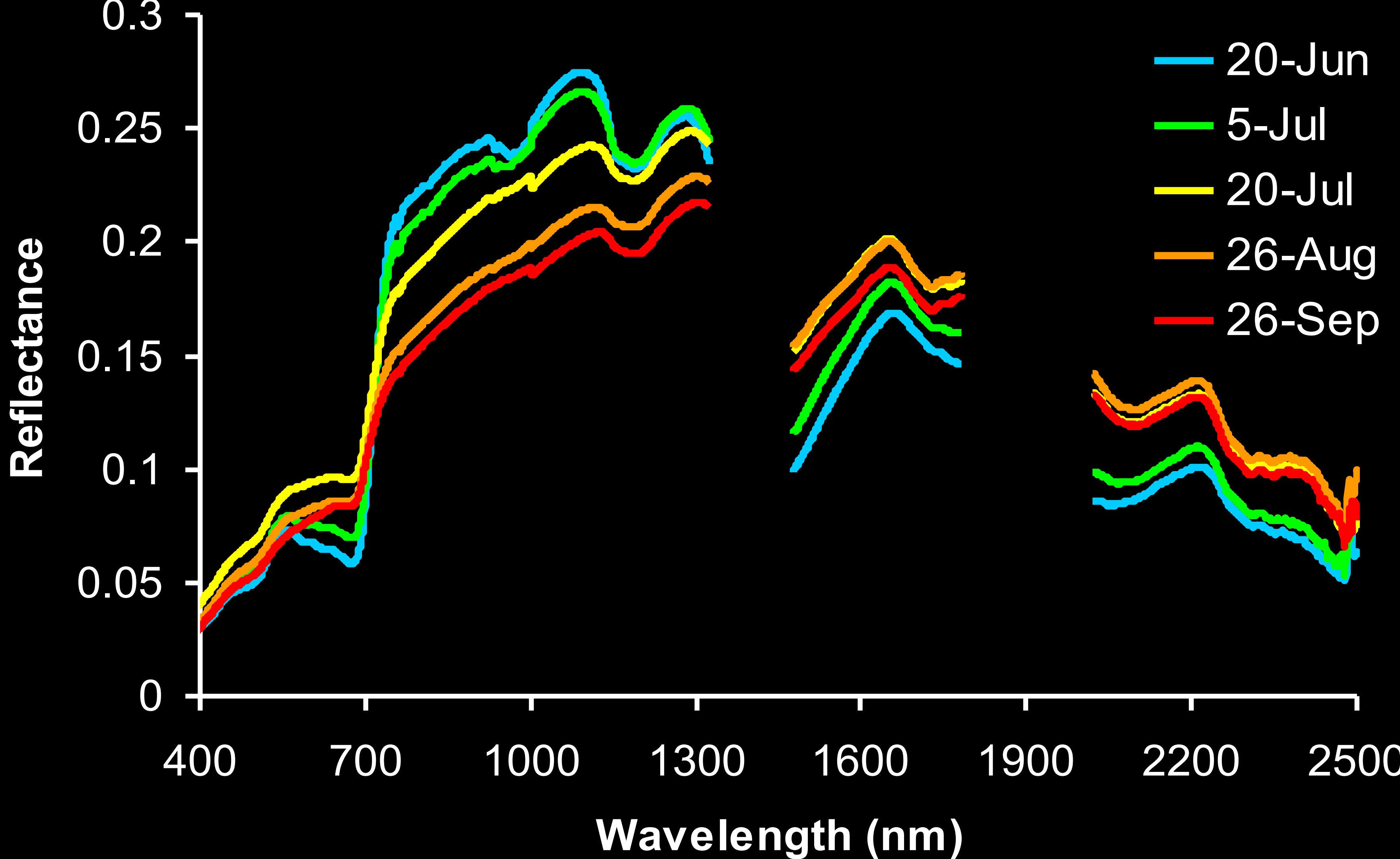


Dry Matter Spectral Signature

- Ligno-cellulose absorption in SWIR



Sagebrush Temporal Spectral Change



Assumptions in LFM Estimation

- $\text{LFM} = \frac{m_w}{m_d} = \frac{m_f - m_d}{m_d} = \frac{CWC}{DMC}$
- Empirical methods use vegetation indices, such as NDVI and NDWI, to indirectly estimate LFM.
- Radiative transfer modeling often assumes stable DMC and fluctuating CWC.
- Fire behavior models (e.g. Rothermel) also assume stable dry matter and fluctuating water content.

Research Objectives

- Examine the seasonal variation of LFM and dry matter content.
- Explore biochemical foundations of LFM and dry matter content variation.
- Understand hyperspectral expression of dry matter content and biochemical constituents.

