Consequences of Institutional Change: Kazakhstan Land Cover Dynamics Project

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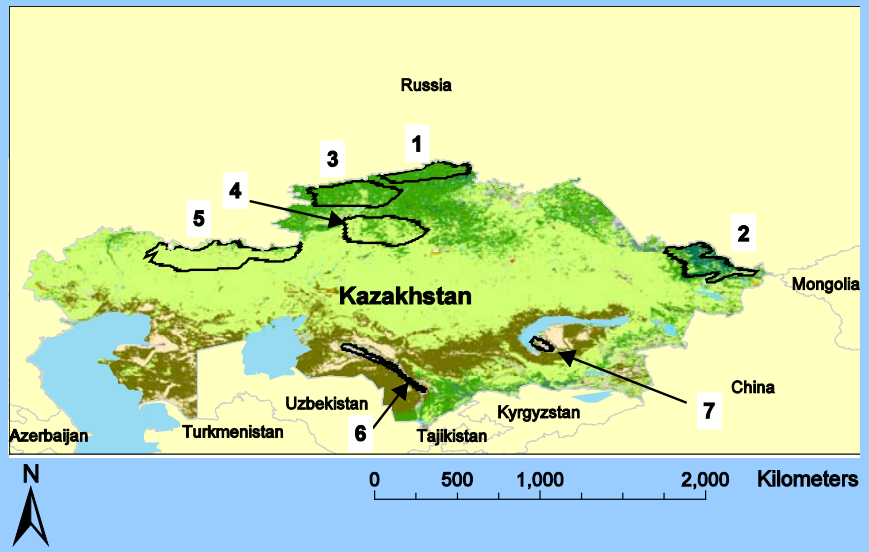
Collaborator: **Lev Spivak**, Space Research Institute, Almaty, KZ



Change and Variation are distinct concepts.

Land cover change analysis that relies on cover class inventories may miss significant within-class variation that affects the "quality" of the land cover.

Land cover change analysis that relies on spectral indices or retrieved biogeophysical variables may confront considerable spatial and temporal variation.

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As a discipline, we need tools that are more sensitive to changes in surface vegetation structure and dynamics. NDVI is not enough due to loss of sensitivity under moderate to high vegetation density.

First, we present the Wide Dynamic Range Vegetation Index (WDRVI) that can complement the NDVI and provide a fresh look at archived imagery.

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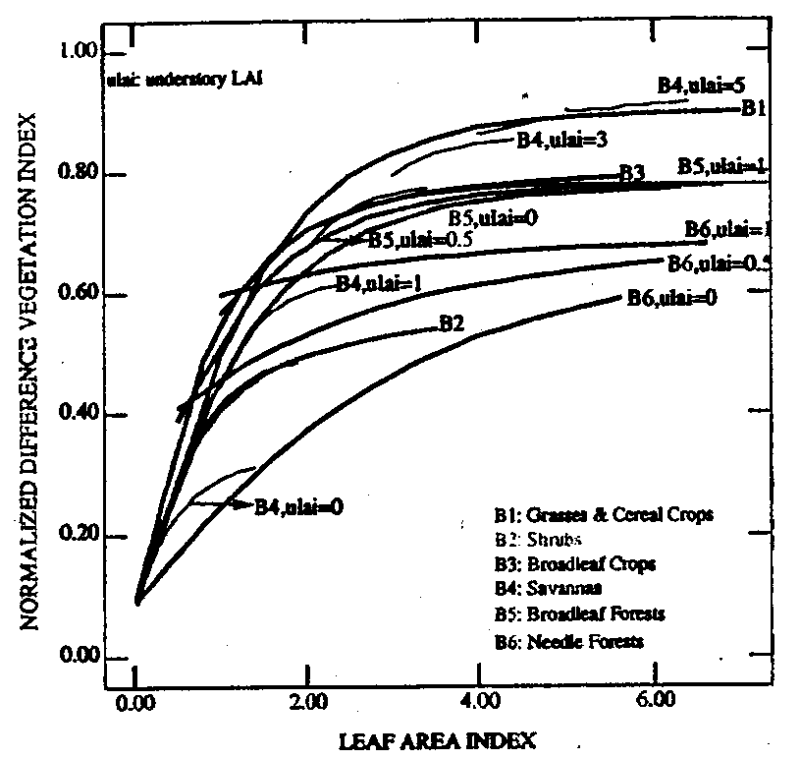
As a discipline, we need statistical frameworks to evaluate long image time series for trends and step changes. Change analysis requires more than change detection. It is critical to discern with confidence the unusual from the average and expected variation from significant change.

Second, we present results from a statistical analysis of the PAL data that partitions seasonal, interannual, and sensor-specific variation to identify *significant* land cover change following institutional change.

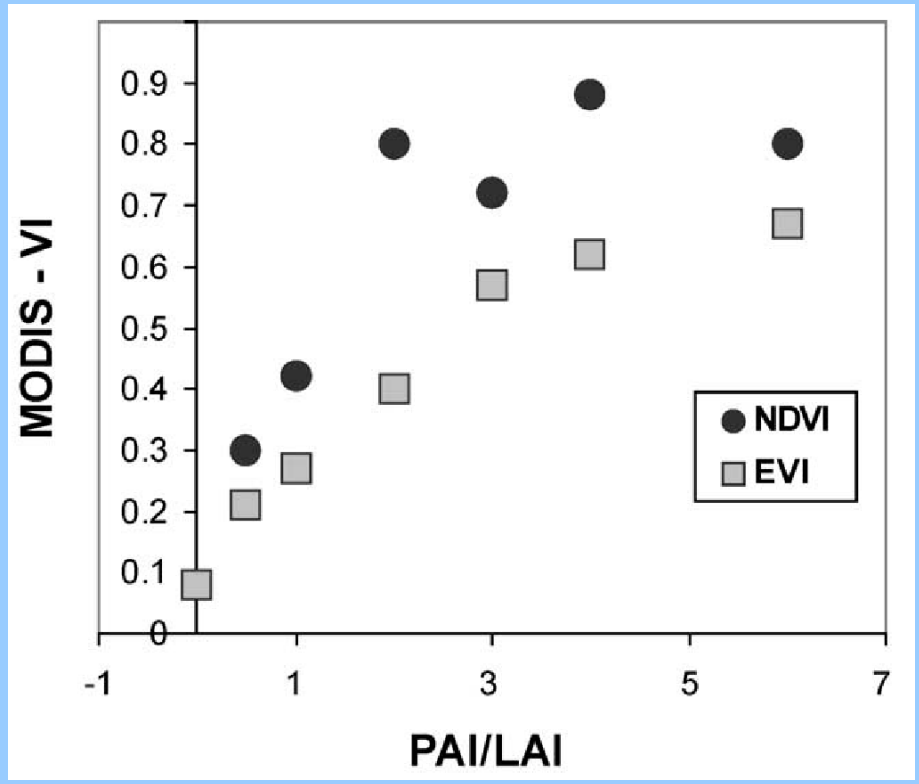
1. WIDE DYNAMIC RANGE VEGETATION INDEX

The NDVI approaches saturation asymptotically under conditions of moderate-to-high green aboveground biomass.

