# The Nature of the Pulse:

*Hydrologic triggers of phenological activity in creosotebush-dominated ecosystems*

**Dr. Shirley (Kurc) Papuga**
**School of Natural Resources and Environment**
**October 3rd, 2009**
**RISE Symposium**

# Acknowledgements:


- The University of Arizona College of Agriculture and Life Sciences (CALS)

- The Arizona University System Technology and Research Initiative Fund (TRIF)

- The University of Arizona Office of the Vice President for Research (VPR)

- The United States Department of Agriculture Cooperative State Research, Education, and Extension Service (CSREES)

- The University of Arizona Institute for the Study of Planet Earth (ISPE) Faculty Exploratory Grant

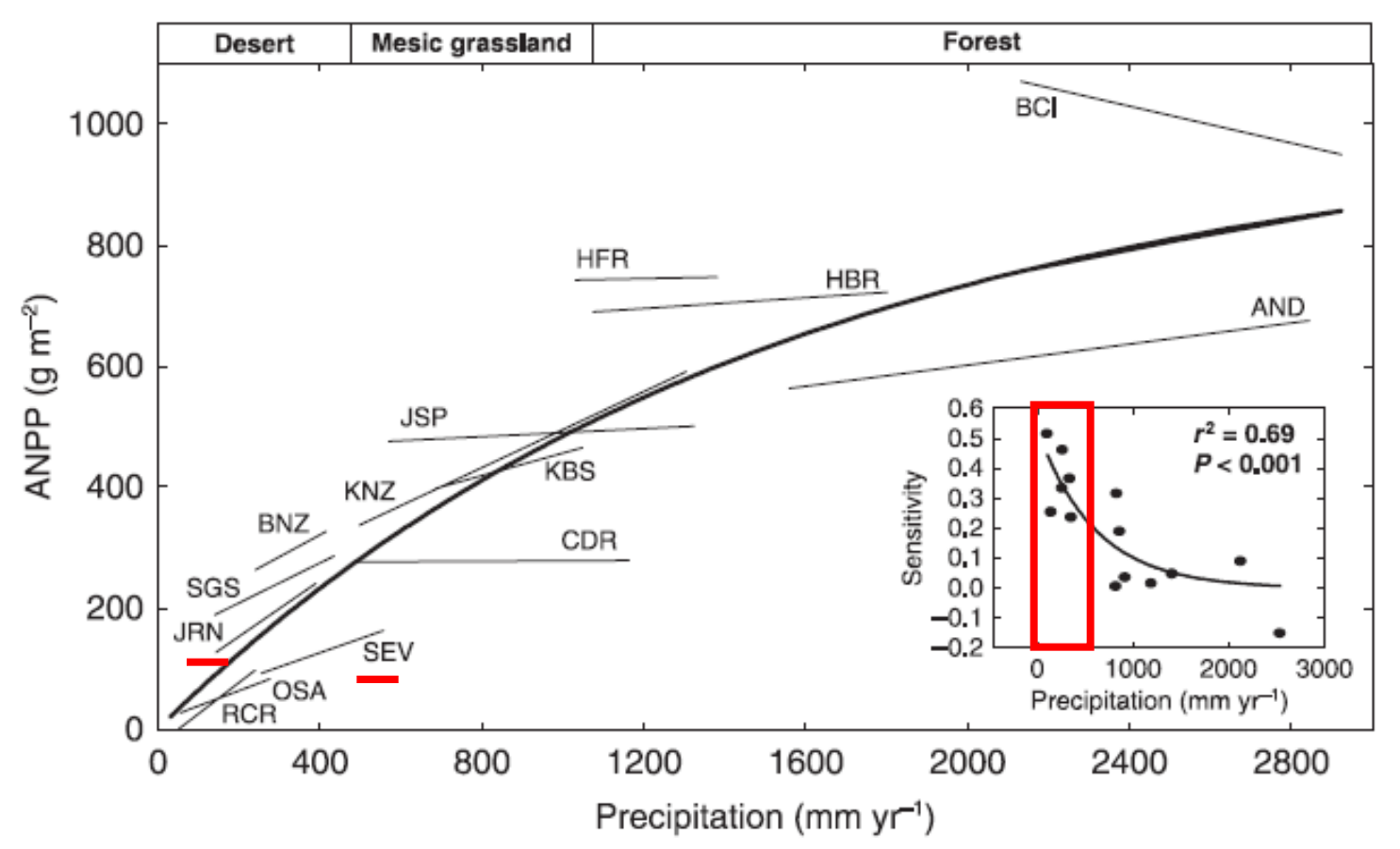

Michelle Cavanaugh

Lisa Benton

Andrew Neal

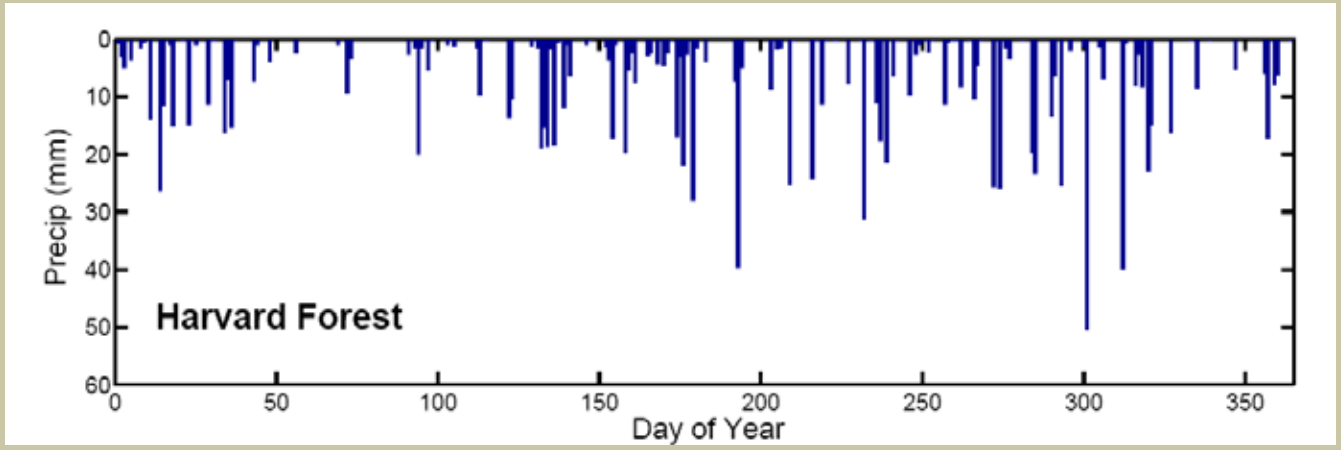
Krystine Nelson

**Compared to other areas which receiver greater annual precipitation, <u>drylands are highly sensitive to precipitation inputs</u>.**




*Fay, P.A., 2009 in New Phytologist and Huxman et al. 2004 in Nature.*

**Dryland ecosystems depend on *pulses* of moisture…"infrequent, discrete, and largely unpredictable precipitation events".**
***(Huxman et al. 2004, Nature)***



