FIELD VALIDATION OF BIOMASS RETRIEVED FROM LANDSAT FOR RANGELAND ASSESSMENT AND MONITORING

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1. INTRODUCTION

Spatial measures of terrestrial biomass that are accurate and repeatable are important to monitoring landscape condition and modeling productivity in the world's grassland and savanna (i.e., rangeland) ecosystems. Remote sensing offers potential to characterize seasonal changes in biomass in a consistent and non-destructive manner. A high degree of structural and spatial heterogeneity [1] and inter-annual variability in production [2] render field datasets for validating remotely sensed estimates of biomass logistically inaccessible in many rangelands.

We capitalized on long-term measurements of aboveground biomass at the Jornada Basin (JRN) Long-Term Ecological Research site in the northern Chihuahuan desert in New Mexico. Fifteen study sites represent five distinct vegetation communities exhibiting a wide range in productivity, physiognomy, and spatial structure [1, 3]. This variability enhances our efforts to relate repeated biomass measurements to spectral vegetation indices (SVI) characterizing vegetation greenness from Landsat 5 Thematic Mapper (TM) imagery. We sought to answer the following questions: (1) Does Landsat 5 TM imagery serve as a reliable and accurate proxy for vegetation biomass in this highly heterogeneous arid ecosystem? and (2) How do differences in vegetation structure influence biomass/SVI relationships?

2. APPROACH

We implemented a pilot study to evaluate patterns in biomass and vegetation greenness from 10 Nov 2006 to 2 Nov 2009 encompassing two anomalously wet years (2006, 2008). Twenty-one images were selected from the Landsat image archive to achieve phenological profiles in addition to relating biomass to the image-based indicators of vegetative vigor; images were temporally well-distributed (Fig. 1). Time series Landsat 5 TM were images were processed to yield top of atmosphere radiance values which were then corrected for atmospheric effects to obtain surface reflectance using the image-based COST method [4]. We evaluated the performance of three SVIs derived from atmospherically corrected images: normalized difference vegetation index (NDVI), enhanced vegetation index (EVI), and soil-adjusted vegetation index (SAVI), however, to facilitate comparison of results from Landsat and the MODIS sensor in this arid ecosystem, we report values for EVI. EVI values were calculated and reported as the mean of 25 values corresponding to the 150-m X 150-m area centered on the 0.5-ha study sites. The long-term field study of net primary productivity at JRN is conducted at 15 70-m X 70-m sites that represent three shrubland (mesquite, tarbush, creosote) and two grassland (upland and playa) plant communities. Monthly precipitation is monitored at each site; biomass measurements are made three times annually (winter, spring and fall).

3. RESULTS

Relationships between EVI and biomass were strong and consistent for sites within a vegetation community (Table 1, Fig. 3). Despite the noted tendency for some spectral vegetation index signals to saturate over densely vegetated areas [5], plant production at the JRN did not exceed 500 g/m^2 (from Nov 2006 to 2009) and falls below the saturation point. Phenological differences between shrub (e.g., mesquite-dominated) and grassland sites are distinct in the EVI signal prior to the rainy season (23 May 07 response, Fig. 2). Dominant perennial grasses response photosynthetically to summer monsoon rains (Jul to Sep) whereas shrub species leaf out in the spring. There was a wide range in biomass over time and across sites (Fig. 3C) illustrating the need for multiple validation sample dates to represent the range of field conditions. There were consistent responses in production (fall 2008) to 2006 and 2008 above-average rainfall that were discernable in the TM record (Fig. 3). EVI effectively tracked increases in biomass across all plant communities (Figs. 3B and C) although EVI exhibited a low dynamic range in values across large differences in plant biomass. Grassland EVI responses do not always clearly reflect changes in biomass (Figs. 3B and C) which may be due to the prominence of senescent vegetation at grassland and playa sites or confounded by the prominence of bare soil in arid ecosystems [6].

4. CONCLUSIONS

The range in vegetation physiognomy and productivity at the JRN LTER is well-suited for field validation exercises for land surface phenology and retrieval of biophysical parameters via remote sensing. Plant responses to changes in climate (e.g., temperature and amount/seasonality of rainfall) manifest through phenological patterns. Therefore, an accurate and robust relationship between spectral vegetation indices derived from freely available moderate resolution satellite imagery and field measurements of biomass is a powerful tool for monitoring landscape condition and land surface phenology in arid and semi-arid rangelands. Future work will extend the TM time series to encapsulate periods of consistent below-average rainfall. In addition, we will explore scaling relationships of plant productivity and biomass across sensor platforms to encompass imagery from unmanned aerial vehicles (UAV). UAV imagery is a cost-effective and increasingly available resource and generation of UAV mosaics has been accomplished so that larger study areas can be examined. This technology can provide a robust basis for scaling relationships for phenology-based research applications as well as those for rangeland monitoring and quantifying ecosystem responses to climate change [7].

