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Bridging field observations and remotely sensed assessments of land surface phenology in the arid southwestern U.S.

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1 Problem

Relating field observations of plant phenological events to remotely sensed depictions of phenology remains a challenge to the vertical integration of data from disparate sources. Different scales of observation, land surface heterogeneity, and timing of observations have precluded clear relationships between field perspectives of phenology and phenological events discernable with satellite remote sensing.

This research conducted at the Jornada Basin (JRN) Long-Term Ecological Research site in the northern Chihuahuan desert in New Mexico capitalizes on legacy datasets pertaining to reproductive phenology and biomass in conjunction with analysis of Landsat Thematic Mapper (TM) imagery.

2 Questions

We explored the utility of long-term ecological datasets to inform satellite-based interpretations of land surface phenology. Specifically, we sought to answer the following questions:

(1) How can field measurements of reproductive phenology for dominant grass and shrub species enhance depictions of land surface phenology using Landsat 5 TM imagery? and,

(2) Does Landsat 5 TM imagery serve as a reliable and accurate proxy for vegetation biomass in this highly heterogeneous arid ecosystem?

3 Approach

We implemented a pilot study to evaluate patterns in biomass, phenology, and vegetation greenness from May 2006 to Nov 2009 encompassing two anomalously wet years (2006 and 2008). This cross-scale approach involves data collected at multiple spatial and temporal scales (Fig. 1).

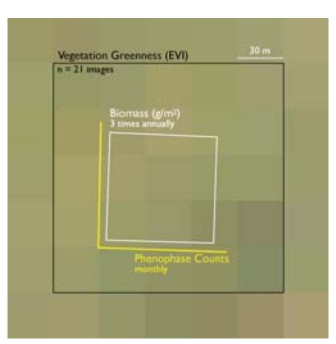

Fig. 1: Field data represent phenophase counts (Table 1) along two 75- X 1-m belt transects (yellow) collected monthly; biomass is measured three times annually (winter, spring, and fall) within 70-m X 70-m plots (white; Huenneke et al. 2001). Vegetation greenness is represented with the Enhanced Vegetation Index (EVI) and is summarized as the mean EVI for 25 TM pixels centered on the study site (black).

Table 1. Plant species on the JRN LTER in southern New Mexico monitored as part of the protocol for reproductive phenology. Data have been collected monthly since 1992 at 15 long-term field sites (Fig. 2). These fifteen species represent perennial grasses, shrubs, and sub-shrub growth forms common to the Chihuahuan desert. The number of species monitored at each site range from one to six (see Fig. 4).

Species name	Common name	No. sites monitored	Growth form
Bouteloua eriopoda	Black grama	3	GRASS
Dasyochloa pulchella	Fluffgrass	4	GRASS
Flourensia cernua	Tarbush	3	SHRUB
Larrea tridentata	Creosote bush	3	SHRUB
Lycium berlandieri	Berlandieri's wolfberry	2	SHRUB
Muhlenbergia arenacea	Ear muhly	4	GRASS
Muhlenbergia porteri	Bush muly	7	GRASS
Panicum obtusum	Vine-mesquite	2	GRASS
Pleuraphis mutica	Tobosagrass	4	GRASS
Prosopis glandulosa	Honey mesquite	4	SHRUB
Scleropogon brevifolius	Burrograss	4	GRASS
Sporobolus airoides	Alkali sacaton	2	GRASS
Sporobolus flexuosus	Mesa dropseed	2	GRASS
Xanthocephalum species	Snakeweed	5	SUB-SHRUB
Zinnia acerosa	Desert zinnia	2	SUB-SHRUB

Field data:

Long-term field efforts at JRN are focused on 15 70-m X 70-m sites (Fig. 1) that represent five distinct vegetation communities: three shrublands (mesquite, tarbush, creosote) and two grasslands (upland and playa, Fig. 2). Monthly precipitation is monitored at each site and seasonal biomass measurements are taken three times annually (winter, spring, fall). Phenological observations are made monthly for one to six species per site (Table1) and constitute counts of individuals in each of 5 phenophases: (1) dormant, (2) non-reproductive (leaf out), (3) flowering, (4) budding, and (5) fruiting.

Image data:

Twenty-one TM images were processed to yield top of atmosphere radiance values that were corrected for atmospheric effects to obtain surface reflectance (Chavez 1996). Enhanced vegetation index (EVI) values were then calculated and reported as the mean of 25 EVI values corresponding to the 150-m X 150-m area (Fig. 1) centered on each of 15 study sites (Fig. 2).