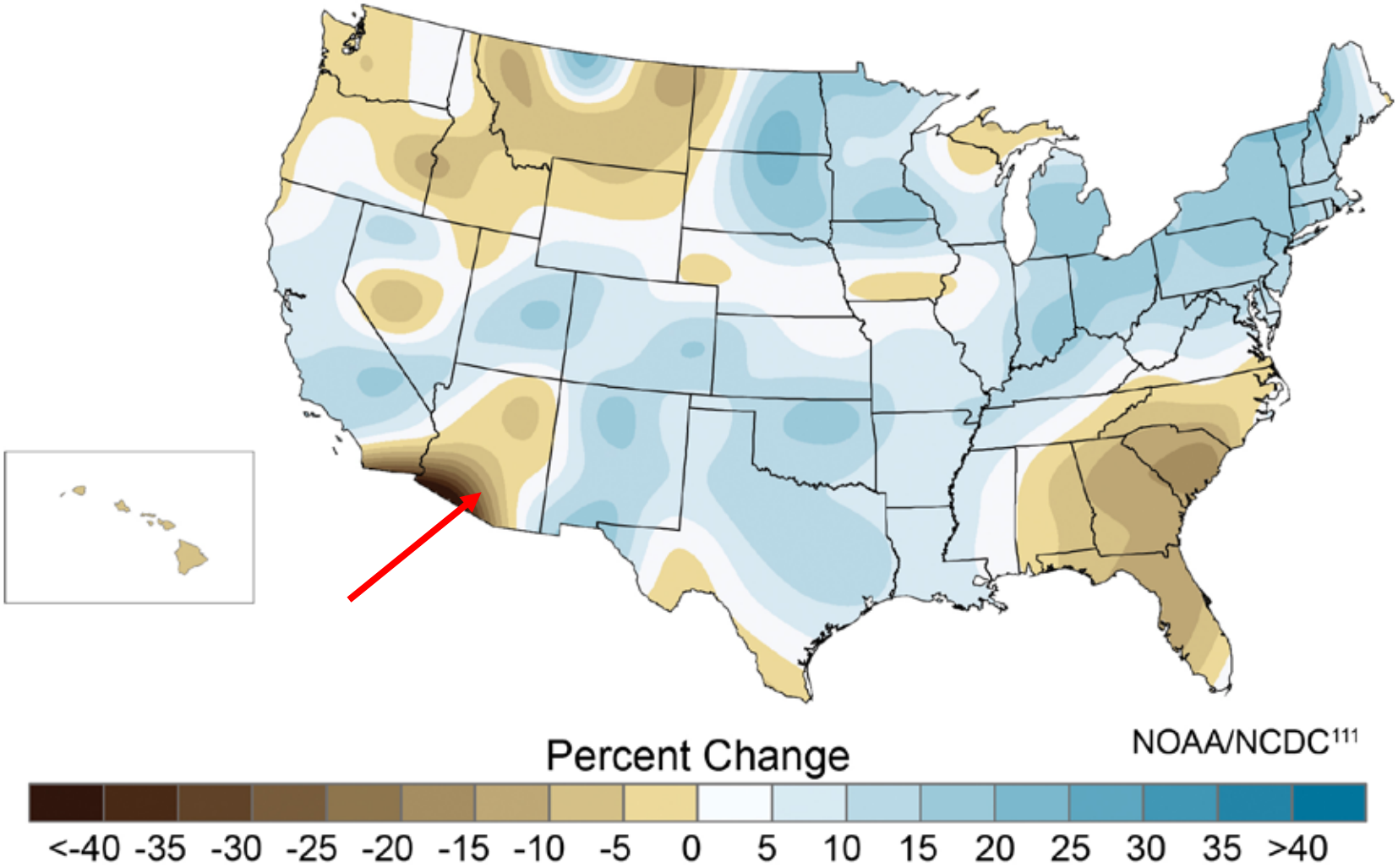
**Energy Limited**

**Water Limited**

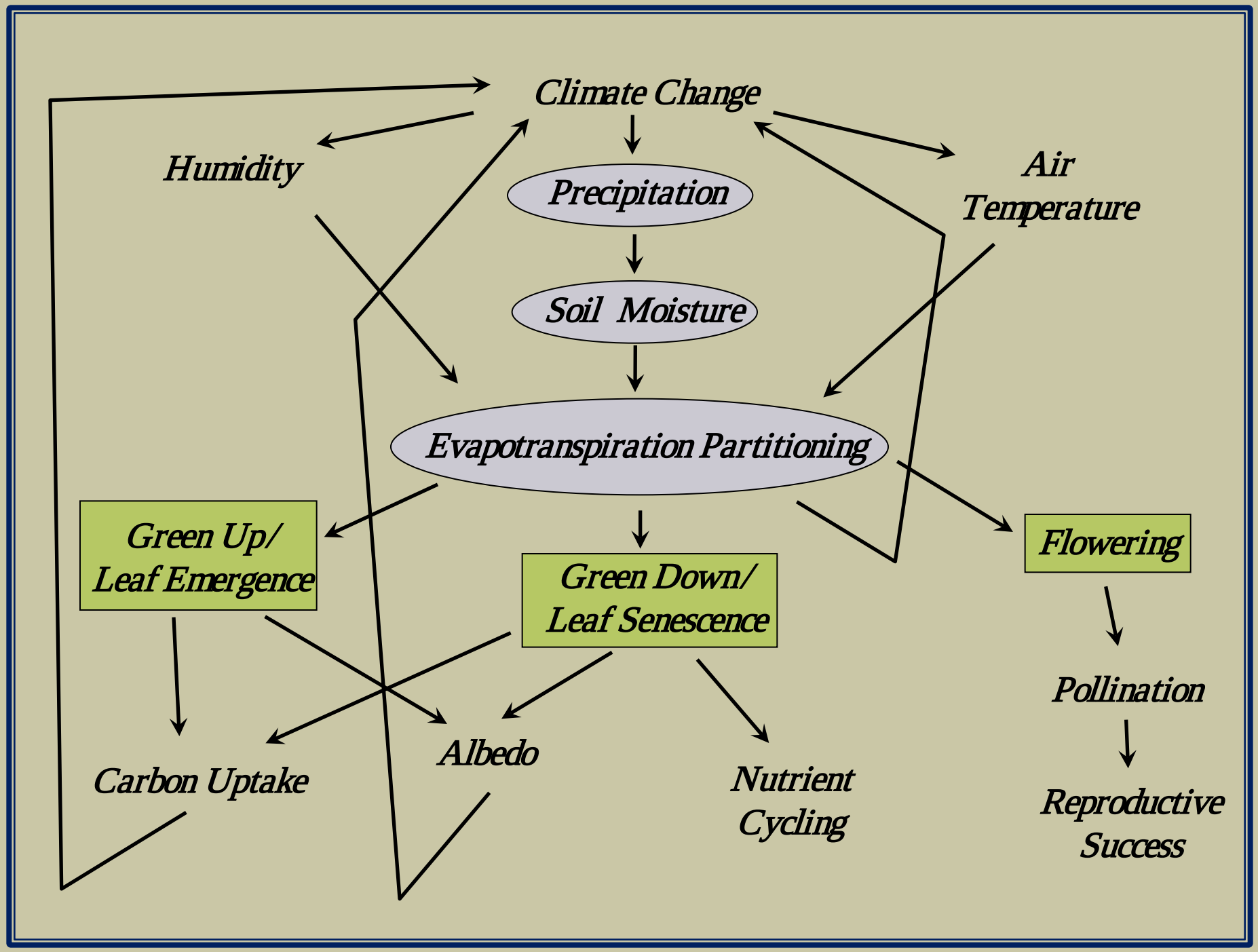
May 14 | May 22 | ©Gary Fewless | May 27 | June 3

Sep 30 | Oct 8 | Oct 15 | Oct 22

Leaf fall for green ash, UW-Green Bay, ©Gary Fewlss



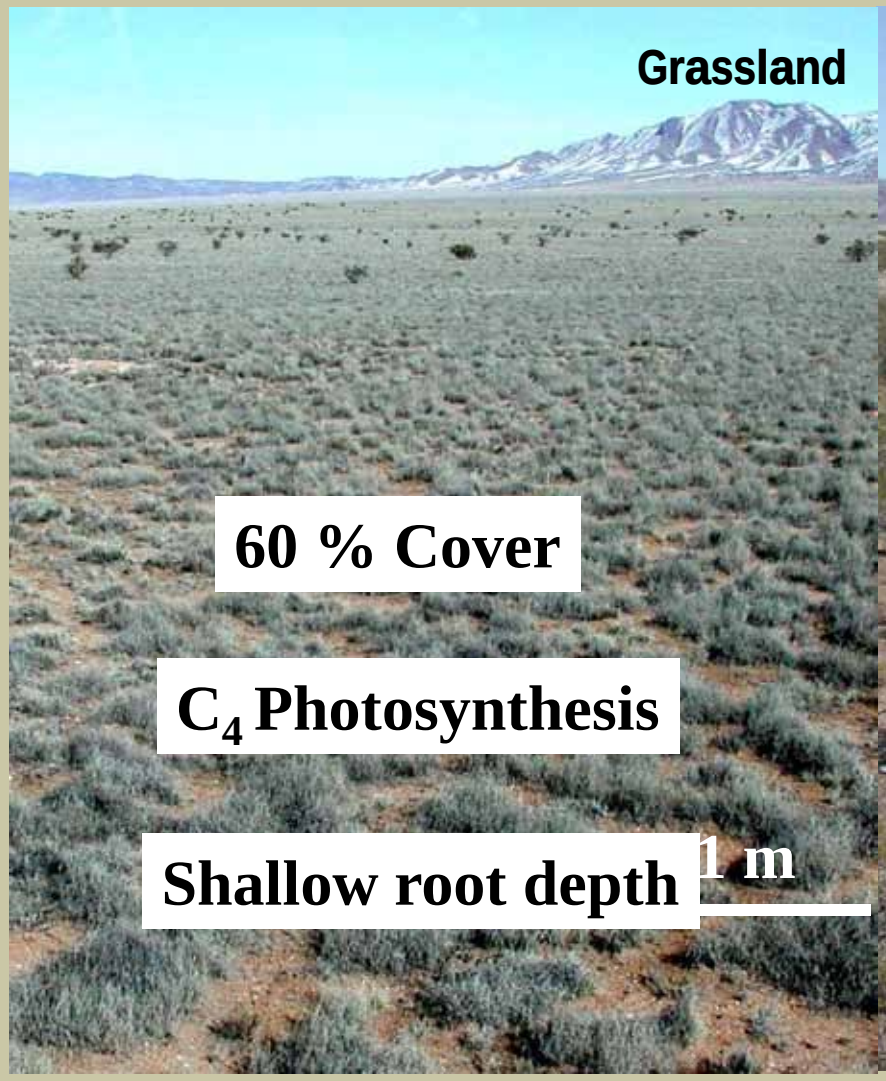

While U.S. annual average precipitation has increased about 5 percent over the past 50 years, there have been important regional differences as shown above.

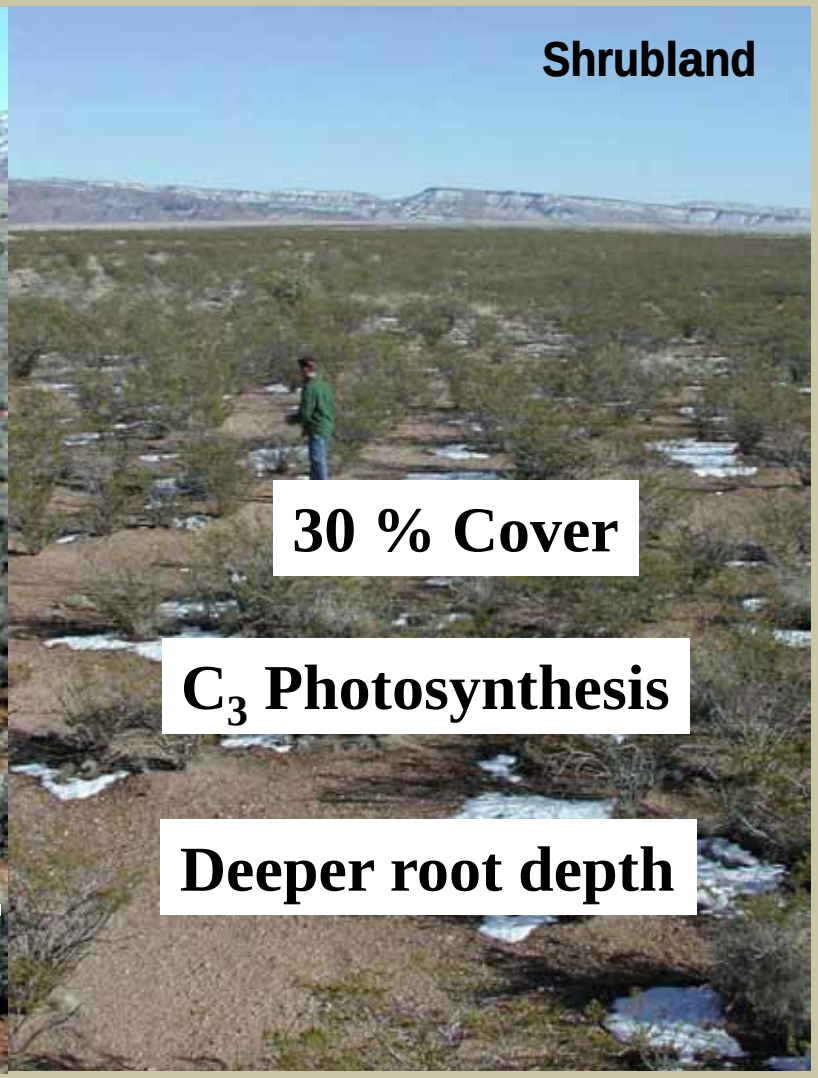

Climate Change
Humidity
Air Temperature
Precipitation
Soil Moisture
Evapotranspiration Partitioning
Green Up/ Leaf Emergence
Green Down/ Leaf Senescence
Flowering
Pollination
Reproductive Success
Carbon Uptake
Albedo
Nutrient Cycling

## Objective:

To understand the hydrologic triggers of [phenological] activity in dryland ecosystems so that we can better anticipate their sensitivity to projected changes in precipitation.