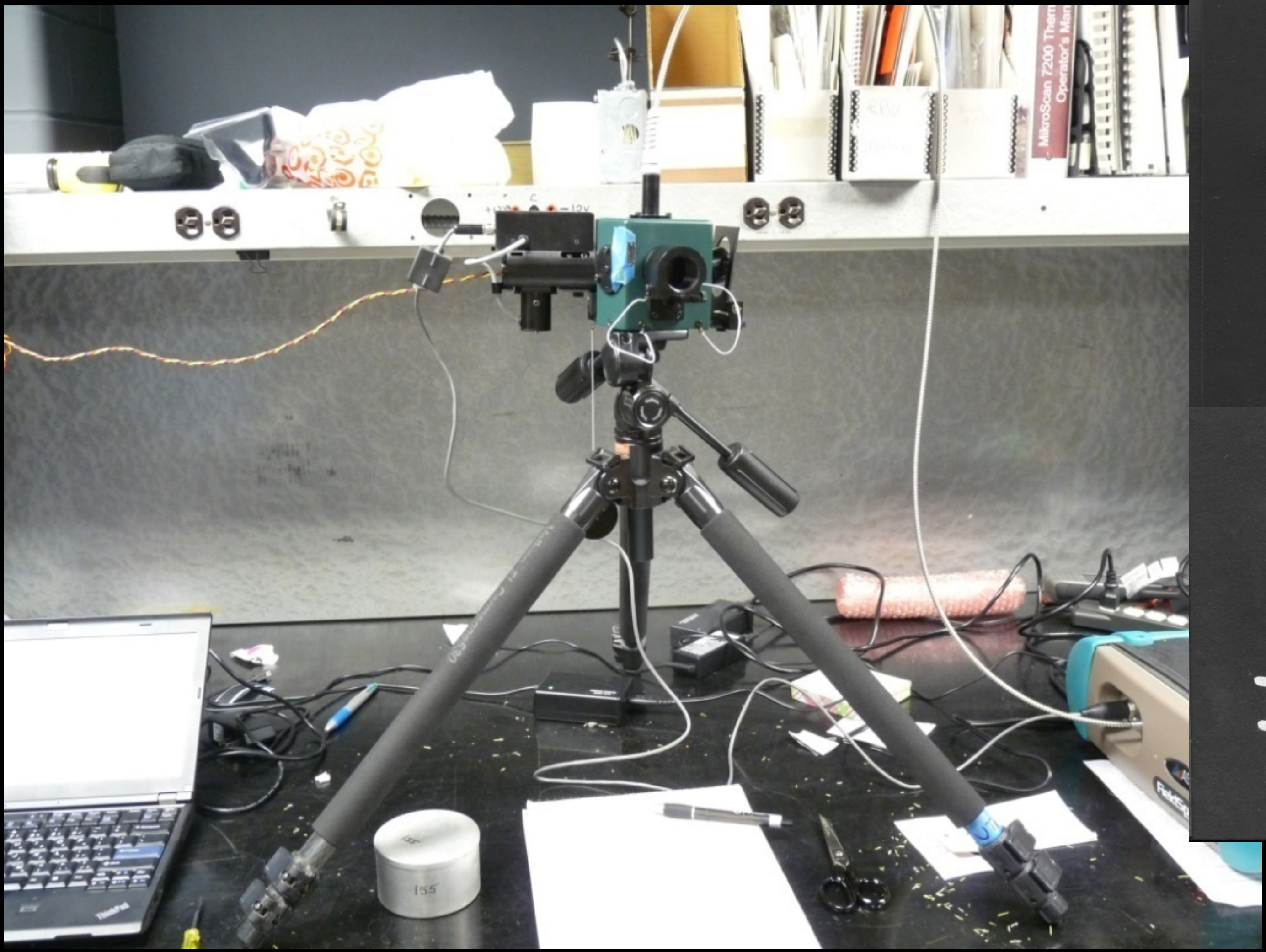
Field Sampling of LFM

- Lodgepole pine (*Pinus contorta*): new and old
- Big sagebrush (*Artemisia tridentata*)
- Dry matter in percentage of fresh mass (DMP)
- Relative water content (RWC)

Biochemical Constituents

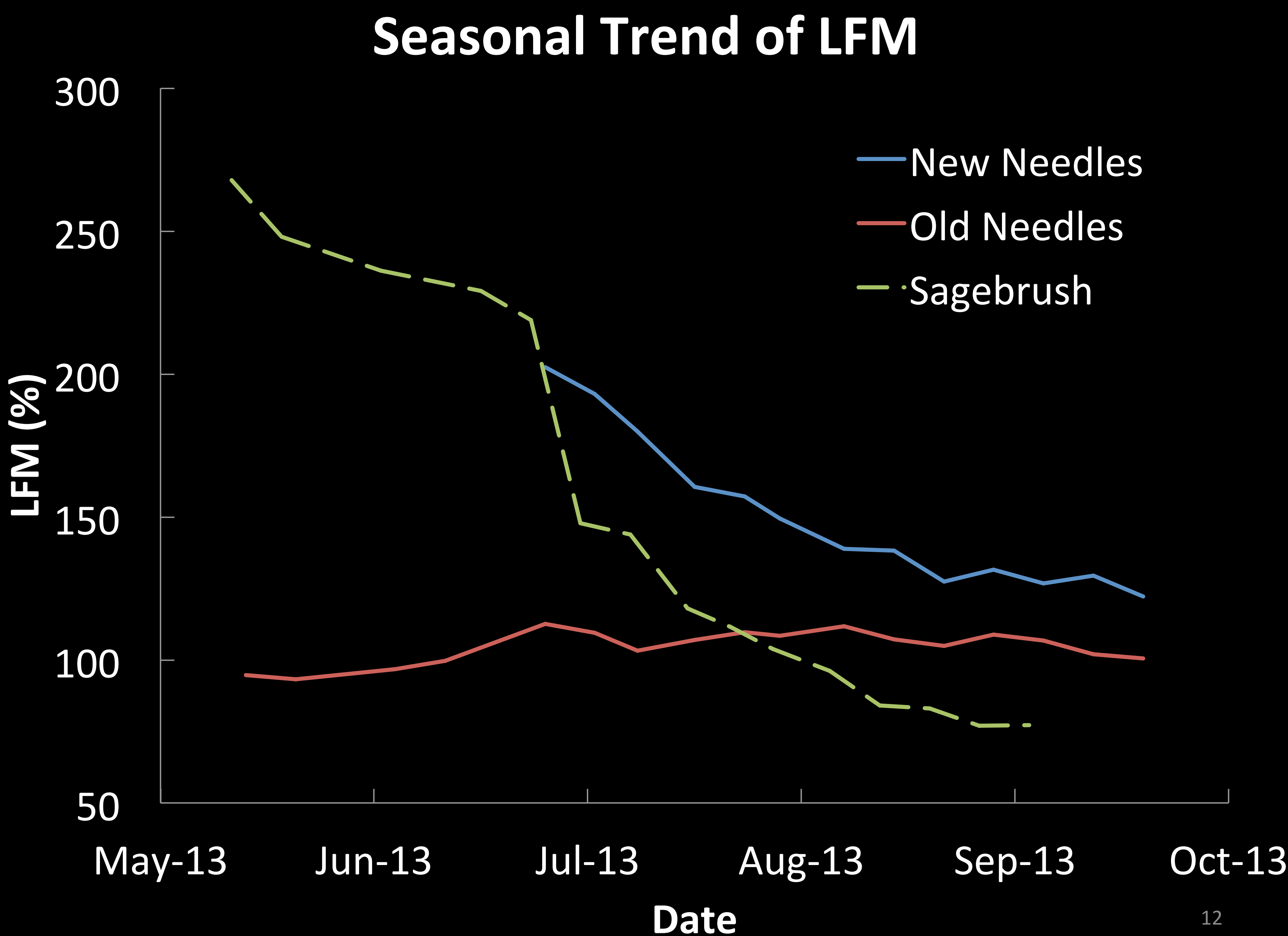
Name	Description
Neutral Detergent Fiber (NDF)	lignin, cellulose
Non-structural carbohydrate (NSC)	sugar, starch
Neutral detergent soluble fiber (NDSF)	hemicellulose
Protein	nitrogen bearing content
Fat	wax and fat
Ash	mineral content