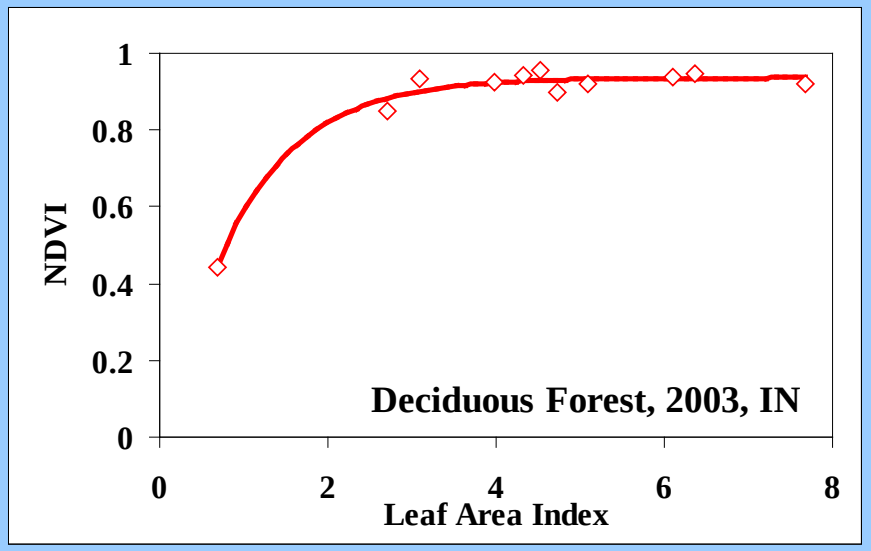


Myneni et al., 1997, *IEEE TGRS* 35:1380-1397.

Huete et al., 2002, *RSE* 83:195-213.

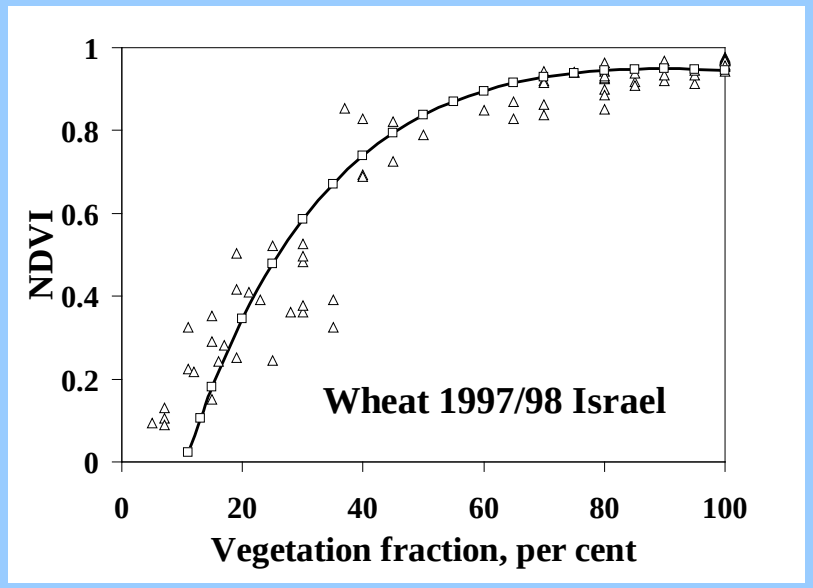


MODIS Imagery



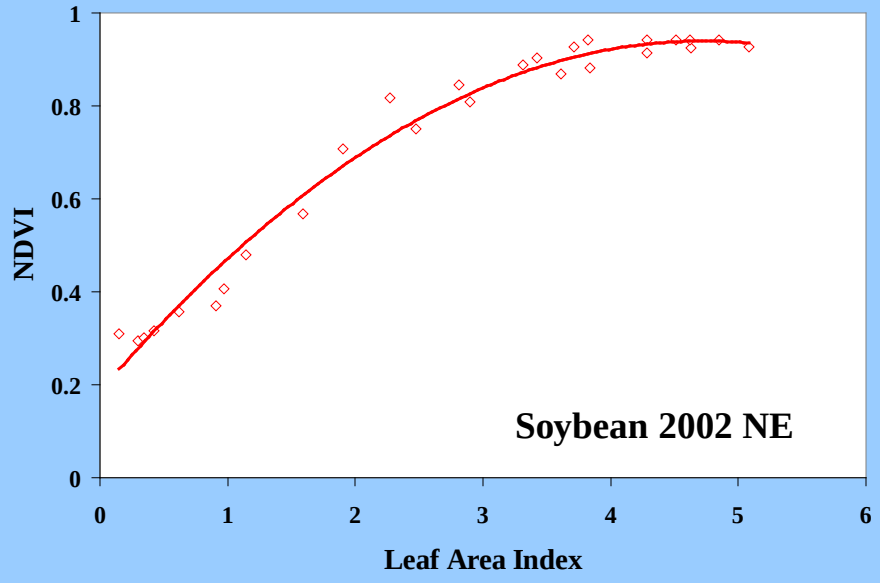
(Courtesy of Fais Rahman, Ball State)

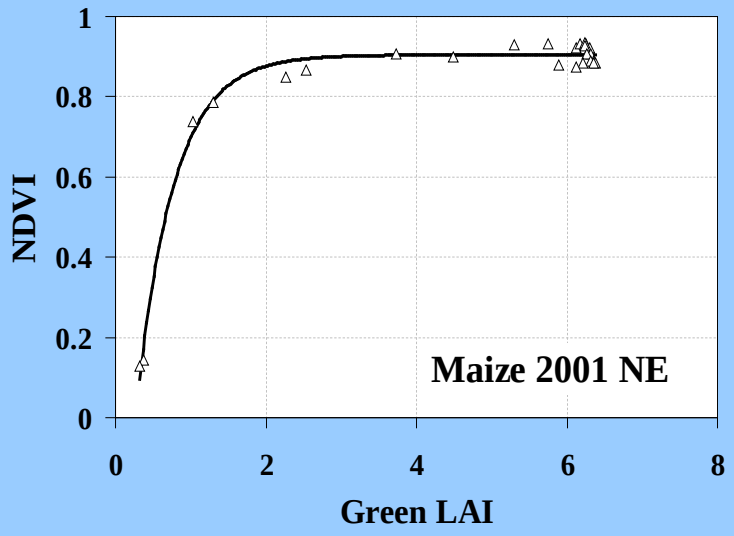
NDVI vs. VF



(Gitelson et al, RSE, 2002)