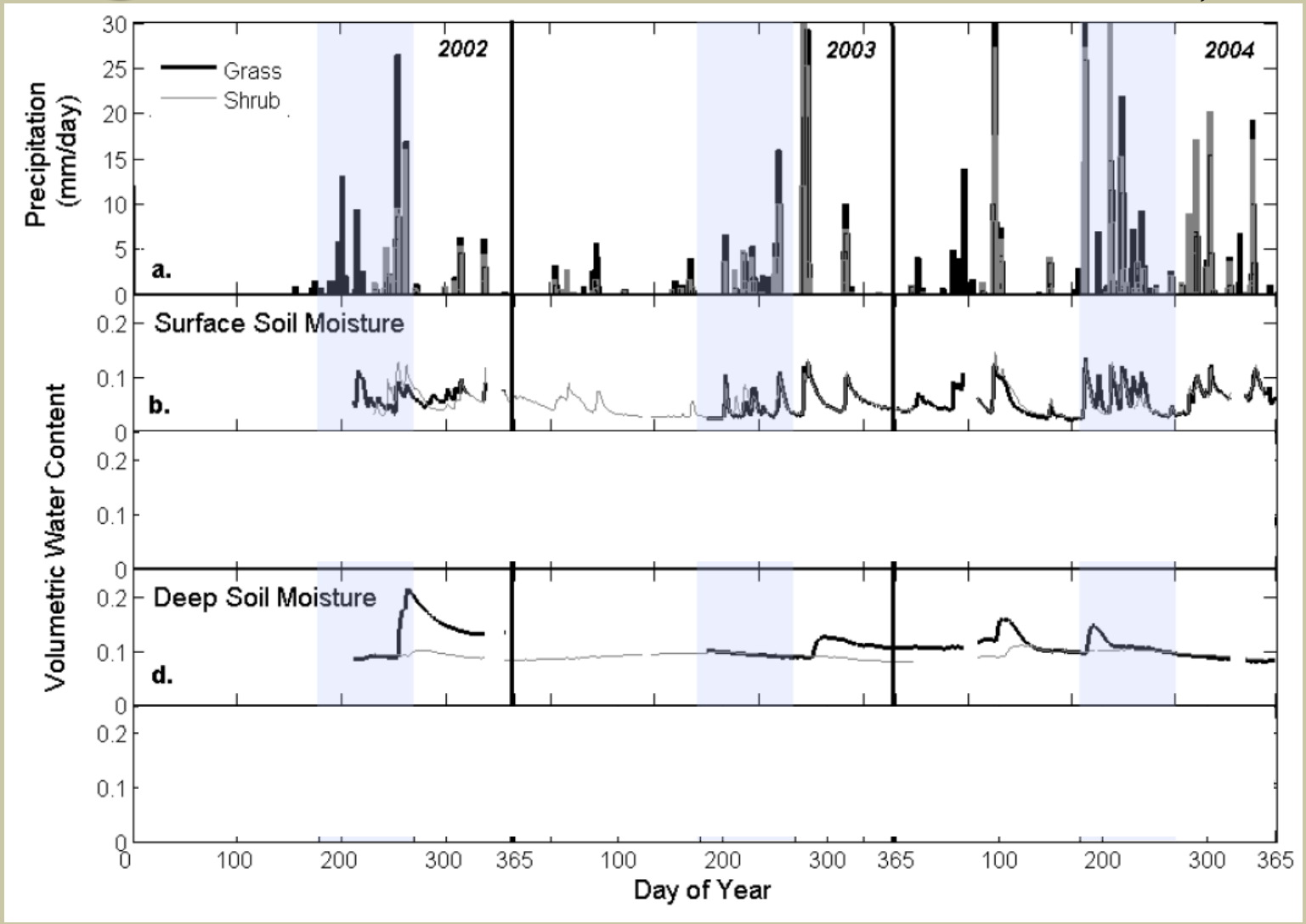
# Background.


Grassland
60 % Cover
$C_4$ Photosynthesis
Shallow root depth
1 m


Shrubland
30 % Cover
$C_3$ Photosynthesis
Deeper root depth

# Background.

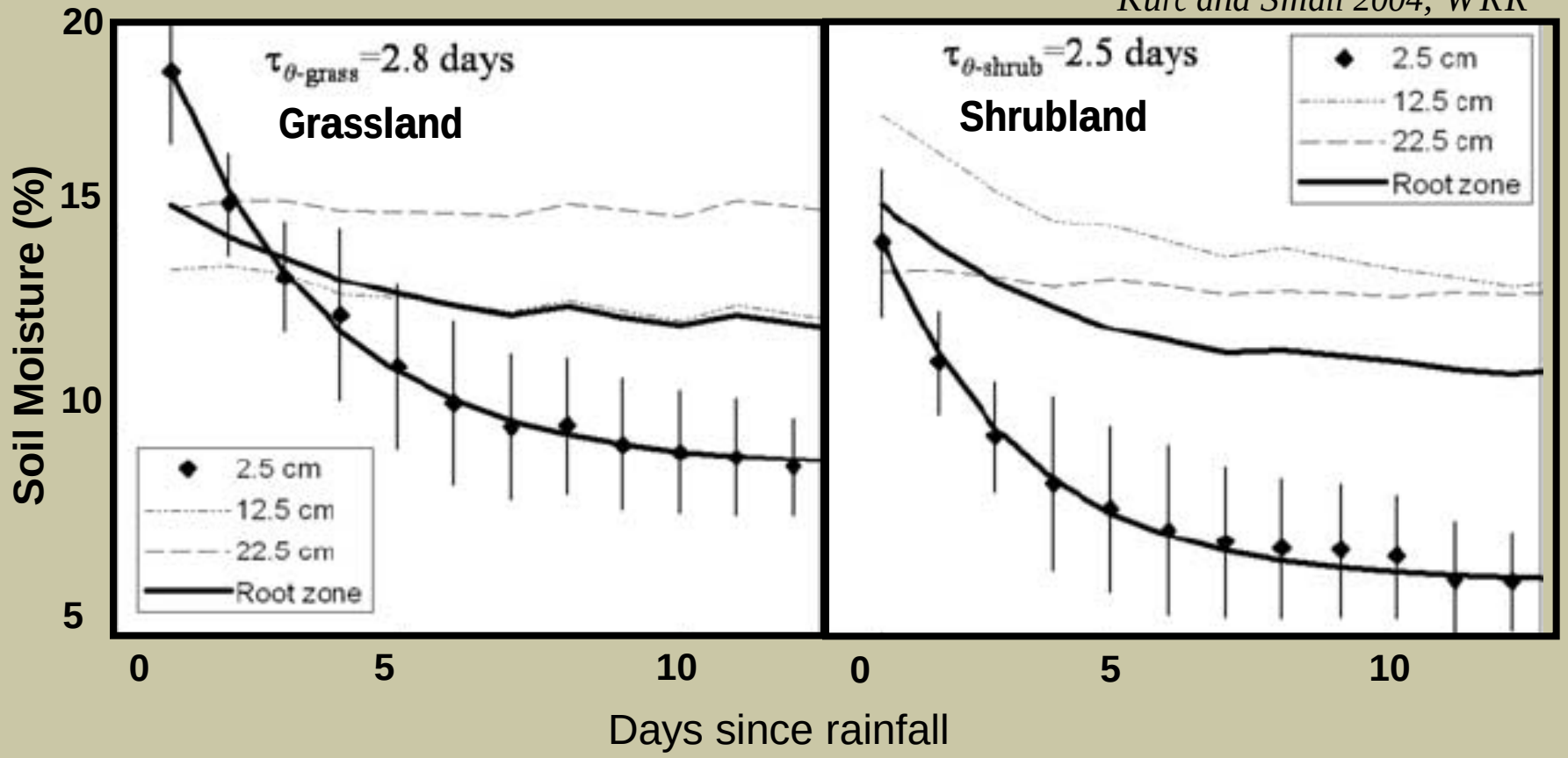
*Kurc and Small 2007, WRR*




- Surface moisture responds to all precipitation events
- Deep moisture responds to large events or series of events

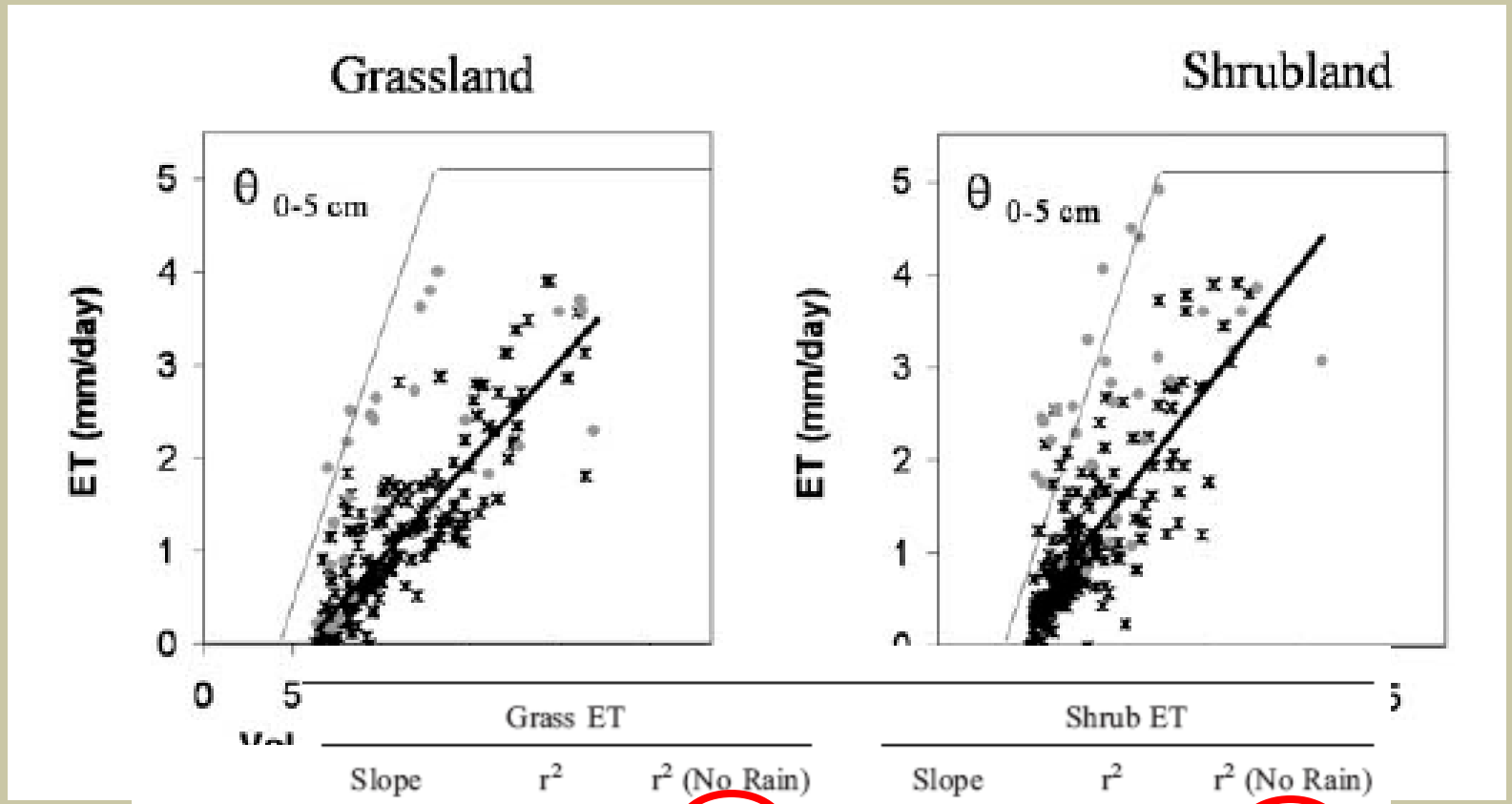
# Background.