Leaf-scale Spectroscopy



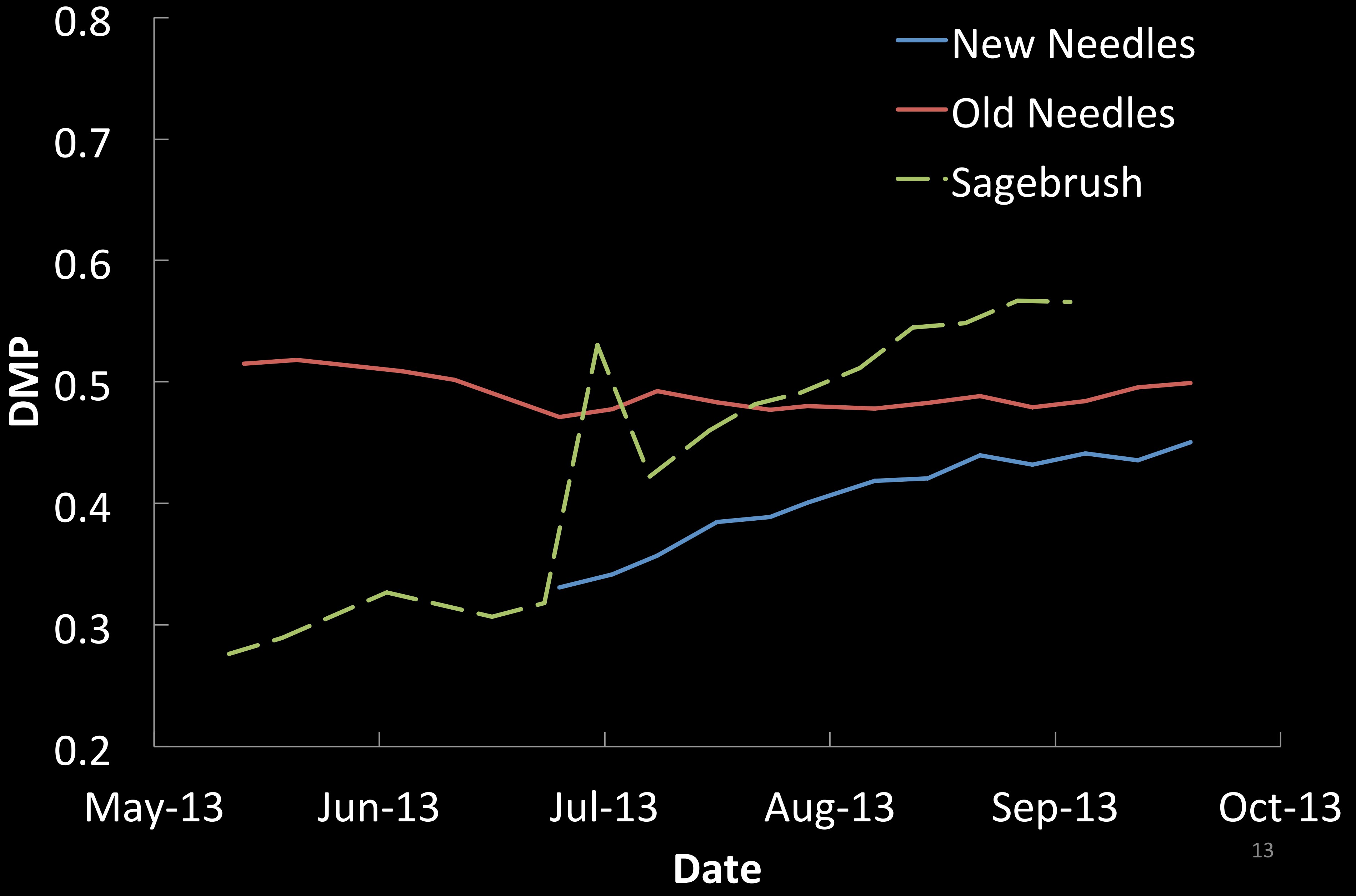
Statistical Analysis

- Principle component analysis (PCA)
  Seasonal patterns of biochemical constituents
- Semi-partial correlation analysis
  Contribution of water and dry matter to LFM
- Partial-least-square regression (PLS)
  Spectral correlations to LFM and dry matter

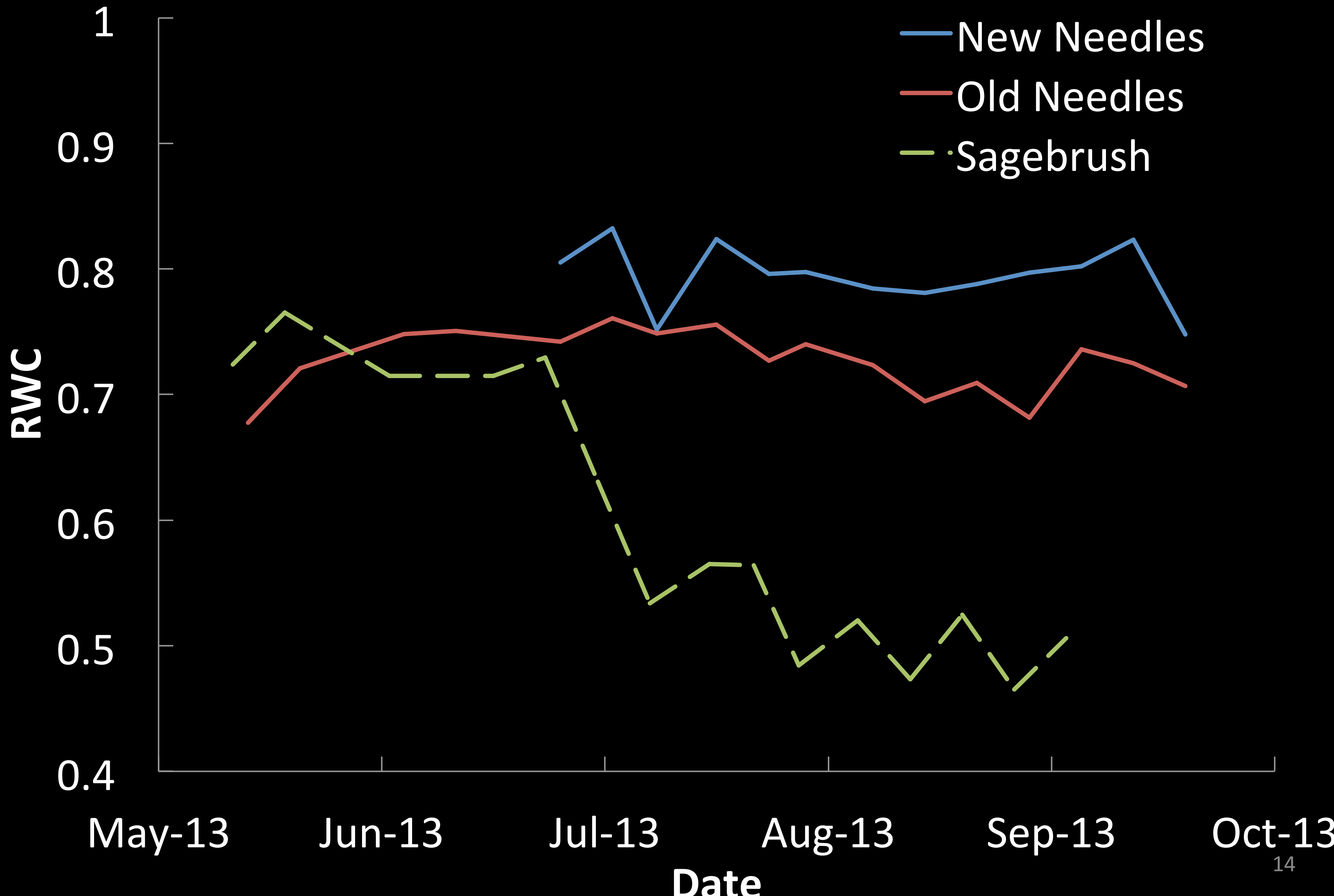


Seasonal Trend of LFM
300
250
200
150
100
50
LFM (%)
New Needles
Old Needles
Sagebrush
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Date