Proximal sensing



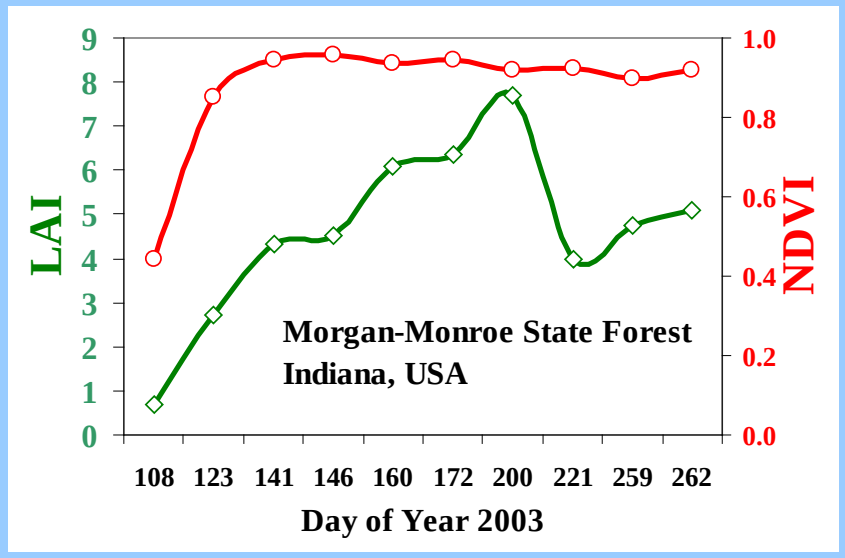


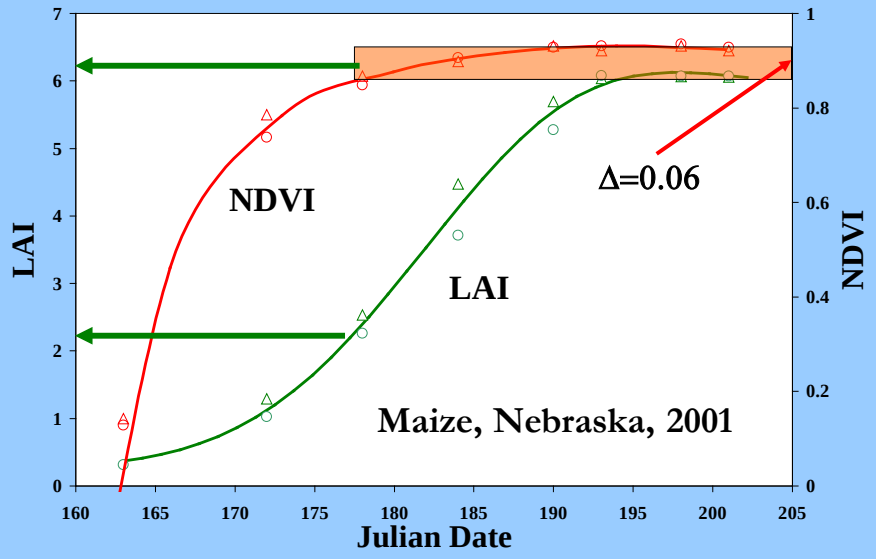
(Gitelson et al, GRL, 2003)

The reduced sensitivity of the NDVI during much of the growing season veils changes in vegetation structure.

Throughout most of the growing season, eastern deciduous forest exhibits little temporal variation in the MODIS NDVI.

(Courtesy of Fais Rahman, Ball State)



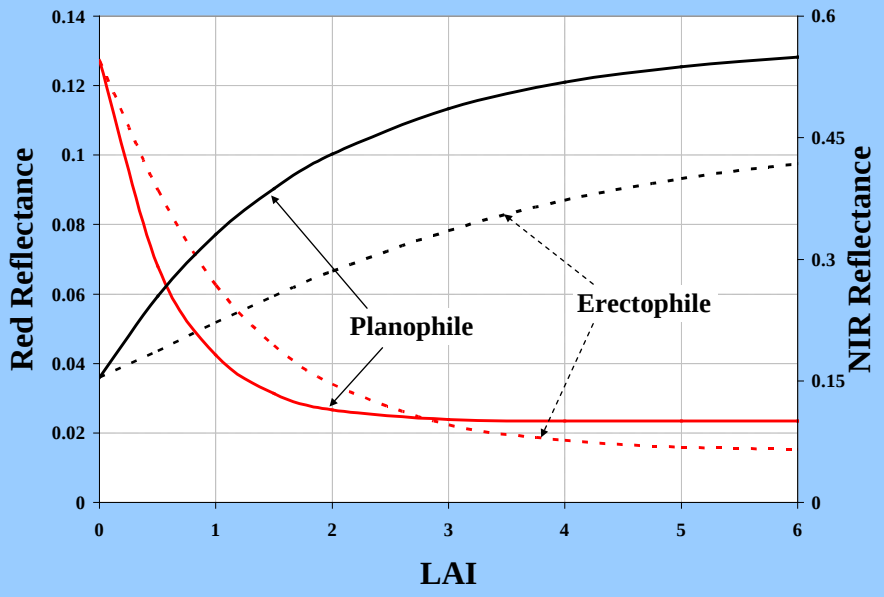


From mid-June through the end of August, the NDVI of maize does not substantially vary despite significant changes in canopy density and structure.

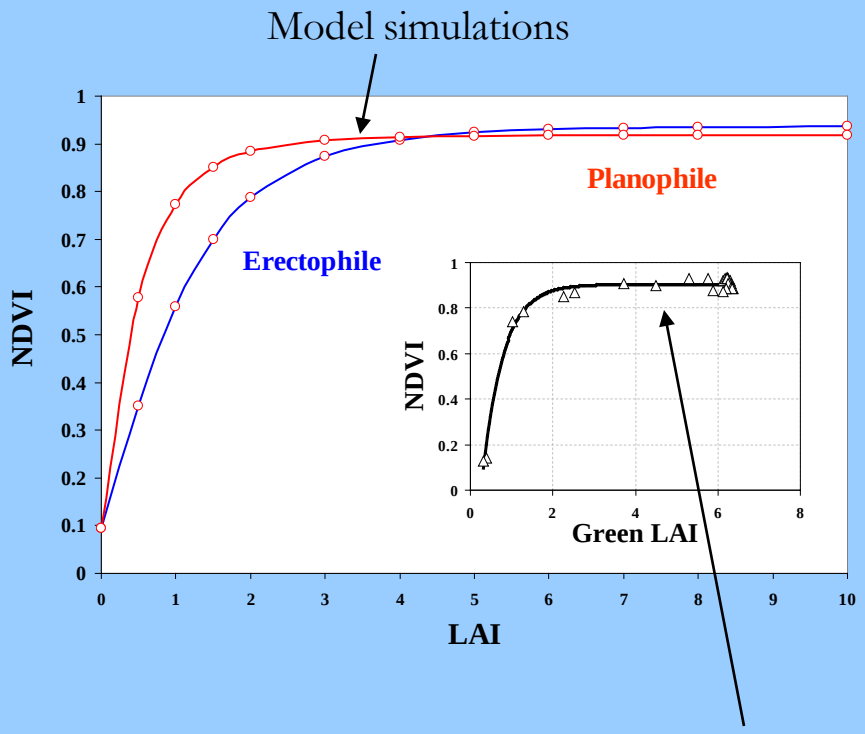
(Gitelson et al., GRL, 2003)

While red reflectance exhibits a nearly flat response once the LAI exceeds 2, the NIR reflectance continues to increase with LAI ranges from 2 to 6.

When the ρ_{NIR}/ρ_{red} exceeds 7-8, NDVI becomes insensitive to change in ρ_{NIR}.



Model simulations (Gobron et al., 1997, JGR, 102:9431-9446). Courtesy of Nadine Gobron.