*Kurc and Small 2004, WRR*




- Surface moisture remains available for only ~ 2 to 3 days.

# Background.

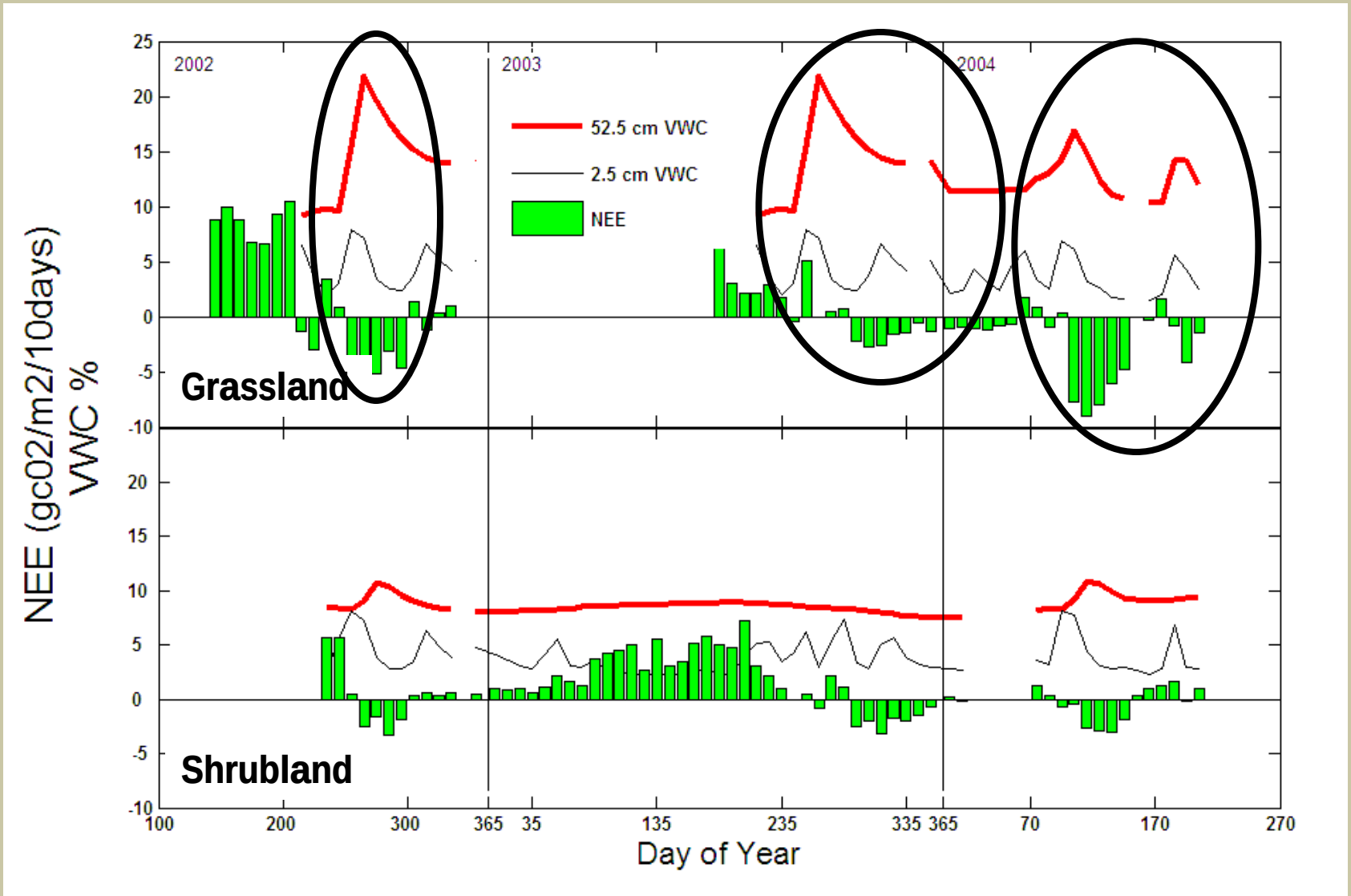



| | Grass ET | | | Shrub ET | | |
|---|---|---|---|---|---|---|
| | Slope | $r^2$ | $r^2$ (No Rain) | Slope | $r^2$ | $r^2$ (No Rain) |
| 2.5 cm | 20.4 ± 2.1 | 0.63 | 0.74 | 24.8 ± 3.2 | 0.53 | 0.64 |
| 12.5 cm | 12.6 ± 2.7 | 0.28 | 0.39 | 13.8 ± 3.3 | 0.25 | 0.41 |
| 22.5 cm | 11.9 ± 3.3 | 0.18 | 0.13 | 11.9 ± 4.8 | 0.10 | 0.20 |
| Root Zone | 18.2 ± 3.0 | 0.39 | 0.56 | 14.1 ± 3.4 | 0.24 | 0.36 |

- Surface moisture is the primary source of water for ET

# Background.

*Kurc and Small 2007, WRR*

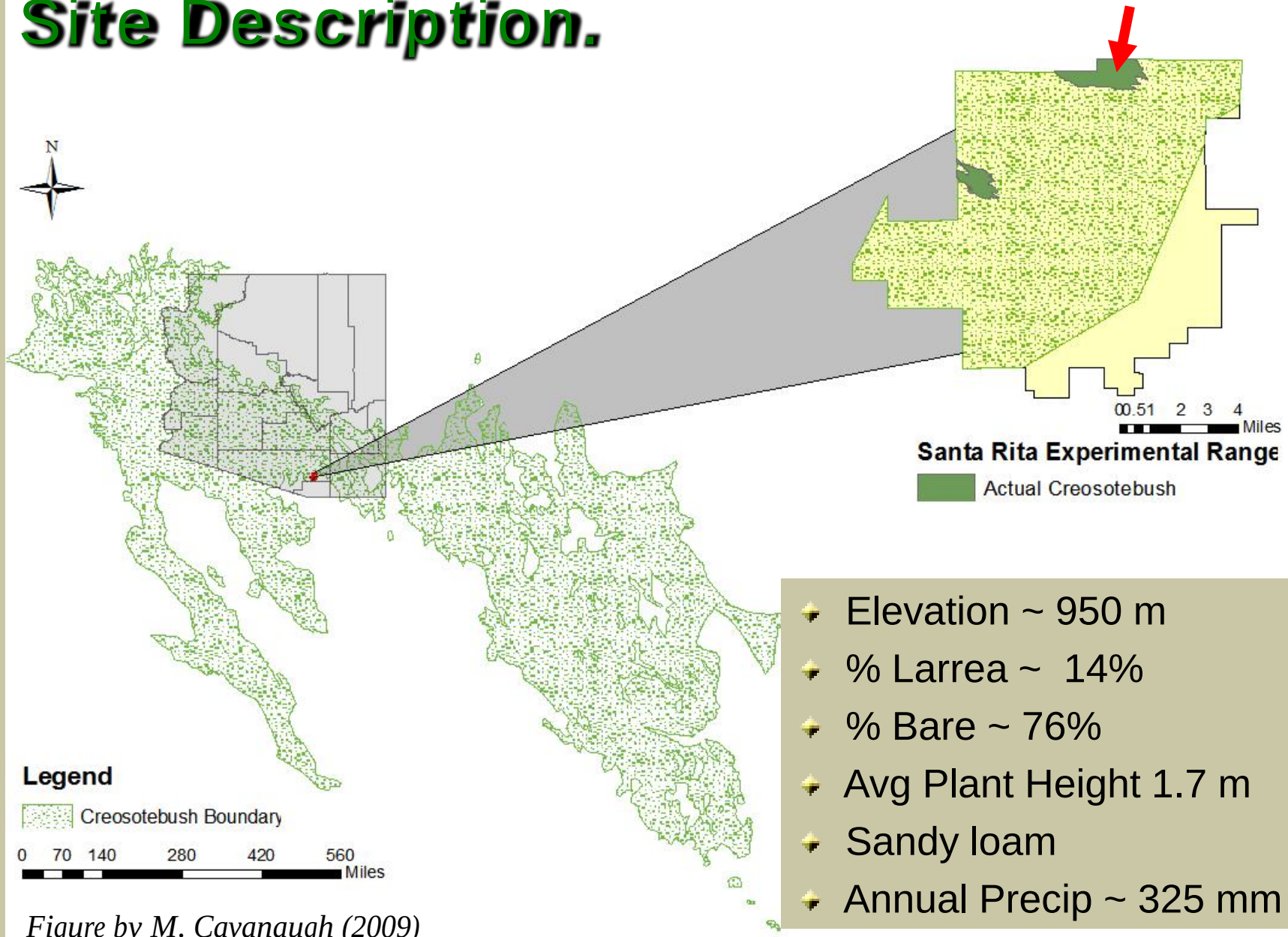



- Net carbon uptake is linked with pulses of deep soil moisture.

# New Questions.

- Does deep soil moisture control transpiration?
- Does deep soil moisture control green-up?
- Can we relate green-up to carbon uptake?
- Does deep soil moisture control flowering?