5. REFERENCES

1. Phinn, S., et al., Biomass distribution mapping using airborne digital video imagery and spatial statistics in a semi-arid environment. *Journal of Environmental Management*, 1996. **47**(2): p. 139-164.
2. Huenneke, L.F., et al., Desertification alters patterns of aboveground net primary production in Chihuahuan ecosystems. *Global Change Biology*, 2002. **8**(3): p. 247-264.
3. Huenneke, L.F., D. Clason, and E. Muldavin, Spatial heterogeneity in Chihuahuan Desert vegetation: implications for sampling methods in semi-arid ecosystems. *Journal of Arid Environments*, 2001. **47**(3): p. 257-270.
4. Chavez, P.S., Jr., Image-based atmospheric corrections--revisited and improved. *Photogrammetric Engineering and Remote Sensing*, 1996. **62**(9): p. 1025-1036.
5. Huete, A., et al., Overview of the radiometric and biophysical performance of the MODIS vegetation indices. *Remote Sensing of Environment*, 2002. **83**(1-2): p. 195-213.
6. Huete, A.R., A soil-adjusted vegetation index (SAVI). *Remote Sensing of Environment,* 1988. **25**: p. 295-309.
7. Morisette, J.T., et al., Tracking the rhythm of the seasons in the face of global change: phenological research in the 21st century. *Frontiers in Ecology and the Environment*, 2009. **7**(5): p. 253-260.

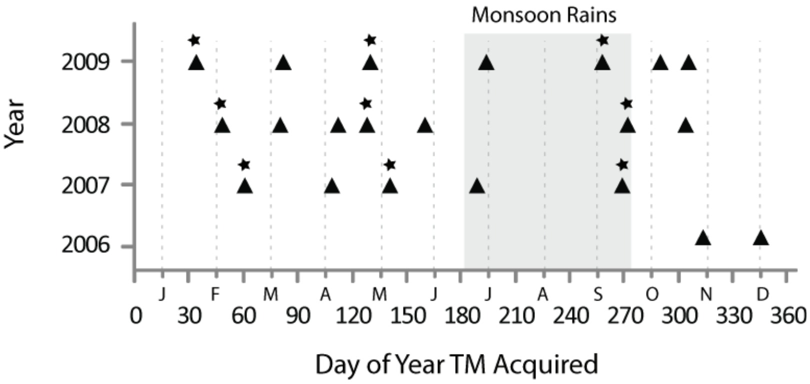

Fig. 1: Twenty-one Landsat 5 Thematic Mapper (TM) images used to relate Enhanced Vegetation Index (EVI) values to coincident field measurements of biomass (denoted with asterisk symbols). Circa 50% of annual rainfall occurs from Jul to Sep (gray bar).

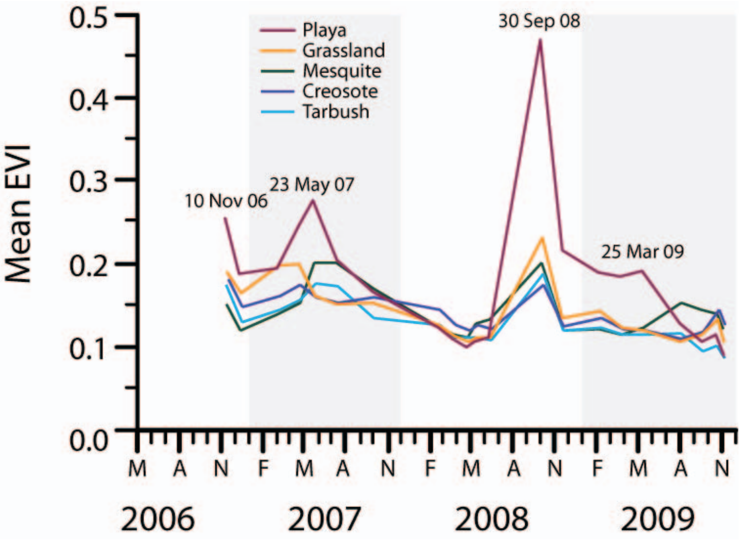

Fig. 2: Enhanced vegetation index (EVI) curves representing patterns in photosynthetic activity for five distinct vegetation communities at the JRN from 10 Nov 06 to 2 Nov 09.