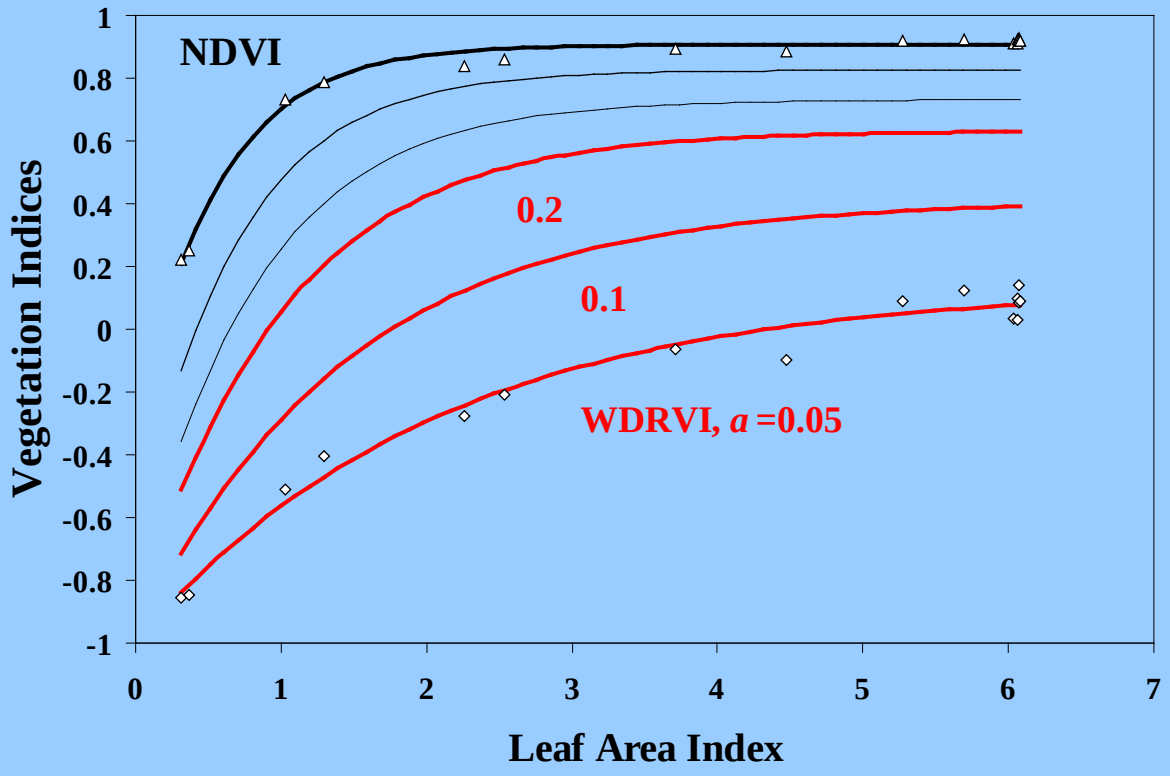
Maize, Nebraska, 2001

To avoid the loss of NDVI sensitivity, the values of both items – ρ_{NIR} and ρ_{red} – *should be comparable*, then let

$$\mathbf{WDRVI = (a*\rho_{NIR} - \rho_{red})/(a*\rho_{NIR} + \rho_{red})}$$

where ***a*** is a weighting coefficient

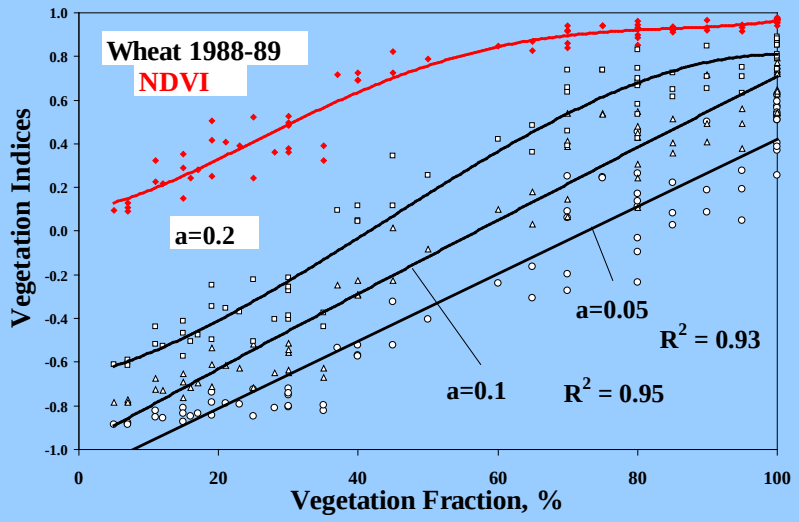
(Gitelson 2004, J. Plant Physiol., 161:165-173)

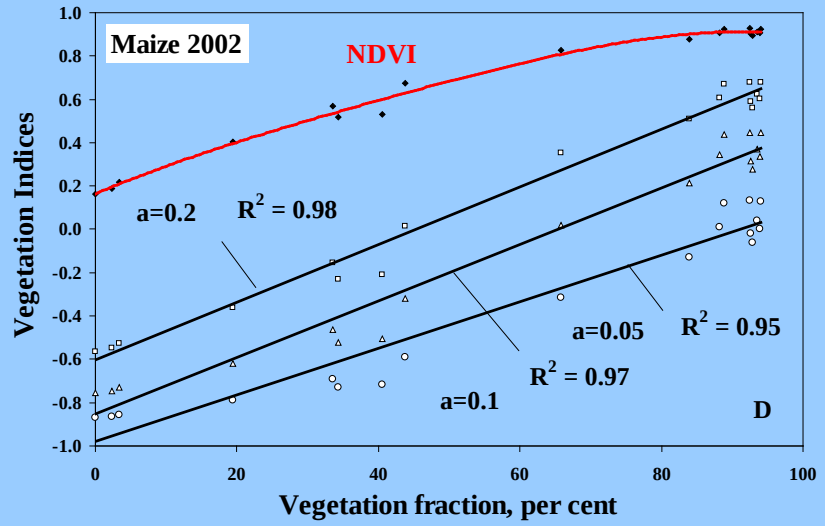


With a decrease in the weighting coefficient ***a***, the relationship WDRVI vs. LAI becomes more linear and more sensitive to an increasing LAI.

The enhancement is especially pronounced (2X-4X) in the range of the LAI ranged from 2 to 6 with *a* between 0.05 and 0.2.

The WDRVI is sensitive and linearly related to the vegetation fraction across the entire range of its variation.