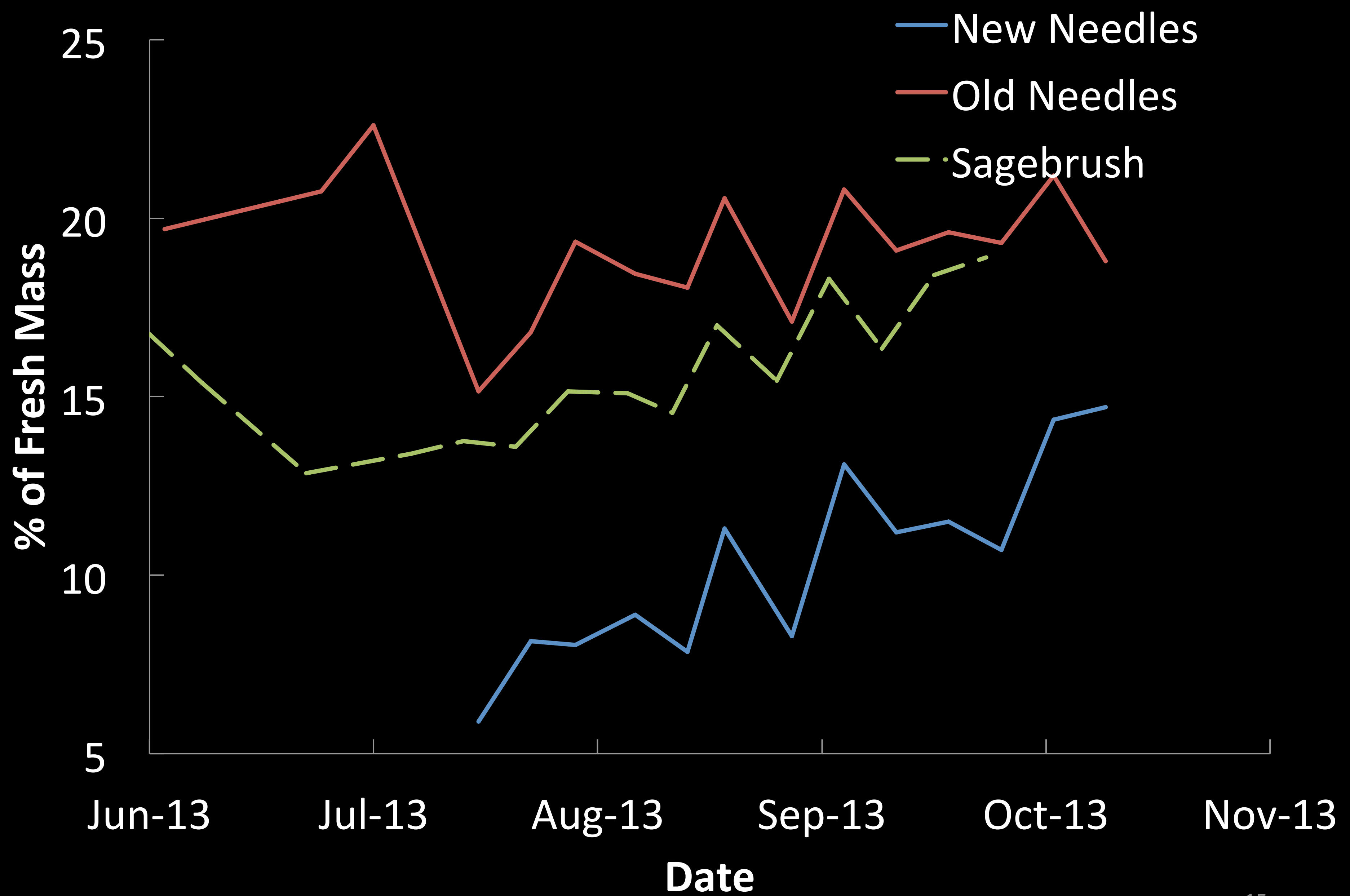
Seasonal Trend of DMP



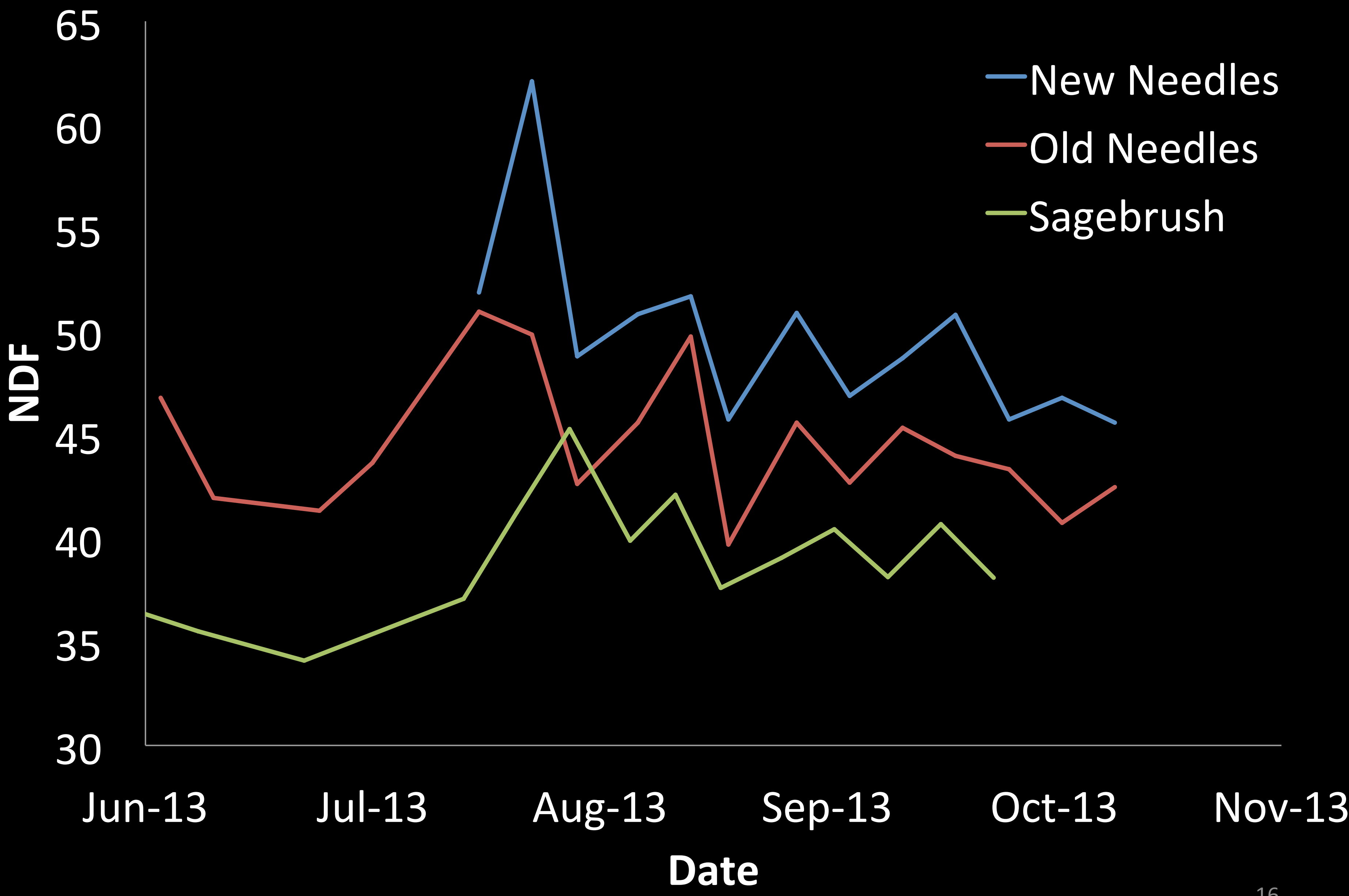
Seasonal Trend of RWC



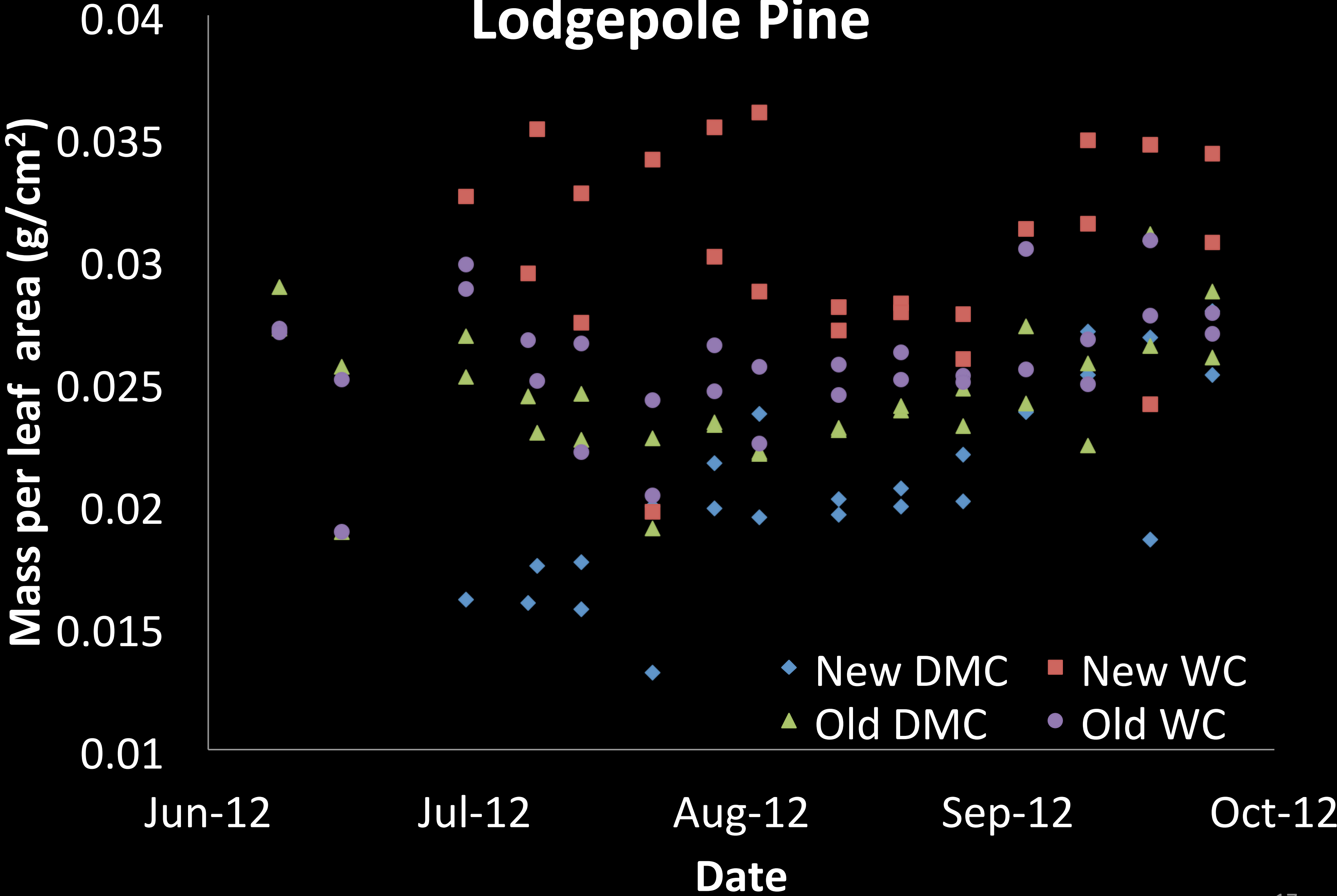
Seasonal Trend of NSC



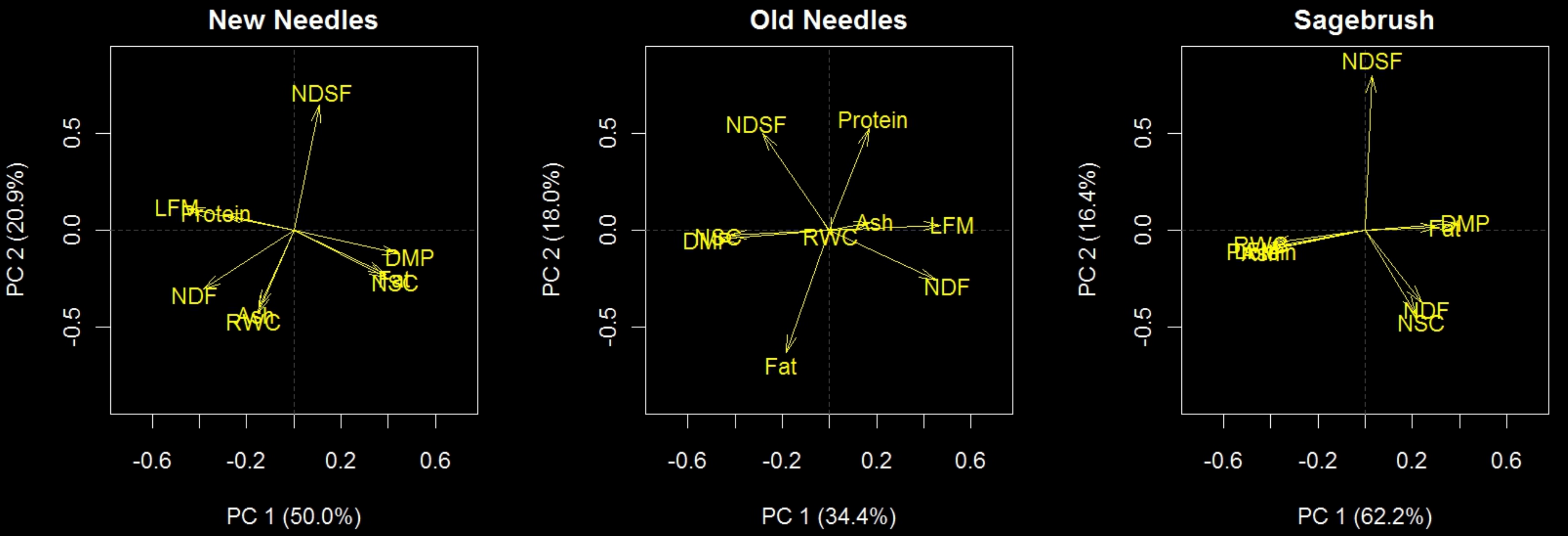
Seasonal Trend of NDF