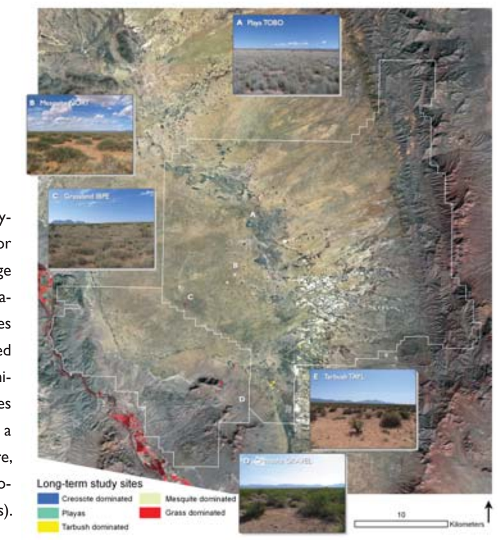

Fig. 2: JRN LTER (white polygon) on a 02 Nov 09 false color composite Landsat TM5 image (red represents green vegetation). Fifteen 2.25 ha study sites for Landsat analysis are outlined in color corresponding to dominant vegetation (species names noted in Table 1) representing a range in vegetation structure, species composition, and productivity (inset photos).

4 Results

Landsat-biomass

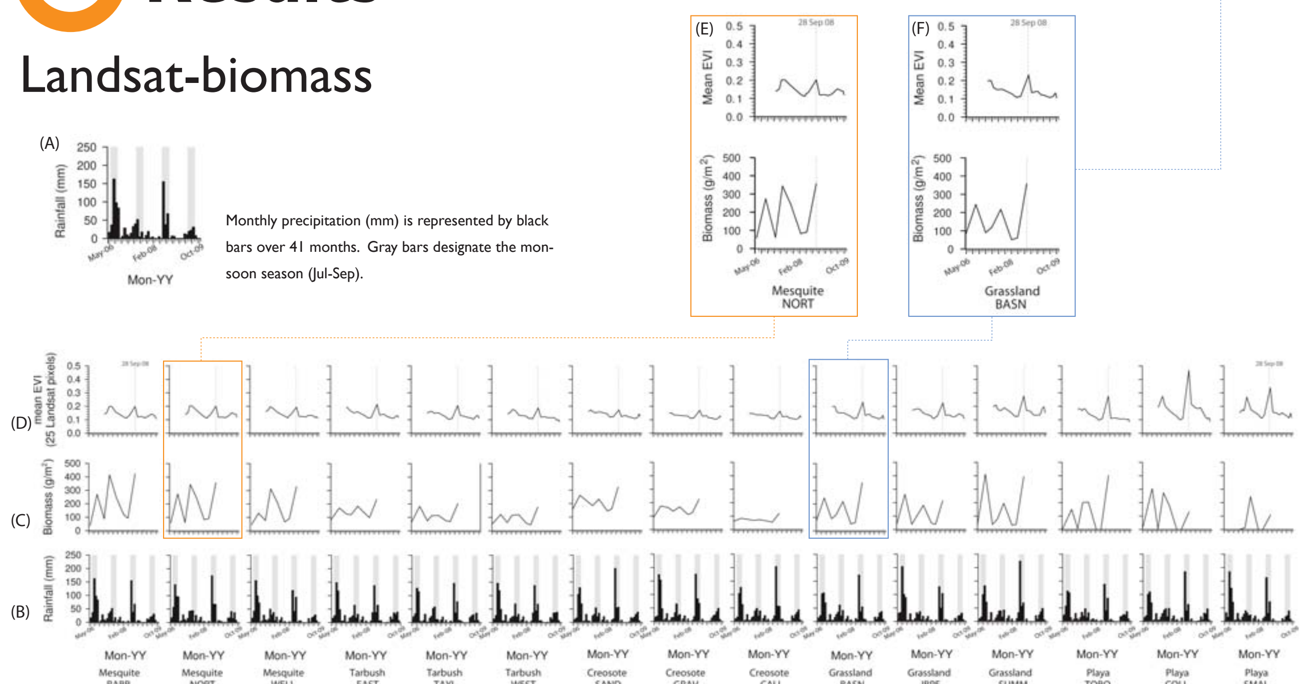

Fig. 3: Rainfall and plant production at 15 study sites on the JRN as revealed from field and satellite data from May 2006 to Nov 2009. Monthly rainfall is collected at each study site with 50% annual rainfall occurring during Jul to Sep denoted with gray bars [B, detailed inset at (A)]. Seasonal biomass at each site is collected annually in winter, spring, and fall (C); vegetation greenness using the Landsat TM imagery is expressed as EVI (D). Satellite and field perspectives for biomass at representative mesquite-dominated (E) and grassland (F) sites are highlighted in detail for comparison.