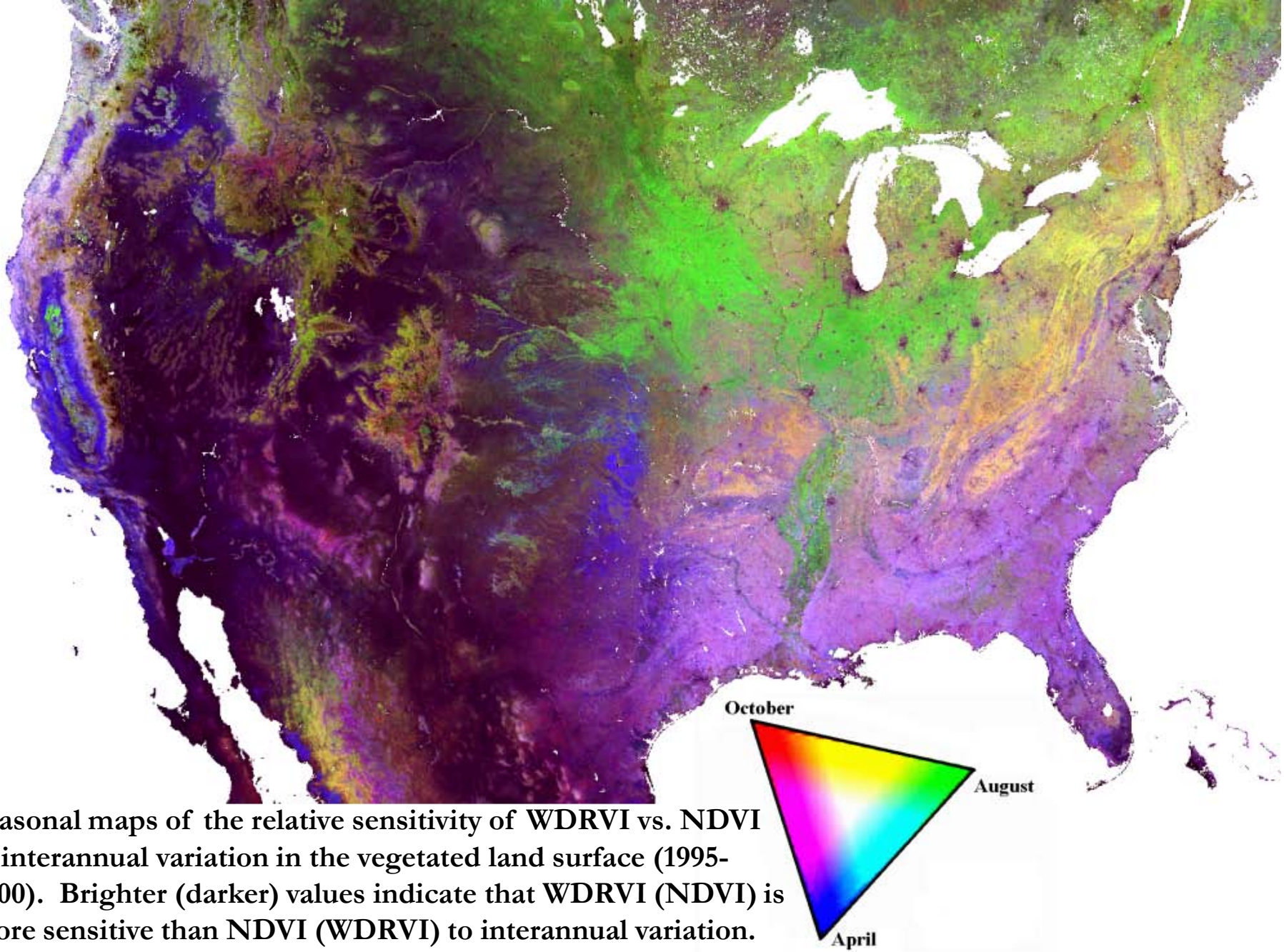




How does this increased sensitivity to moderate-to-high vegetation fraction and density translate into imagery?

Land Surface Phenology: AVHRR WDRVI 2000

R=Jun02-Jun15, G=Jul14-Jul27, B=Mar10-Mar23



Seasonal maps of the relative sensitivity of WDRVI vs. NDVI to interannual variation in the vegetated land surface (1995-2000). Brighter (darker) values indicate that WDRVI (NDVI) is more sensitive than NDVI (WDRVI) to interannual variation.
(Viña, Henebry, Gitelson, *GRL*, 2004)

2. ASSESSING CHANGE AMIDST VARIATION

Land surface phenology is the spatio-temporal development of the vegetated land surface as revealed by synoptic sensors at spatial scales relevant to atmospheric boundary layer dynamics.

Phenological patterns in temperate climates provide ecological motivation for ***baselines*** against which to assess the ***magnitude*** and ***significance*** of observed change amidst seasonal and interannual variation.

Huge land cover change events in the 20th Century were associated with communism:

(1) the collectivization of agriculture in Eurasia, especially following WWII
(2) the Virgin Lands Program, which converted 40 million hectares of steppe to spring wheat during 1954-56
(3) the collapse of the Soviet Union in 1991 and the effects on agricultural production in Eurasia in the 1990s

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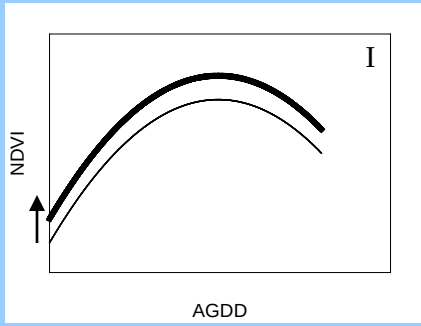
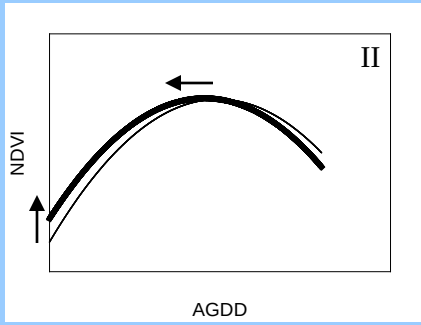
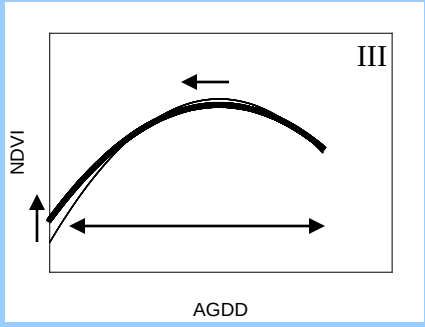
Do land surface phenologies respond to institutional change?

YES! And the type of change is not uniform across Kazakhstan.

Phenology model:
NDVI = α + β*AGDD + γ*AGDD²







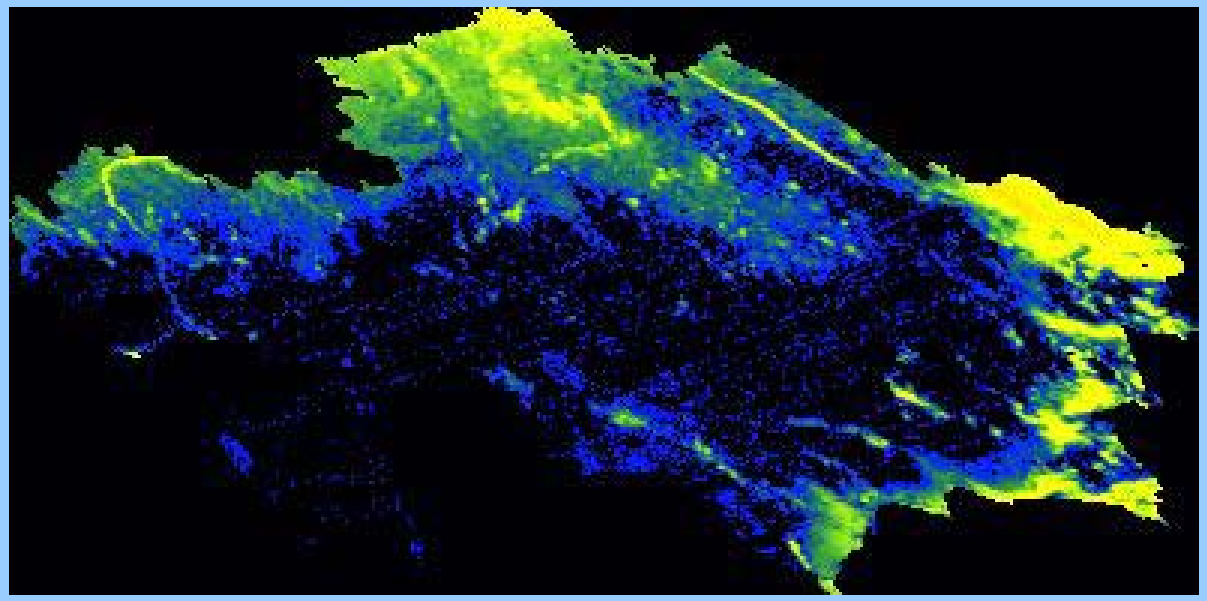
Only 3 of 15 possible change behaviors observed in PAL data:

I. **Higher NDVI at low AGDD**
II. **Higher NDVI at low AGDD, earlier peak**
III. **Higher NDVI at low AGDD, earlier peak, longer observed season**

Consistent results whether functional[1] or ecoregional[2] partitioning.
Comparing NOAA-9 and NOAA-14 AVHRR observations only[2].

[1] de Beurs and Henebry, 2004, *RSE*. [2] de Beurs and Henebry, in review, *IJRS*.

Distribution of reduced NDVI sensitivity across Kazakhstan shows the applicability of the WDRVI in the semi-arid northern steppes and in the riparian and mountainous forested regions.



Pathfinder AVHRR Land (PAL) data, April-October, 1982-1999

Red = sum of dekads exceeding NDVI threshold of 0.5
Green = standard deviation of number dekads exceeding threshold
Blue = skewness of number of dekads exceeding threshold

QUESTIONS?