# Site Description.




- Elevation ~ 950 m
- % Larrea ~ 14%
- % Bare ~ 76%
- Avg Plant Height 1.7 m
- Sandy loam
- Annual Precip ~ 325 mm

*Figure by M. Cavanaugh (2009)*

# Instrumentation: Flux Tower

- **Open Path $CO_2$/$H_2O$**
  *Li-Cor 7500*
- **Sonic Anemometer**
  *CSAT*
- **4 – Component Net Radiation**
  *Kipp & Zonen CNR1*
- **Ground Heat Flux**
  *Hukseflux HFP01SC*

# Instrumentation: Micrometeorology

- **Wind Speed/Direction**
  *RM Young 05103*
- **Air Temperature/Humidity**
  *Vaisala HMP45C*
- **Precipitation**
  *TE525 Tipping Bucket*
- **Soil Temperature** (5 cm)
  *TCAV*
- **Infrared Radiometer**
  *Apogee IRR*

# Instrumentation: Soil Moisture

- **Volumetric Water Content**

  *CS616 x 42 probes*

- **7 Depths (Matches SEV Depths)**
  - *2.5 cm*
  - *12.5 cm*
  - *22.5 cm*
  - *37.5 cm*
  - *52.5 cm*
  - *67.5 cm*
  - *82.5 cm*

- **3 Bare Profiles/3 Canopy Profiles**

# Instrumentation: Sap Flow Sensors

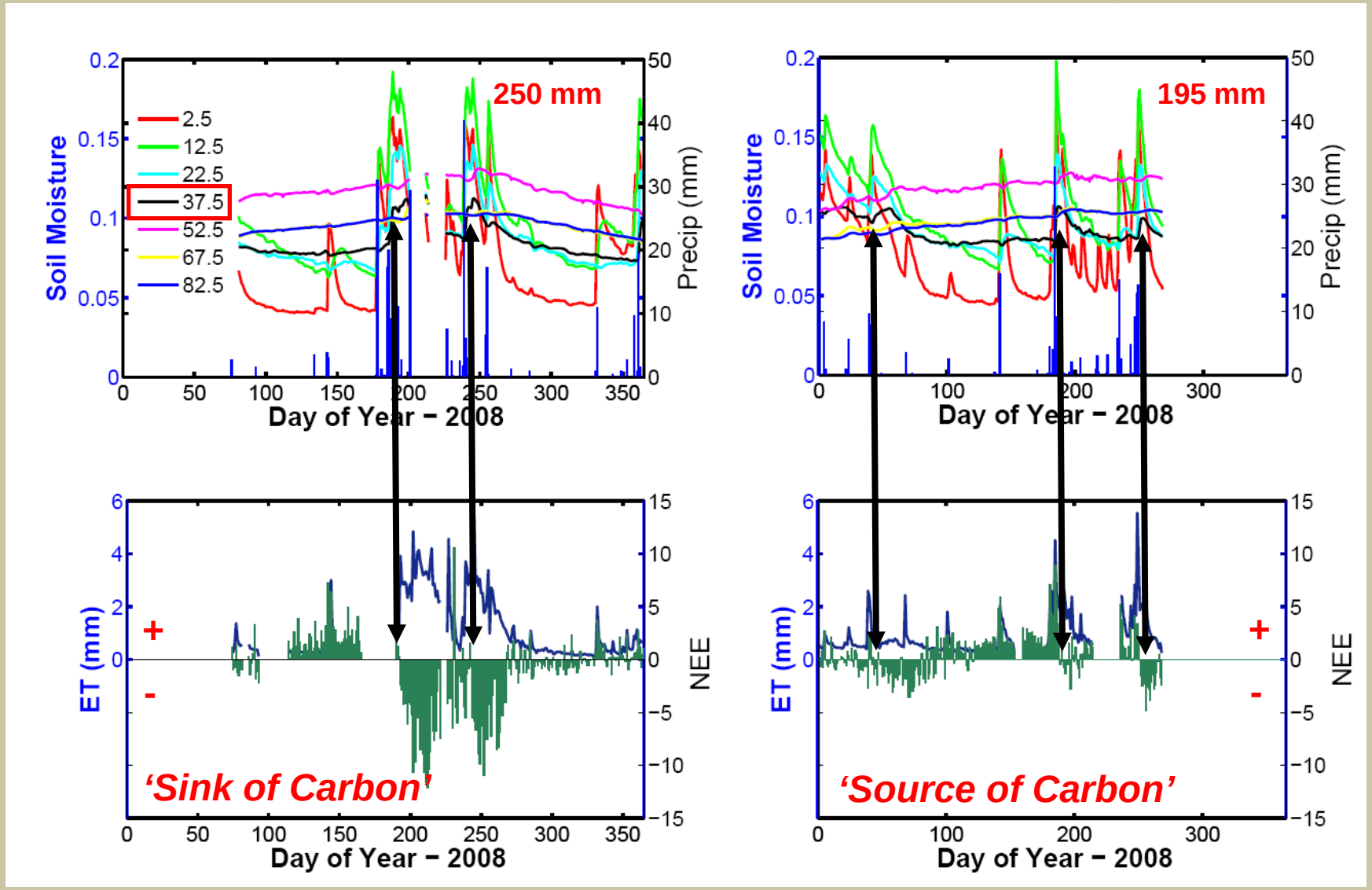
- **Heat Balance Sap Flow Sensors**
  *16 sensors per site*
  *SRER Creosote*
- **Scaled to Ecosystem Level**
- **Installed Spring 2008**
- **Ran for Summer 2008**

# Instrumentation: Pheno-Cams

- **Time-Lapse Digital Photography**
  *Moultrie Game Camera x 3*
- **10 MegaPixel Images**
- **Daily images (at 12:00 pm)**
- **Facing North**
- **Parallel to Ground Surface**
  *Maximizes veg 'sampled'*
  *Integration of many plants*

Provides a continuous record that we can directly relate to our flux or micro-meteorological data!!

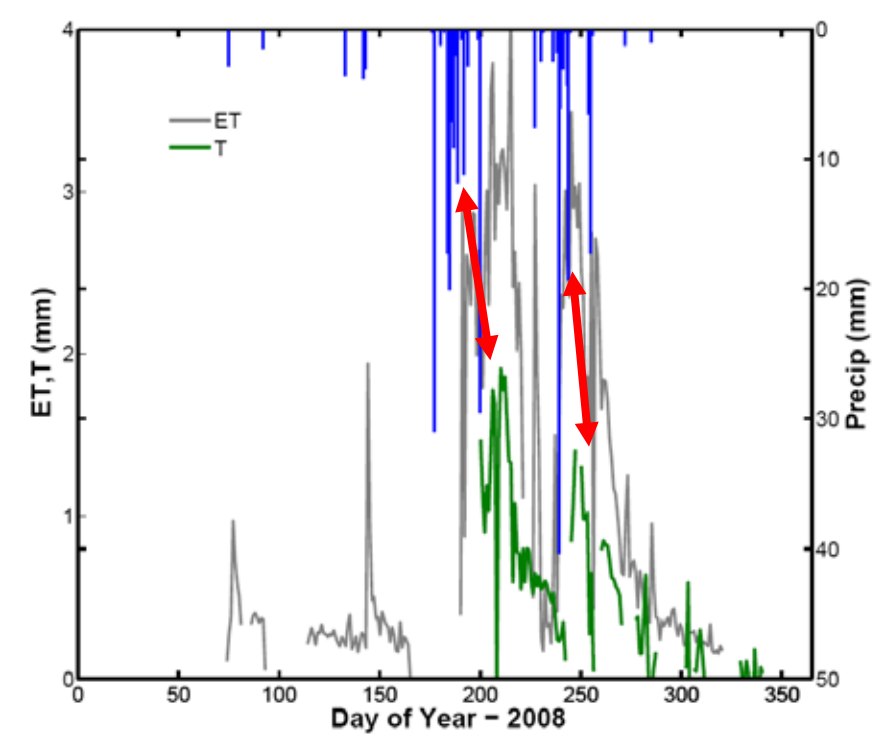
# Results: Interannual Variability




Yet, deep moisture linked with carbon dynamics in both years.

# Results: Transpiration

*Cavanaugh, Kurc and Scott, in review*




$E = ET - T$

**Creosotebush Dominated Shrubland**

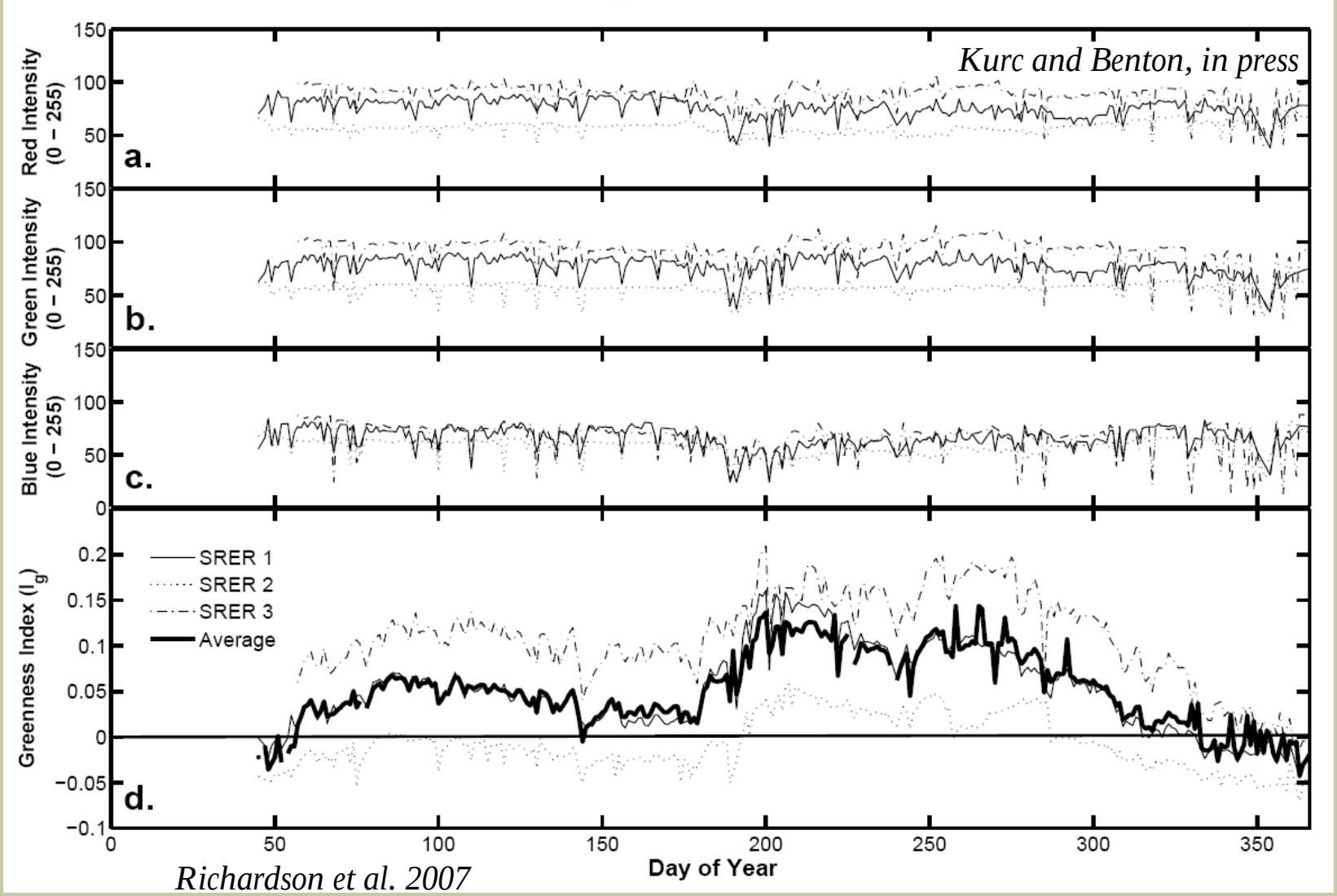
| *Depth (cm)* | *ET* | *T* | *E* |
|---|---|---|---|
| 2.5 | 0.69 | 0.15 | **0.57** |
| 12.5 | 0.67 | 0.17 | 0.51 |
| 22.5 | 0.72 | 0.30 | 0.56 |
| 37.5 | **0.78** | **0.65** | 0.46 |
| 52.5 | 0.44 | 0.40 | 0.12 |
| 67.5 | 0.44 | 0.56 | 0.11 |
| 82.5 | 0.36 | 0.20 | 0.10 |

Transpiration ‘pulses’ linked with deep soil moisture ‘pulses’.