Phenology

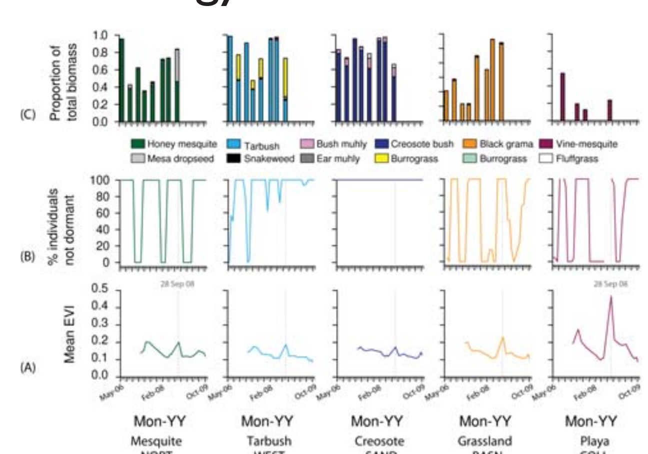

Fig 4. Phenological profiles for representative study sites at JRN. (C) Proportion of total biomass (eight field sample dates) for all species monitored as part of the long-term phenology study. Panel (B) demonstrates temporal patterns in dormancy from May 2006 through Nov 2009 for the dominant species at each representative site. Proportions of total biomass and phenological patterns are placed in the context of the satellite record of vegetation greenness [EVI, panel (A)]. Lines in (A) are color-coded to denote the dominant species (C). Scientific names are found in Table 1.

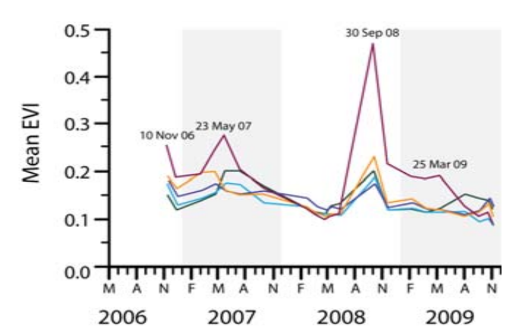

Fig 5. Enhanced vegetation index (EVI) curves representing patterns in productivity for five distinct vegetation communities at the JRN from over three years. Select image dates are noted to enhance temporal interpretation. Color coding for Playa, Grassland, Tarbush, Creosote, and Mesquite sites corresponds to dominant species in **Fig. 4**.

1. There was a wide range in biomass over time and across sites (Fig. 3C) and were consistent TM-discernble responses in production (fall 2008) to 2006 and 2008 above-average rainfall (Fig. 3).
2. Cumulative effect of 2006 and 2008 rainfall most prominently reflected in fall 2008 biomass at mesquite sites (Figs. 3C, 3E and 23 May 07 EVI in Fig. 5).
3. Grassland EVI responses do not always clearly reflect changes in biomass (Figs. 3C, D, and F) which may be due to the prominence of senescent vegetation at grassland and playa sites.
4. EVI effectively tracked increases in biomass across all plant communities (Figs. 3C and D) although EVI values exhibited a low dynamic range across large differences in plant biomass.
5. Phenophase counts by species did not translate directly to EVI values due to confounding factors related to species differences in biomass and dominance.

Fig 6. Panoramic mosaic of digital photographs taken at Grassland BASN on 16 Sep 09.

5 Conclusions

1. Field data regarding reproductive phenology are most informative where there are clear dominant species. Remote sensing applications require efforts to characterize photosynthetically active vegetation (e.g. Fisher et al. 2006, Fisher & Mustard 2007) and a biophysical basis (e.g., biomass) for quantitative relationships. Nonetheless, the field perspective is historically unrivaled for highlighting species responses to climate drivers.
2. Range in vegetation physiognomy and productivity at the JRN LTER is well-suited for field validation exercises of land surface phenology and retrieval of biophysical parameters via remote sensing.
3. Plant responses to changes in climate (e.g., temperature and amount/seasonality of rainfall) manifest through phenological patterns. Therefore, field-tested protocols for monitoring plant phenology hold great promise for landscape monitoring and quantifying ecosystem responses to climate change (Morisette et al. 2009).
4. Free access to the Landsat archive provided by U.S. Geological Survey facilitates monitoring efforts across broad spatial scales in a consistent manner.

6 References

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