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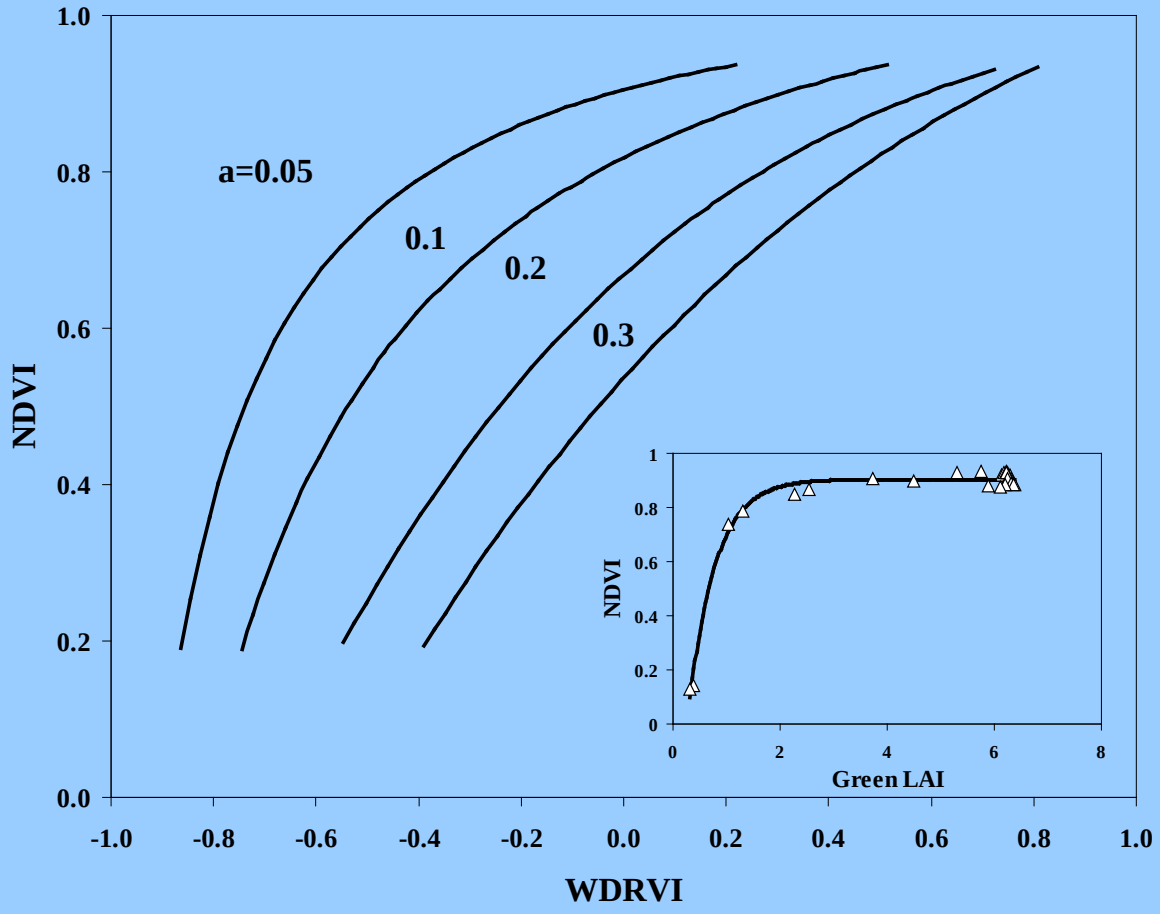
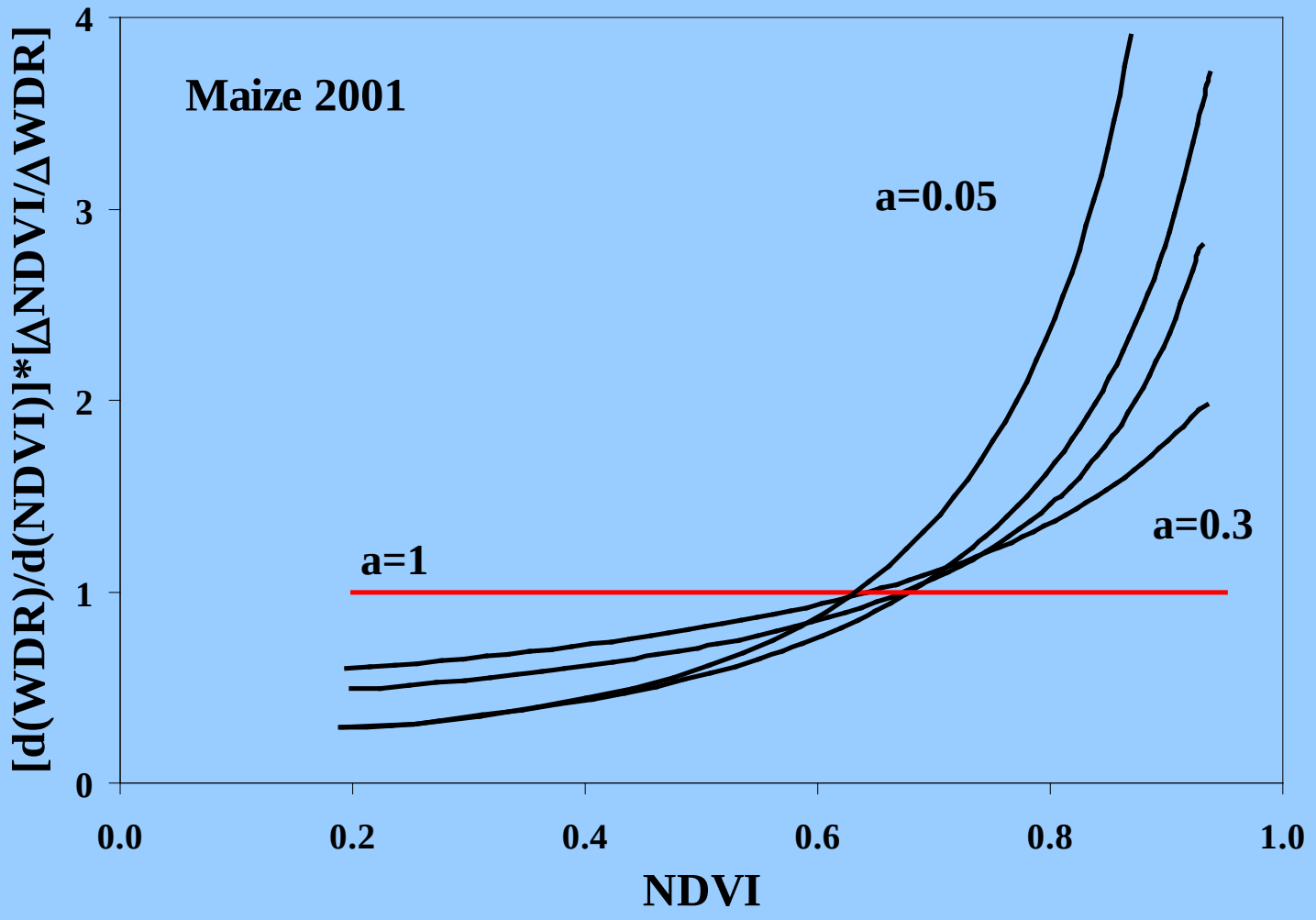
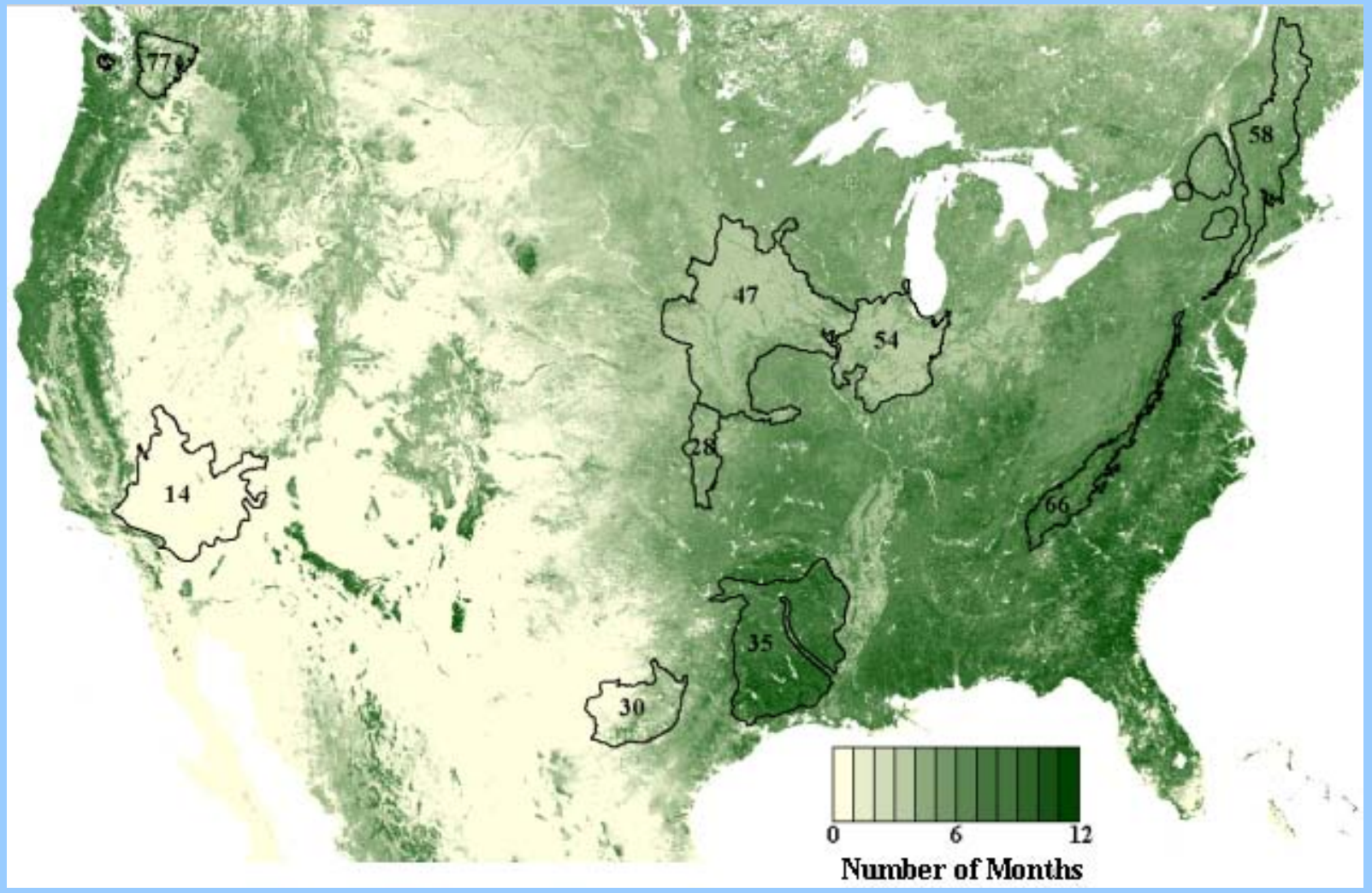
Center for Advanced Land Management Information Technologies
CALMIT
University of Nebraska