# Example Pheno-Cam 'Video'

Digital archive of valuable phenological information.

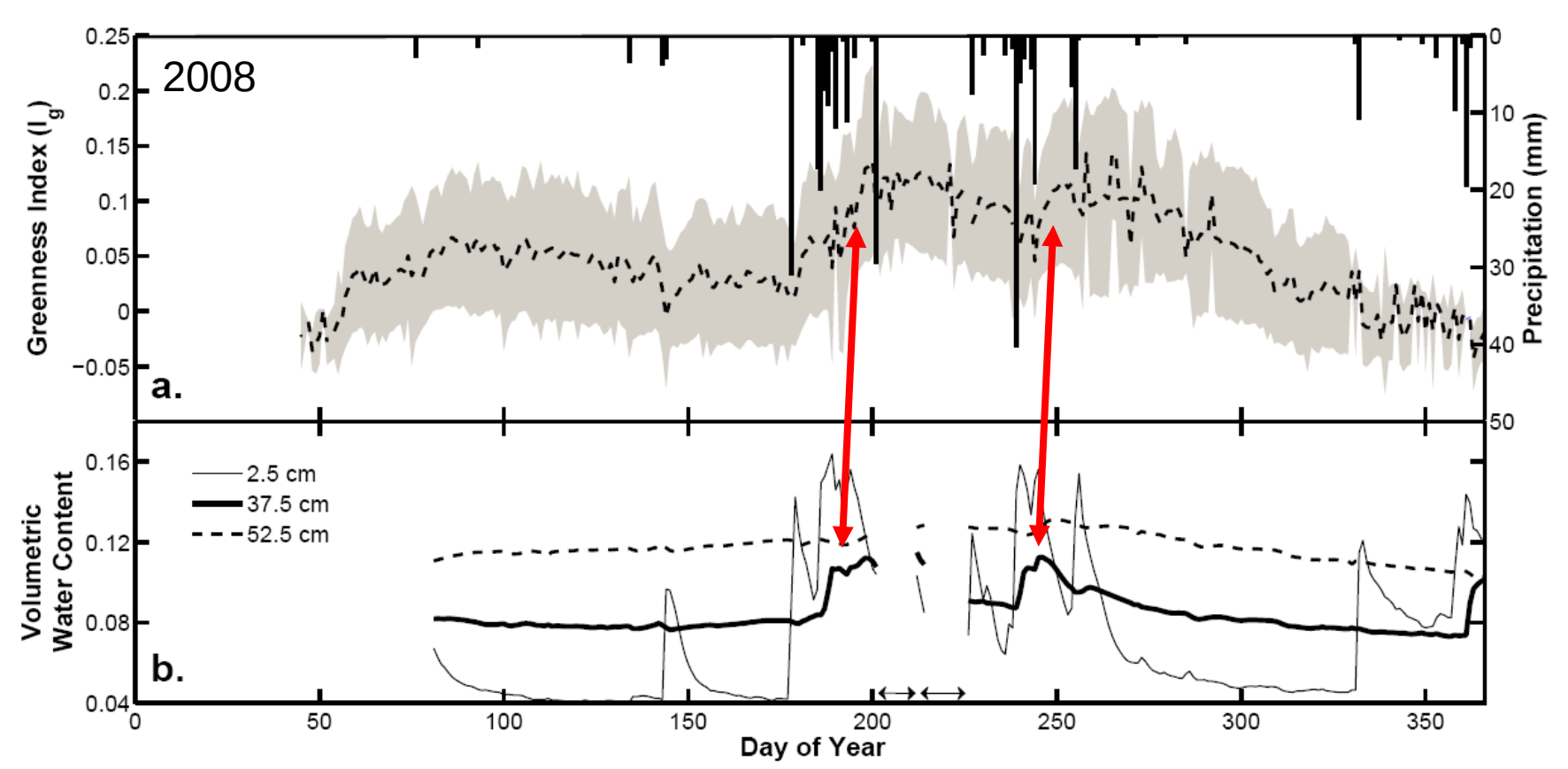
# Results: Deriving Greenness




$I_g = (R-G)+(B-G)$ → *Average of the 3 cameras*

# Results: Image-Derived Greenness

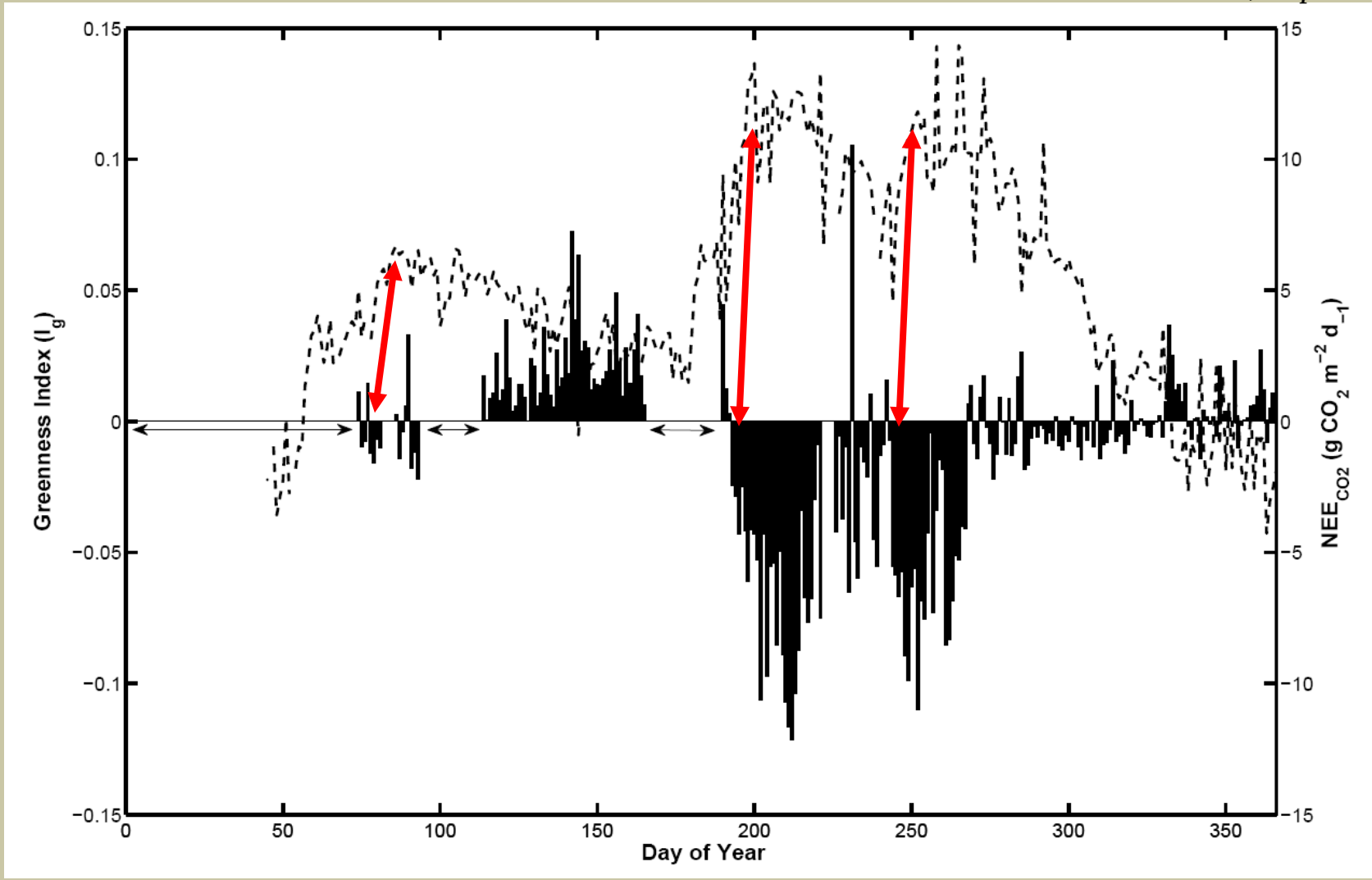
*Kurc and Benton, in press*




Greenness linked with deep soil moisture ‘pulses’.

# Results: Image-Derived Greenness

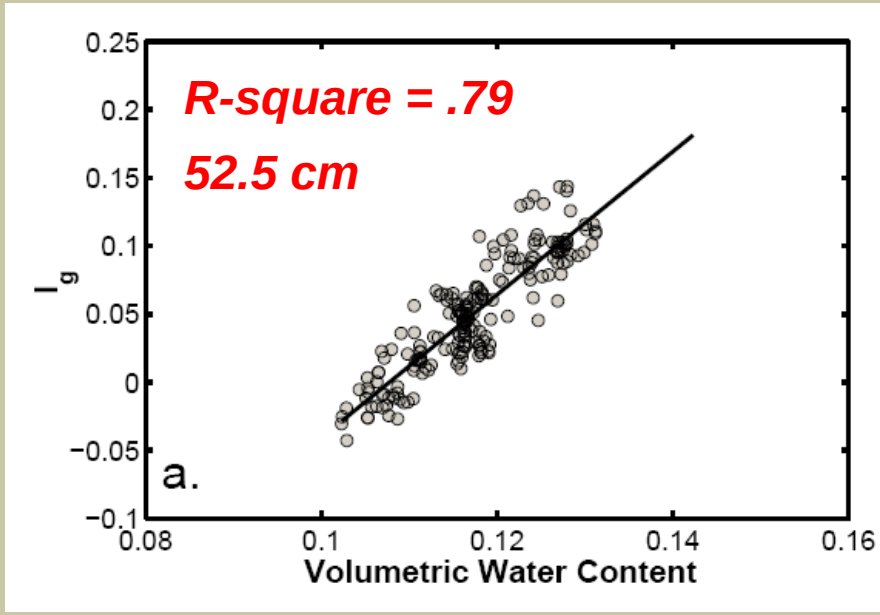
*Kurc and Benton, in press*




Carbon dynamics linked image-derived greenness.