Seasonal Trend of DMC and WC in Lodgepole Pine



PCA of All Variables



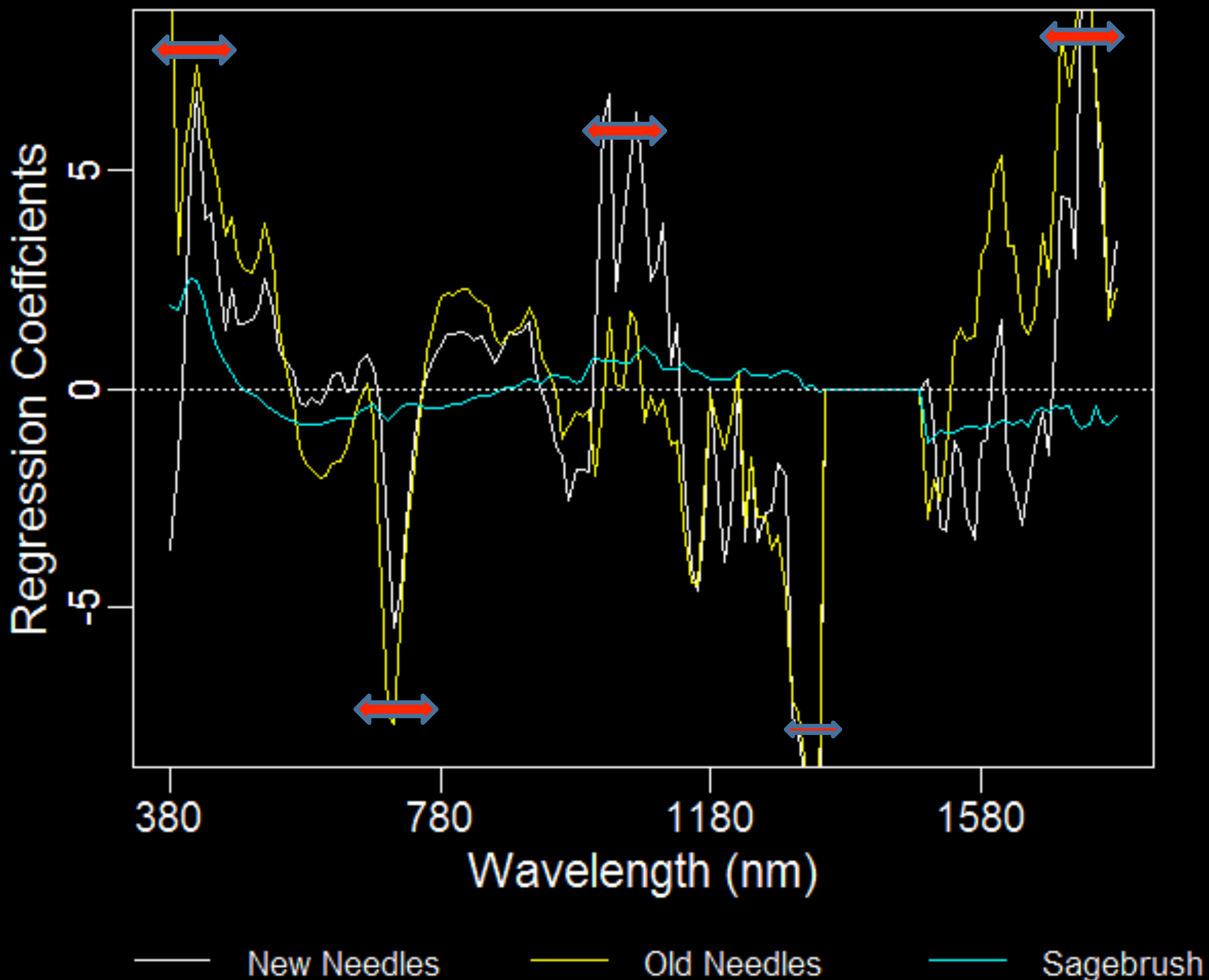
Semi-partial Correlation

Species	Dry matter (g)	Water (g)	Common Variance
New needles	0.37	0.05	0.45
Old needles	0.17	0.1	0.45
Sagebrush	0.24	0.23	0.08