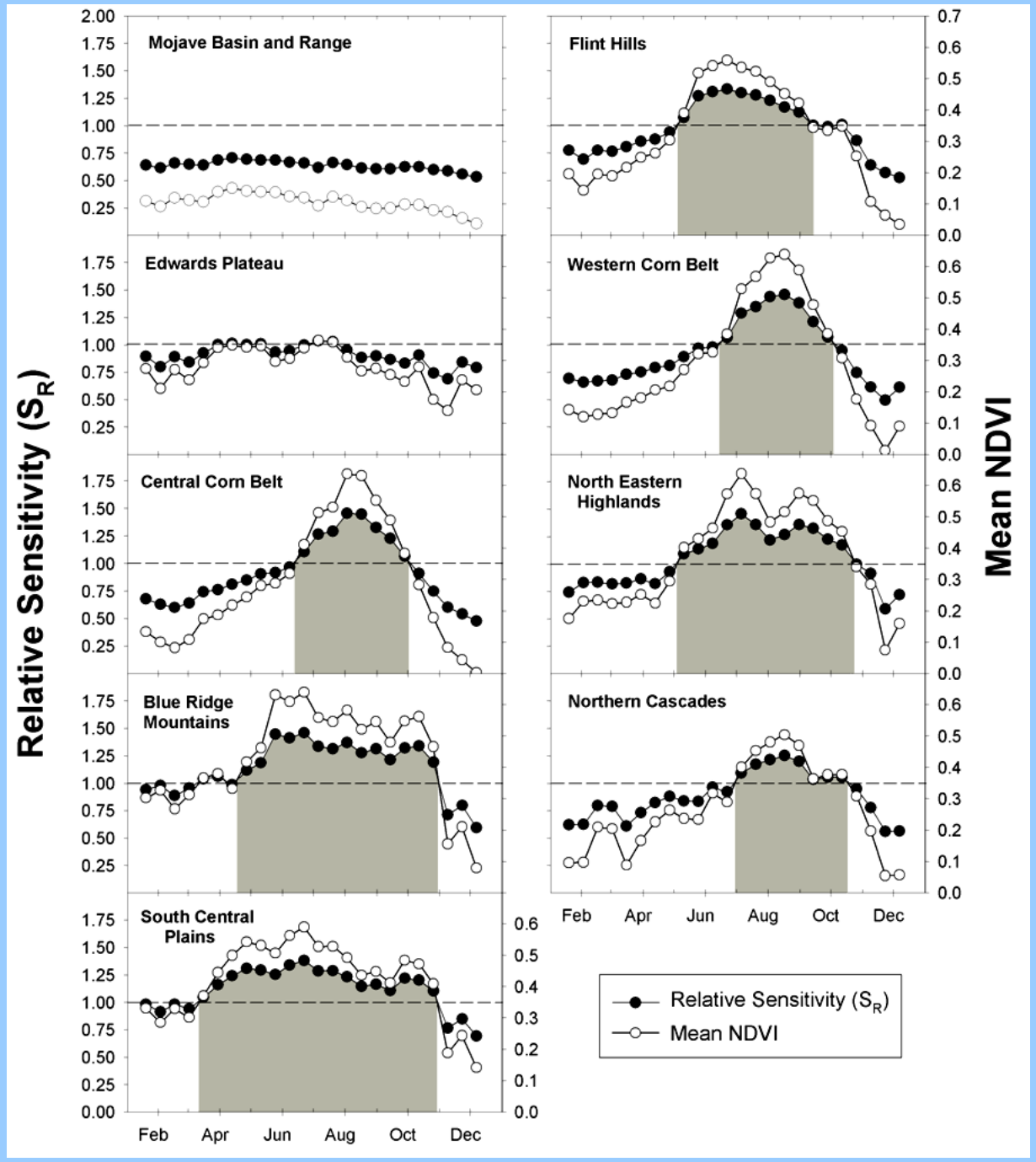
NDVI vs. WDRVI



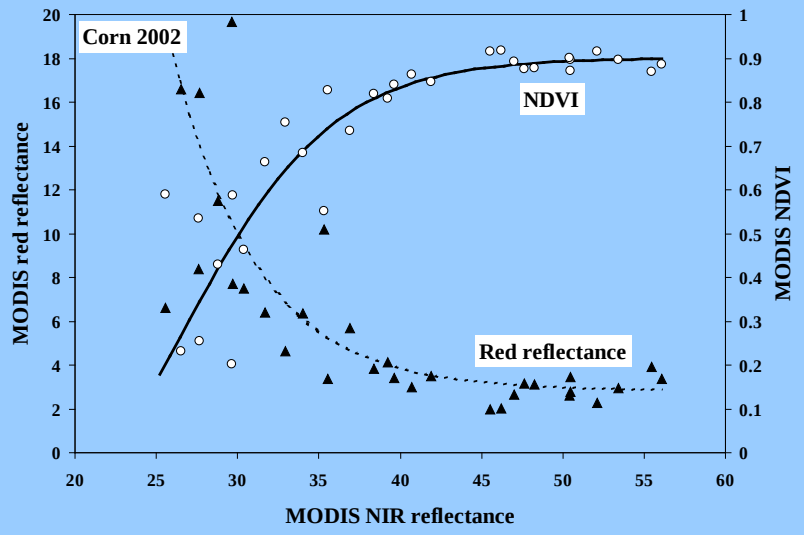
The relative sensitivity of WDRVI vs. NDVI