# Results: Image-Derived Greenness

*Kurc and Benton, in press*



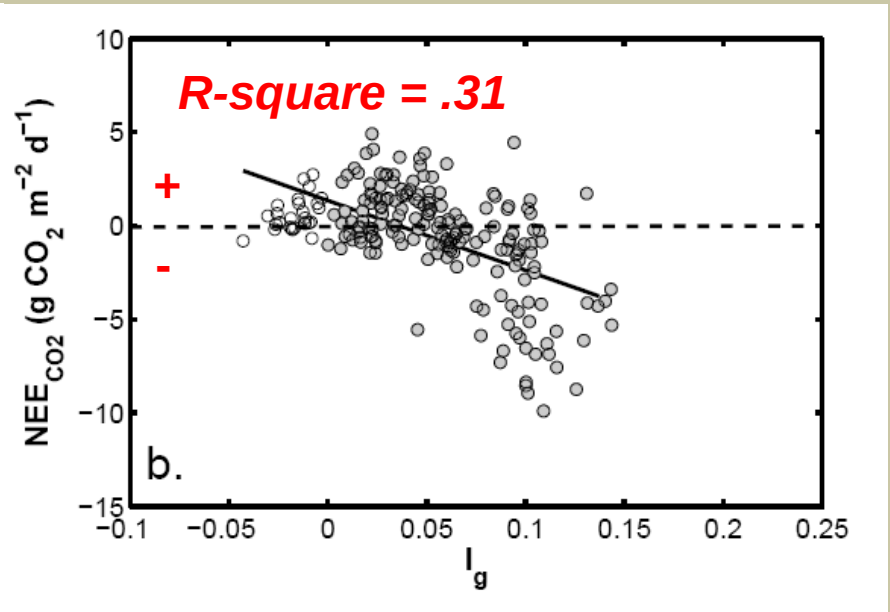
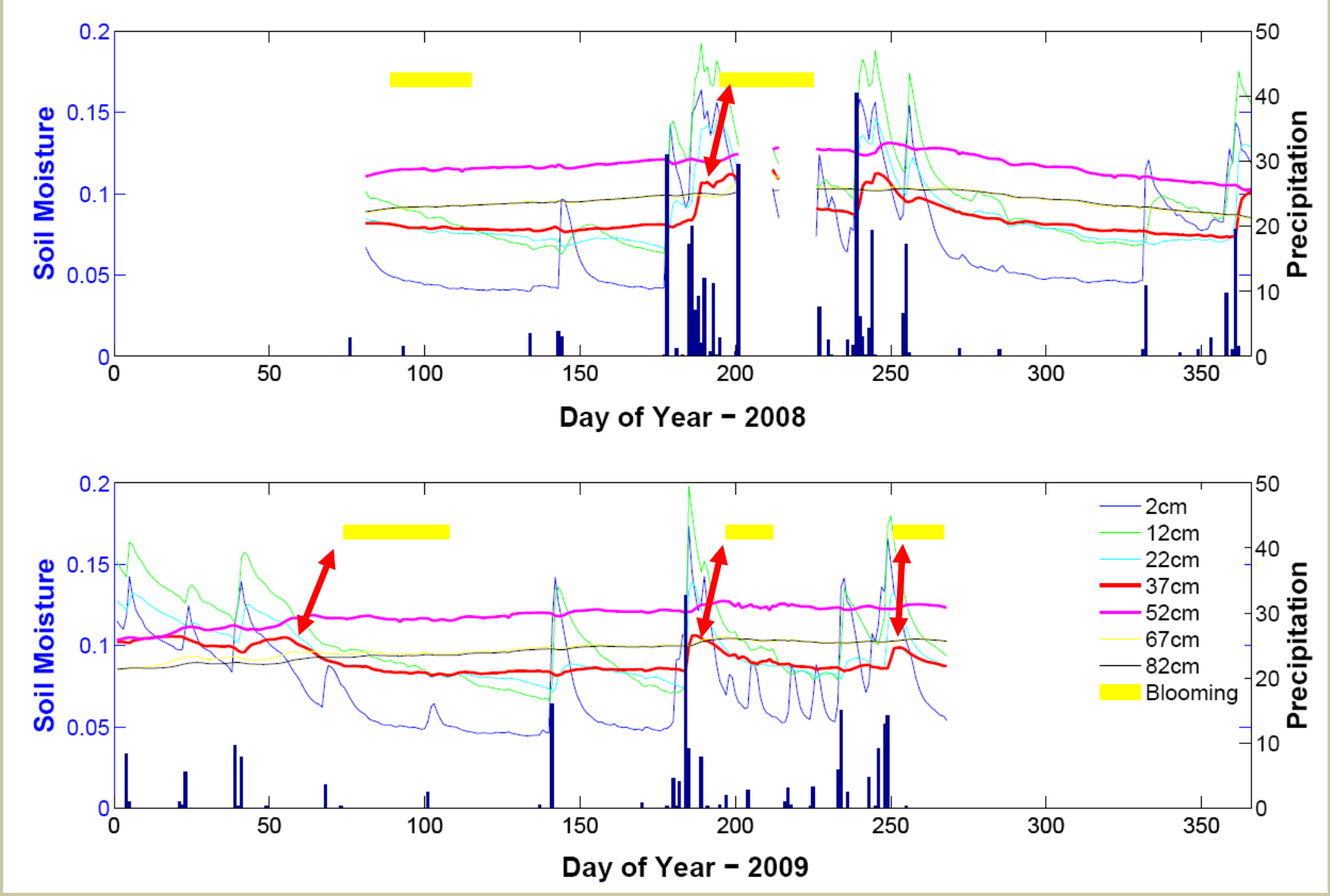




Image-derived greenness linked with deep soil moisture.

Carbon dynamics linked image-derived greenness.

# Results: Flowering

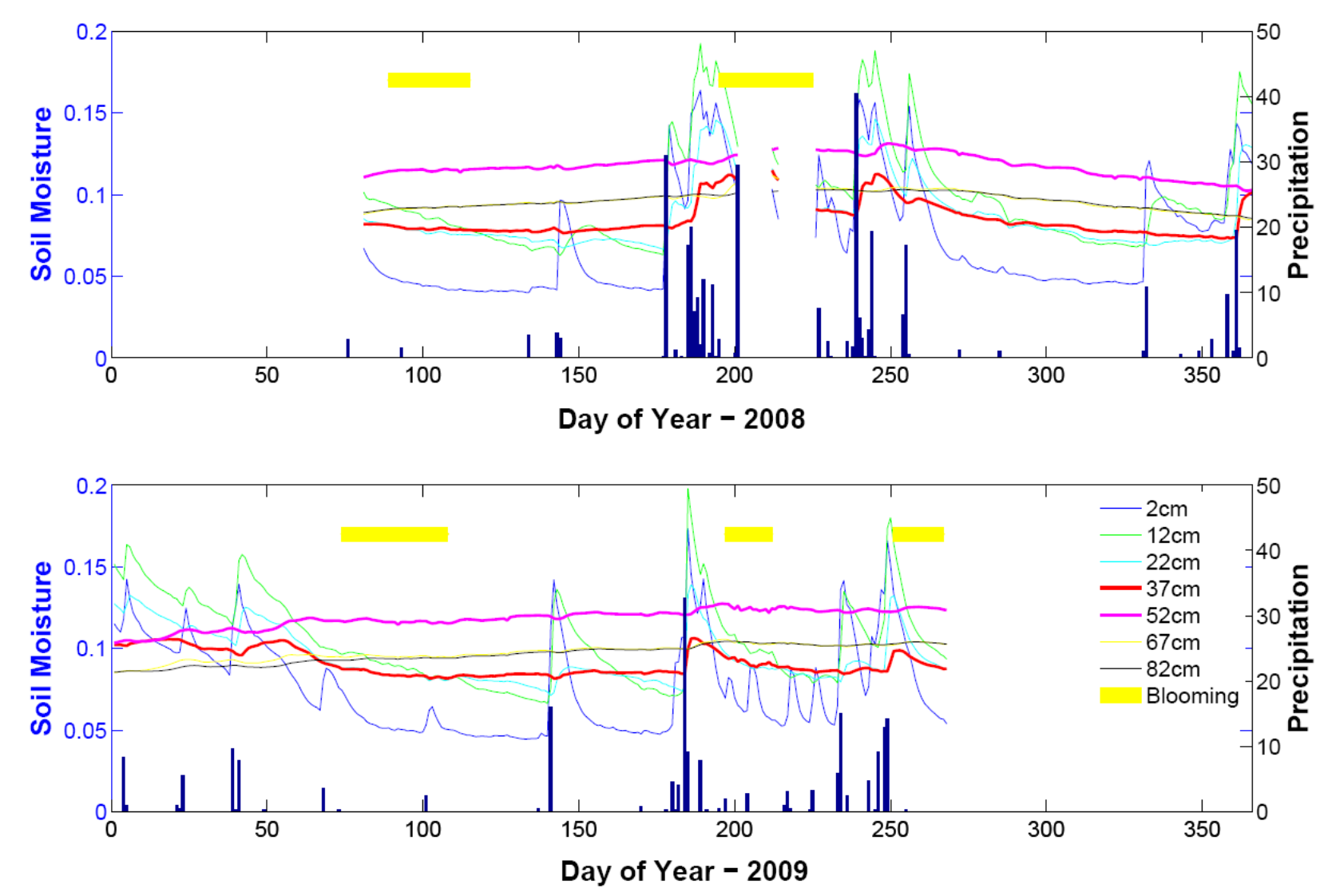
*Kurc and Nelson in prep*




Flowering linked with deep soil moisture.