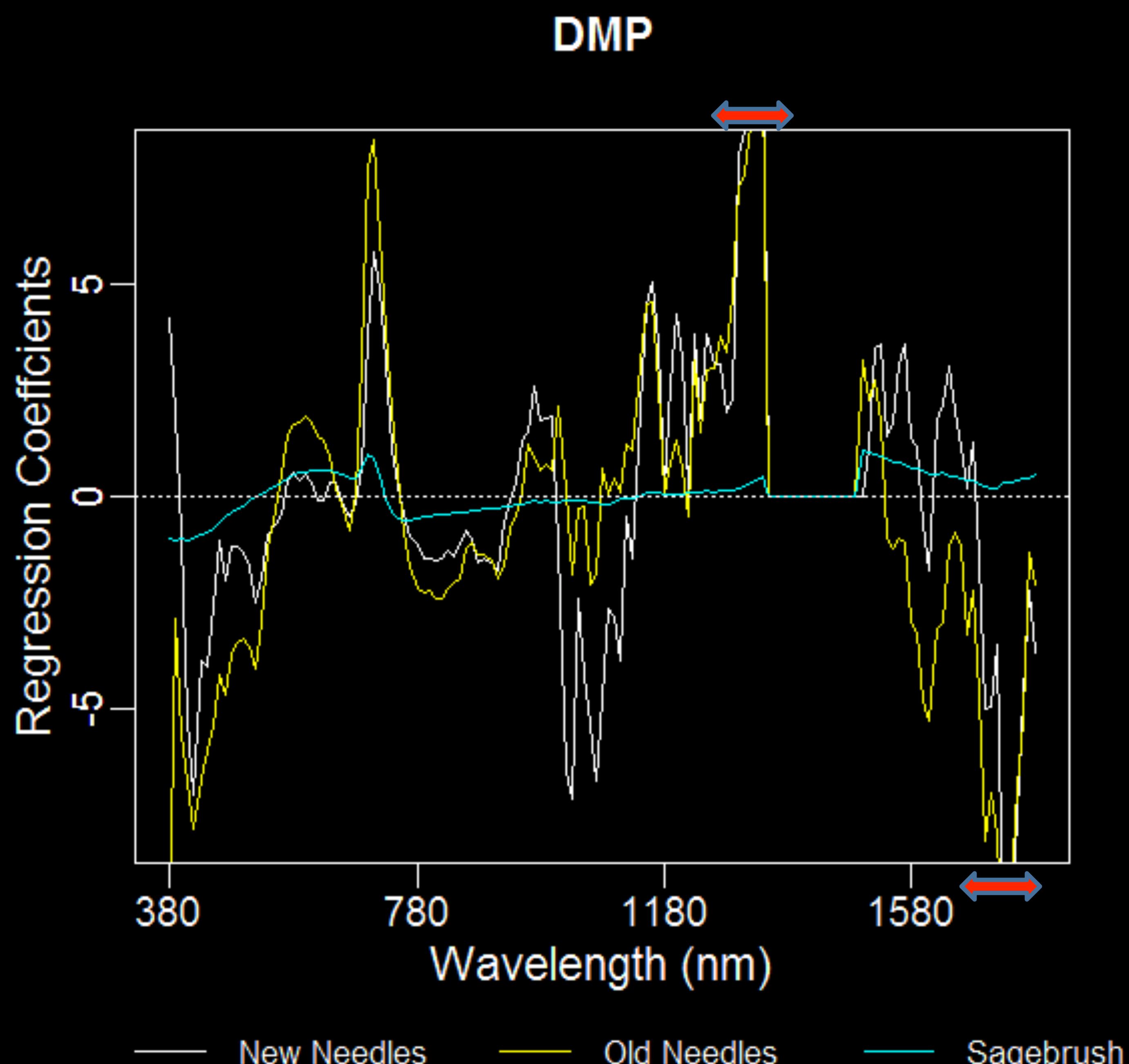
PLS Results

	New Needle R^2	Old Needle R^2	Sagebrush R^2
LFM	0.94	0.72	0.91
DMP	0.94	0.75	0.8
RWC	0.15	0.43	0.85
Protein	0.7	0.4	0.9
NDF	0.6	0.3	0.4
Fat	0.8	0.3	0.6
Ash	0.6	0.5	0.9
NSC	0.7	0.3	0.5
NDSF	0.3	0.2	0.1