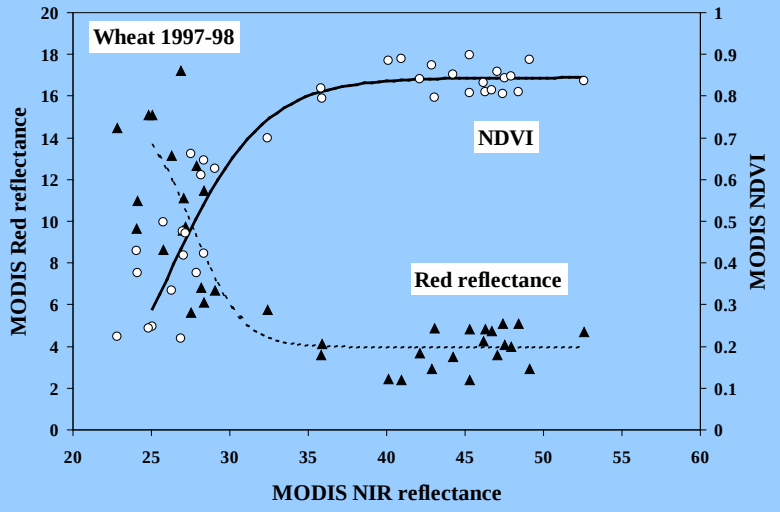


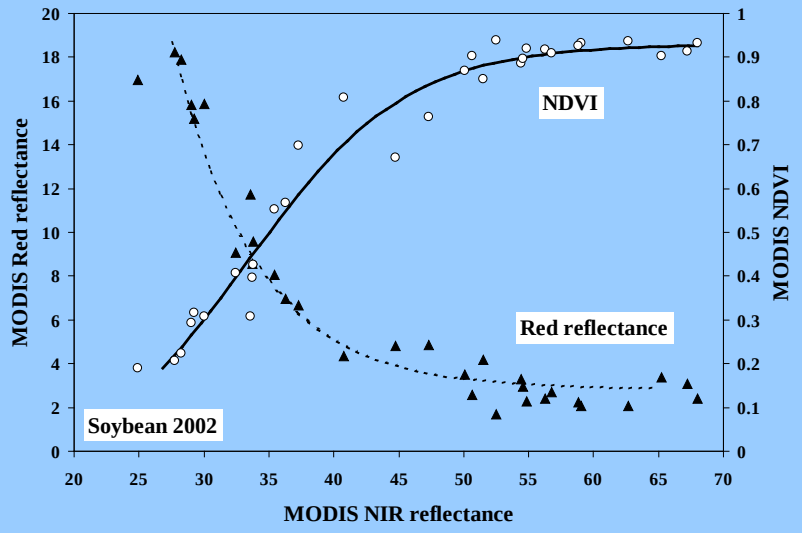

77
58
47
54
28
14
66
35
30
0
6
12
Number of Months


Mojave Basin and Range
Flint Hills
Edwards Plateau
Western Corn Belt
Central Corn Belt
North Eastern Highlands
Blue Ridge Mountains
Northern Cascades
South Central Plains
Relative Sensitivity (S_R)
Mean NDVI
Feb
Apr
Jun
Aug
Oct
Dec
Relative Sensitivity (S_R)
Mean NDVI

However, this sensitivity of the NIR reflectance has little effect on NDVI values once the ρ_{NIR}/ρ_{red} > 7-8 (or ρ_{NIR} exceeds 30%).



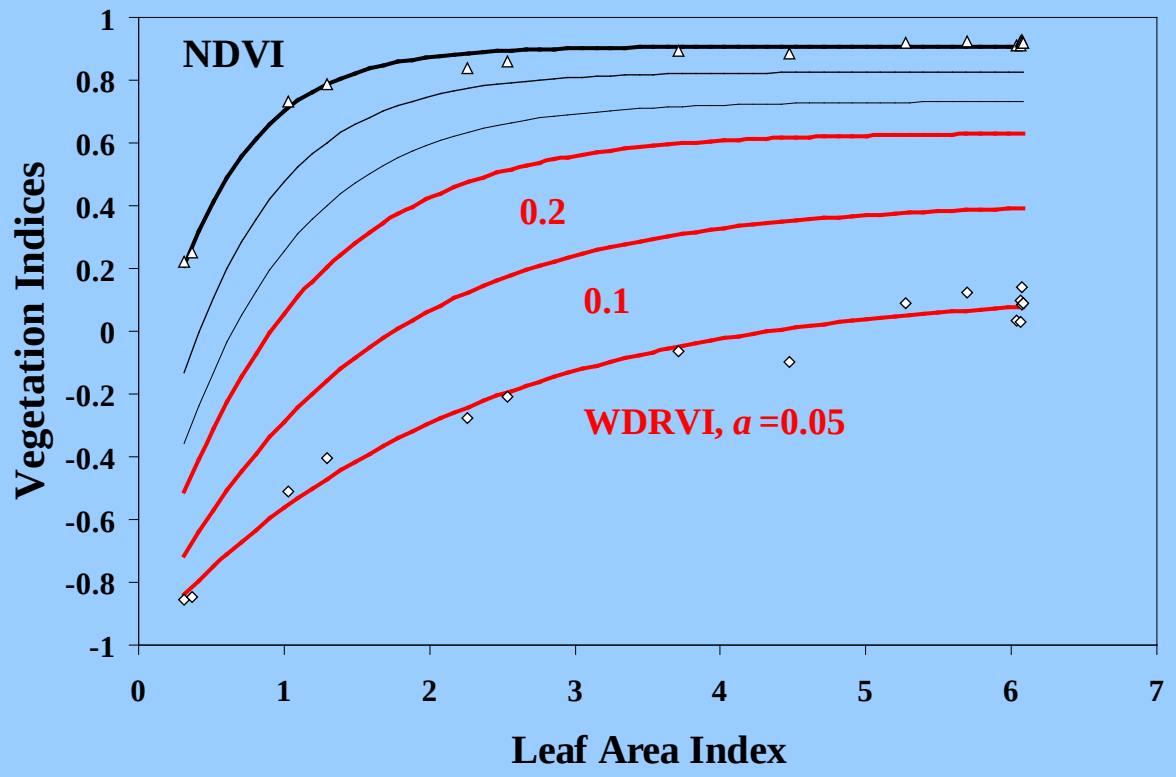




An increase in the ρ_{NIR} from 30% to 55-65% produced virtually no change in the NDVI.

(Gitelson JPP, 2004, 161:165-173)

The sensitivity of the WDRVI to the LAI increased at least three-fold compared to that of the NDVI



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