# Results: Flowering

*Kurc, and Nelson in prep*




Drier year has more periods of blooming…

# Conclusions.

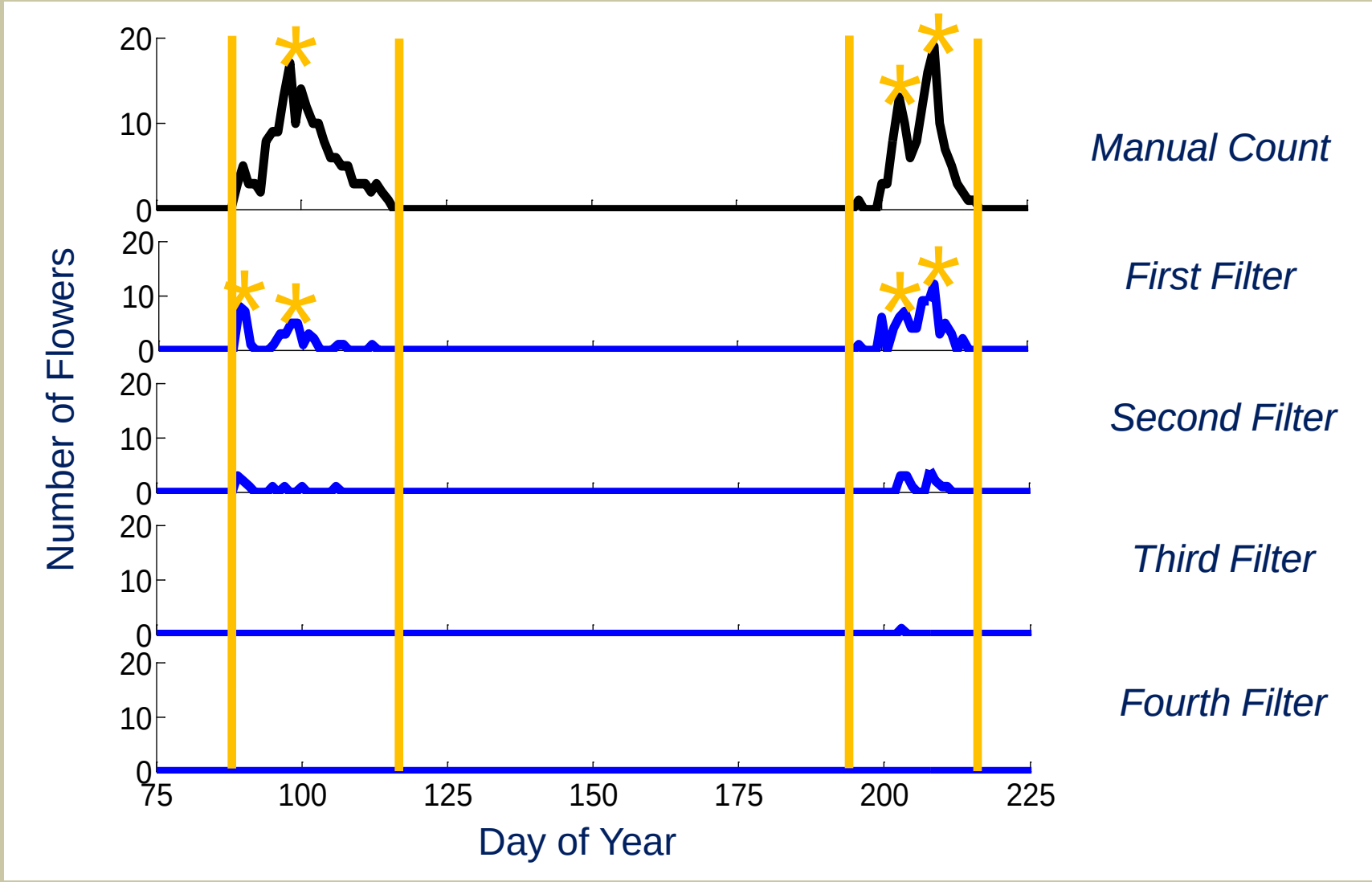
- Creosotebush phenological phases linked with *pulse* events.
- Creosotebush phenological activity linked with ‘deep’ soil moisture.
- Creosotebush carbon dynamics linked with phenological activity.

## Future Directions.

- How consistent are these relationships across dryland ecosystems?
- How vulnerable will dryland ecosystems be to precipitation changes?
- At what scale might these relationships matter in land surface – atmosphere interactions?

# Some Future Directions.

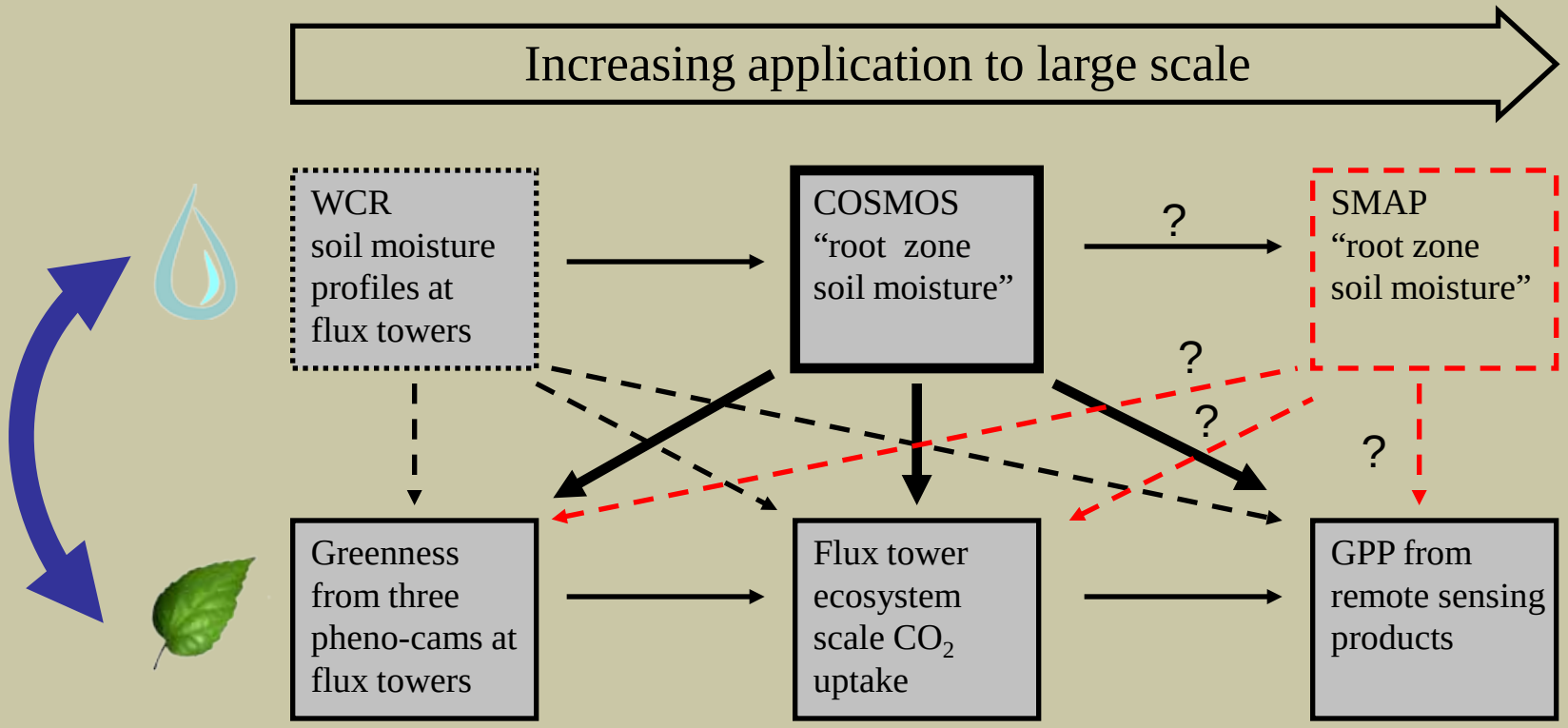
*Benton, Kurc, and Nelson, in prep*




Automated image processing for derivation of flowering.

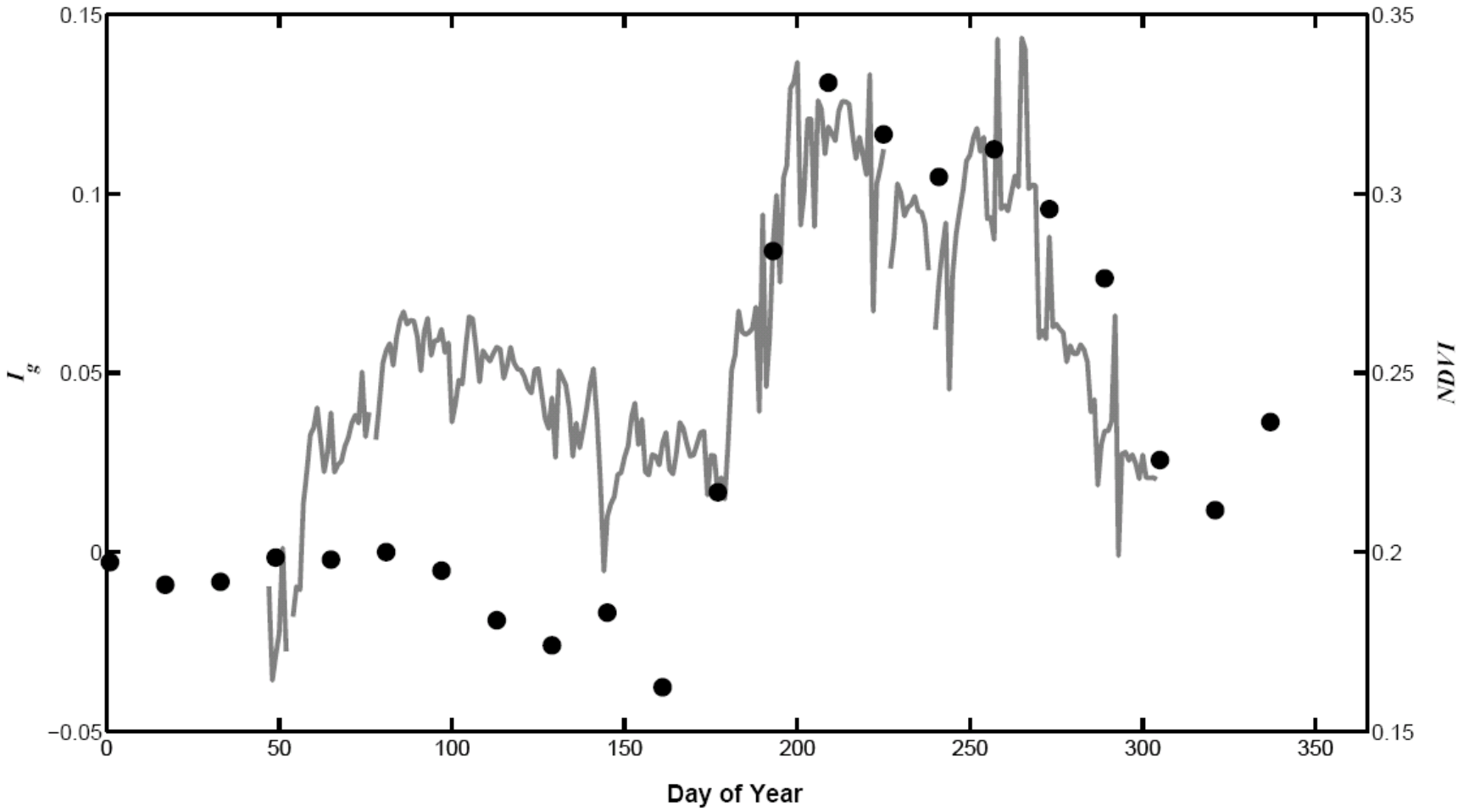
# Some Future Directions.

Understanding how well large "root zone" soil moisture products derived from COSMOS or NASA SMAP will be able capture moisture dynamics that are important for plant phenology in dryland ecosystems.



# Questions?

# Discussion Point.




- Information from 16 Day NDVI composites could be augmented with digital - image derived greenness