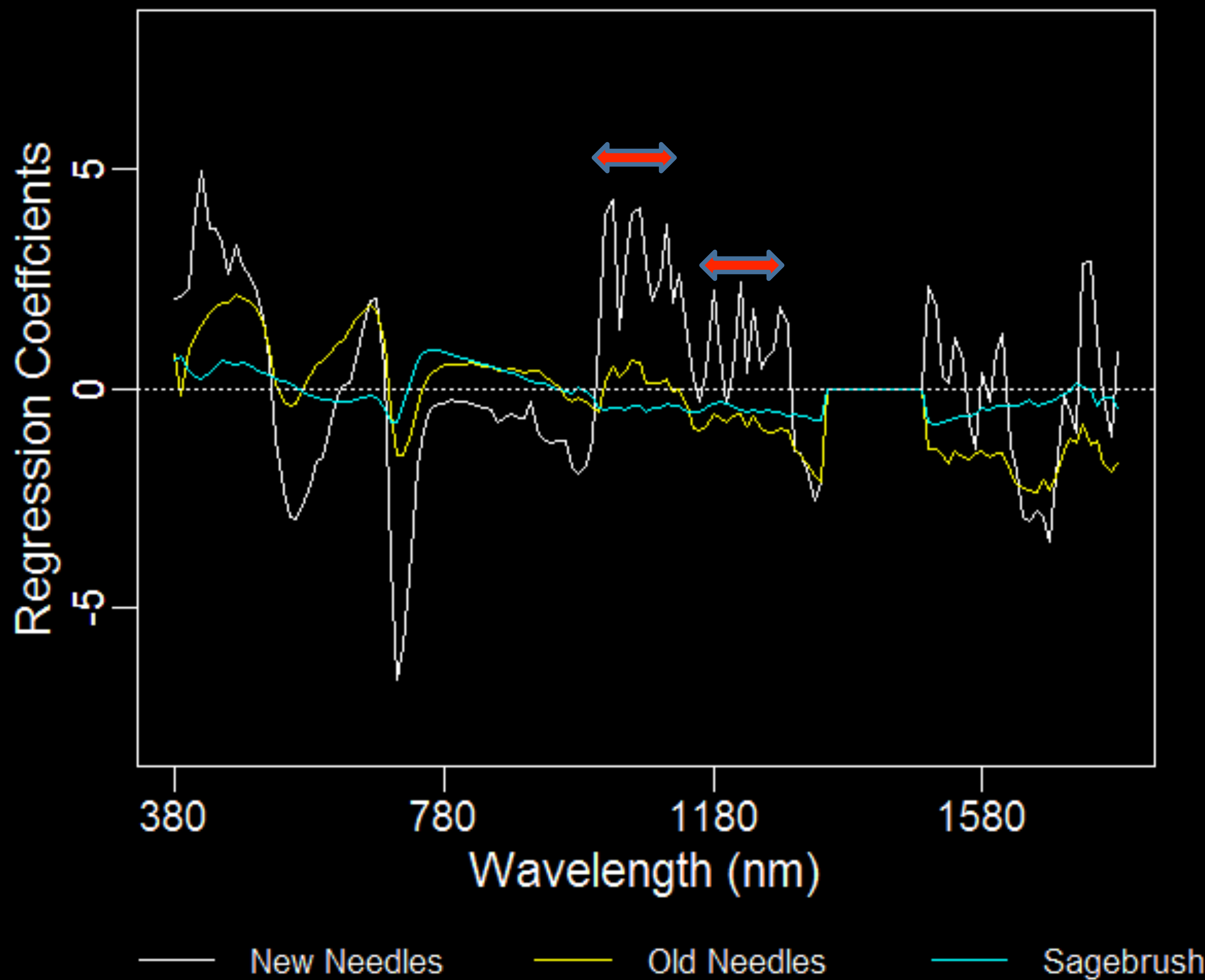
LFM



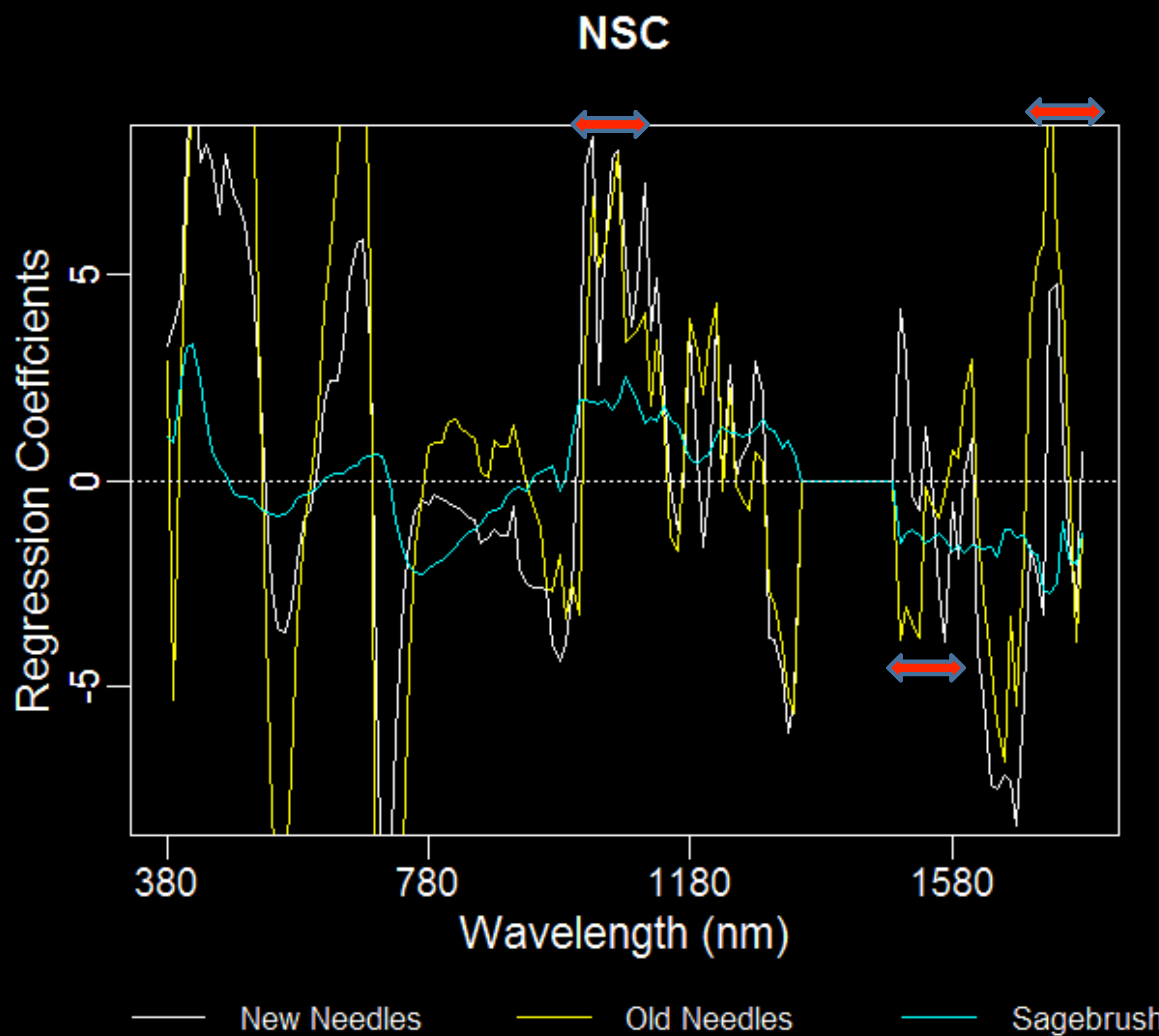
Regression Coeffcients
5
0
-5
380
780
1180
1580
Wavelength (nm)
New Needles
Old Needles
Sagebrush