Table 1. Linear regression coefficients for the relationship between field-measured vegetation biomass with EVI values derived from Landsat 5 TM imagery. Study sites span 5 distinct vegetation communities (1) mesquite- , 2) creosote- , and 3) tarbush-dominated; and 4) upland grassland and 5) grass-dominated lakes or playas.

Site	**r^2**	**EVI coefficient**	**y-intercept**
Mesquite RABB	0.8819	0.0002	0.1062
Mesquite NORT	0.8385	0.0002	0.1096
Mesquite WELL	0.7972	0.0002	0.1172
Tarbush EAST	0.4943	0.0005	0.0842
Tarbush TAYL	0.813	0.0006	0.0885
Tarbush WEST	0.701	0.0005	0.095
Creosote SAND	0.6513	0.0002	0.1053
Creosote GRAV	0.6745	0.0005	0.0693
Creosote CALI	0.6116	0.0007	0.0887
Grassland BASN	0.568	0.0003	0.1216
Grassland IBPE	0.2097	0.0002	0.1398
Grassland SUMM	0.7046	0.0002	0.1506
Playa TOBO	0.5612	0.0003	0.1321
Playa COLL	0.19	0.0004	0.1742
Playa SMAL	0.1826	0.0003	0.1541

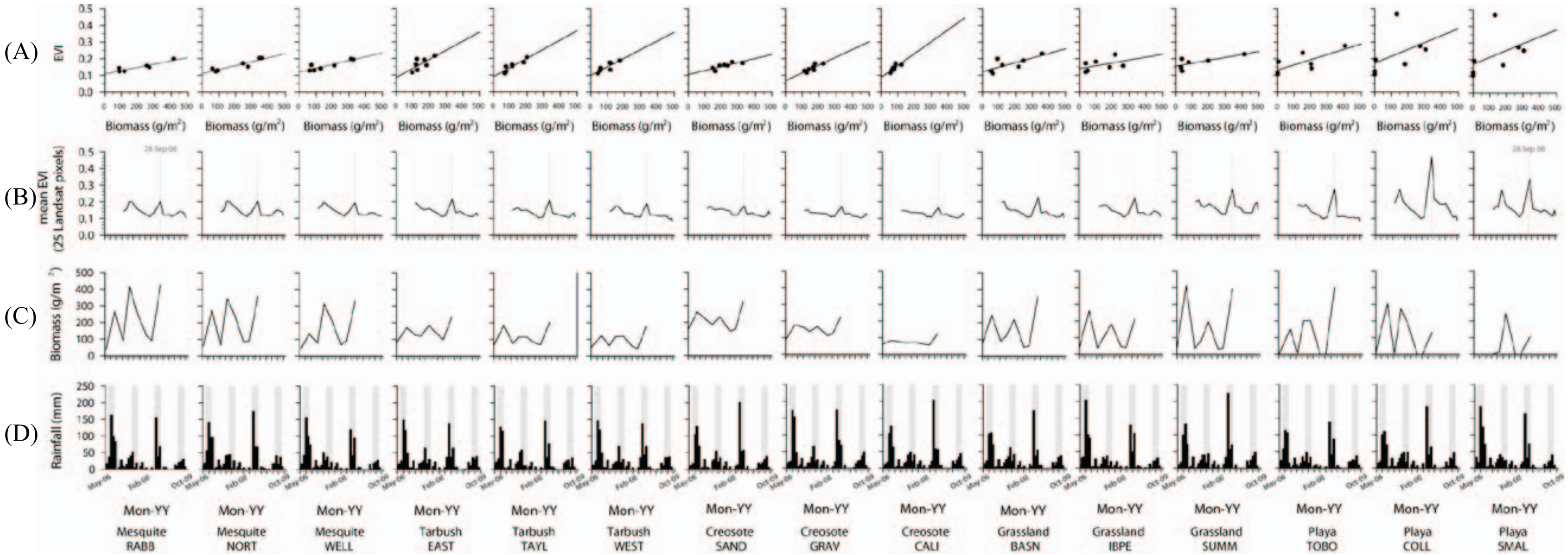

Fig. 3: Linear relationships between EVI and biomass (A) with rainfall (D) and plant production (C) at 15 study sites on the JRN. Landsat 5 TM imagery spans 10 Nov 2006 to 02 Nov 2009 (B). Monthly rainfall is collected at each study site with 50% annual rainfall occurring during Jul to Sep denoted with gray bars (D). 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 (B).