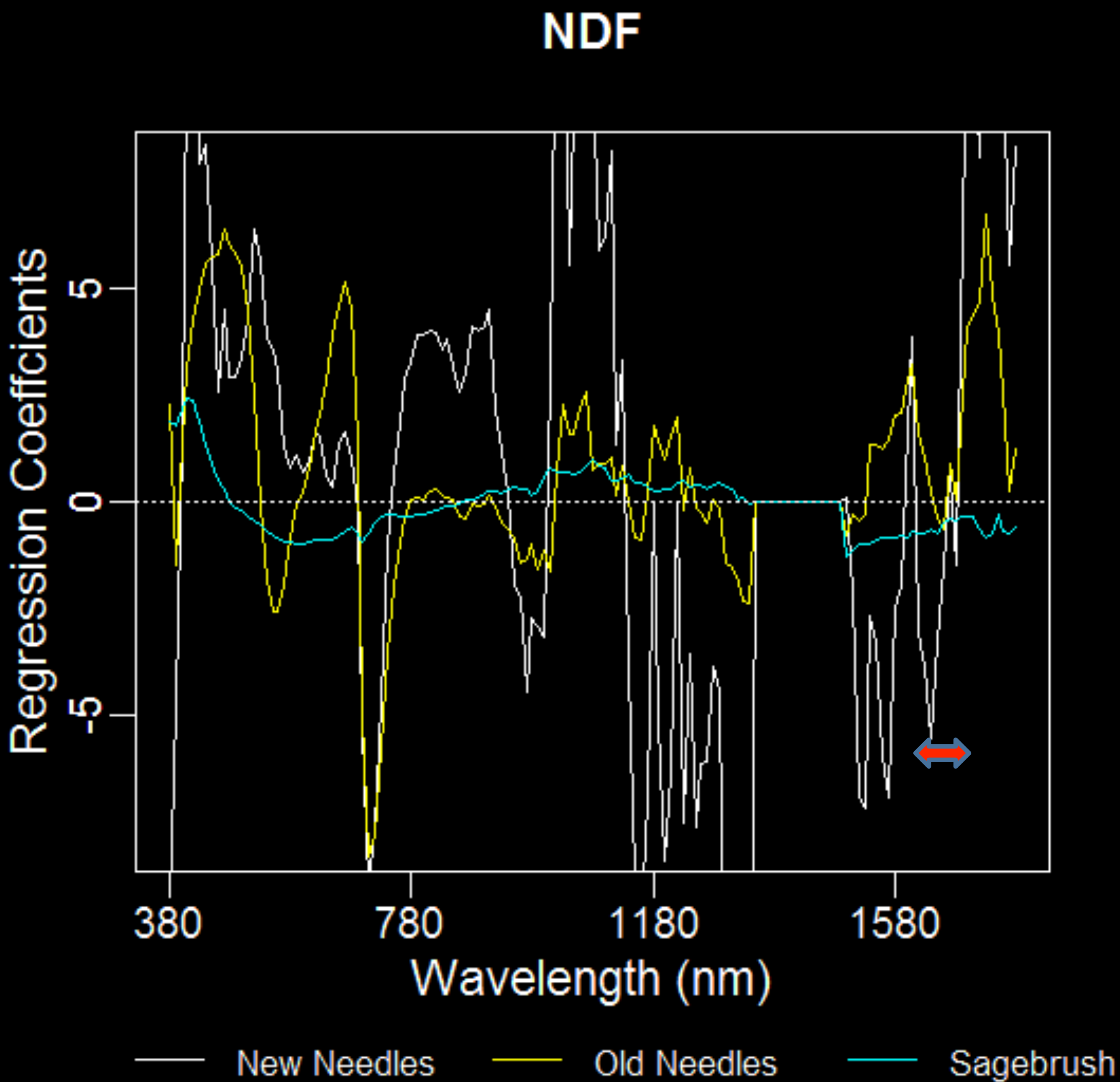

DMP
Regression Coeffcients
5
0
-5
380
780
1180
1580
Wavelength (nm)
New Needles
Old Needles
Sagebrush

RWC



Regression Coeffcients
5
0
-5
380
780
1180
1580
Wavelength (nm)
New Needles
Old Needles
Sagebrush


NSC
Regression Coeffcients
5
0
-5
380
780
1180
1580
Wavelength (nm)
New Needles
Old Needles
Sagebrush



NDF
Regression Coeffcients
5
0
-5
380
780
1180
1580
Wavelength (nm)
New Needles
Old Needles
Sagebrush

Key Finding 1: Temporal Trends

- New needles started with high LFM and converged to similar LFM as old needles.
- Dry matter increased in new needles and sagebrush leaves, and was relatively stable in old needles.
- Relative water content was relatively stable.

Key Finding 2: Biochemical Variation

- Dry matter was more important than water content in driving LFM variation in lodgepole pine needles.
- LFM variation was jointly caused by water and dry matter in sagebrush.
- LFM masks what may be ecologically important temporal variation in water content, dry matter content, and biochemical constituents.

Key Finding 3: Hyperspectral Signature

- Absorption features of multiple biochemical constituents shaped spectroscopic data. Water, chlorophyll, and NIR reflectance are the dominant signals.
- Dry matter content absorption in the SWIR does not have strong changes in expression
- It is difficult to isolate spectral signatures of individual constituents.

Conclusions

- New and old lodgepole pine needles have different seasonal trends in LFM and dry matter content
- Dry matter is a more important driver in LFM variation than water in lodgepole pine needles
- Dry matter content is not uniquely expressed within wavelength 380 – 1800 nm.
- HyspIRI data have higher potential for estimating LFM in sagebrush than lodgepole pine.

Acknowledgements

- Simon Brewer, Department of Geography, University of Utah
- NASA grant #NNX11AF93G

THE UNIVERSITY OF UTAH

URSA