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Regional NPP and Carbon Stocks in Southwestern USA Rangelands: Land-use Impacts on the Grassland-Woodland Balance

9/01/01 – 8/31/02

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Project Abstract

Tree/grass ratios profoundly impact the biogeochemistry of grasslands and savannas by affecting: (i) decomposition of above- and belowground biomass, (ii) vertical distribution, mass, and size of roots in the soil, and (iii) microclimatic influences on soil microbial biomass and rates of organic matter turnover. Because dryland ecosystems comprise half the terrestrial surface, changes in tree/grass ratios likely influence global biogeochemical cycles and climate. Our past work has focused on quantifying how changes in tree/grass ratios affect storage of carbon (C) and nitrogen (N) across topoedaphically diverse landscapes. In this proposal, we will expand our LCLUC work to the greater Southwest, and initiate new objectives addressing the Carbon Cycle Science Initiative. We will extrapolate our high-resolution, validated studies to assess land-use impacts on NPP and C-storage in dryland ecosystems throughout the Southwest. We will integrate aircraft, Landsat, and MODIS data to retrieve, with increasing spatial coarseness, biogeophysical information relevant to biogeochemistry, vegetation dynamics, and land management. Sequenced validation of land cover fractions from plot-to-Landsat-to-MODIS scales using spectral mixture analysis will enable us to determine scaling properties of key biophysical variables (e.g. live vs. dead vegetation) from landscapes to regions in contrasting bioclimatic zones. These variables will constrain the ecosystem process model TerraFlux, and thereby estimate regional productivity and C-storage in vegetation and soil. $\delta^{13}C$ of soil organic carbon (SOC), a biogeochemical tracer of woody-herbaceous inputs, will be obtained for our temperate savanna site and used to test model performance and, hence, the adequacy of the remote sensing inputs. $\delta^{13}C$ of SOC will also enable us to document long-term vegetation history, estimate SOC turnover, and the relative contribution of grasses vs. woody plants to ecosystem productivity and C-storage. This $\delta^{13}C$ database will be comparable to that completed at our subtropical savanna site; therefore, we will be in a position to compare effects of woody plant encroachment on ecosystem C-storage in contrasting bioclimatic regions.

We will also develop a spatially explicit land-use history within our Texas study region to distinguish among land-use practices influencing tree/grass ratios (e.g., grazing, fire, brush clearing, cropland abandonment). Because human management plays a dominant role in this region, we will test scenarios encompassing the range of impacts that might result from contrasting land-use policies. We cannot predict what state/federal policies might be enacted to affect range management practices. Nor can we predict what economic incentives pertaining to 'carbon credits' might arise. However, we can use our linked remote sensing-modeling approach to predict regional C budgets in response to potential policies or incentives that may emerge. Land-use scenarios that define different policy environments (e.g., government subsidies to support woody plant control, or carbon credit incentives that promote woody plant proliferation) will be developed and played out through a simple GIS approach. Consequent prescribed changes in vegetation structure, when coupled with Terraflux, will enable us to estimate the influence that policy changes might have on trajectories in C-sequestration and liberation at the scale of the Southwest region.

Keywords:

1) Research Fields: Carbon Cycling, Rangeland Management, Biogeochemical Cycling, Land Use Modeling
2) Geographic Area/Biome: North America, Semi-Arid, Grassland, Savanna, Woodland
3) Remote Sensing: Landsat, MODIS, hyperspectral
4) Methods/scales: In-situ Data, Mixture Modeling, Regional Scale

Questions

Our project focuses on the third NASA ESE question (ESE Q3) concerning the consequences of LCLUC. We are interested in land management impacts on grassland-woodland transitions within Southwestern rangelands. We are involved in mapping activities, but will not systematically assess historic change in land cover and land use (ESE Q1). Much of our past work has concentrated on the causes of land-cover/land-use change, namely mechanisms involved in the shift of grassland to woodland ((ESE Q2).

Proportion of Research Themes:

Social Science (0-25%): We will examine the results of human management on vegetation structure through a series of GIS scenarios defining different policy environments. We are not looking at the social drivers themselves, but rather their impact on landscape structure/function.

Carbon (50%): Our past and current work focuses on the sequestration and cycling of carbon through field studies of primary productivity and soil processes, and extrapolation via biogeochemical modeling.

Remote Sensing (25-50%): We use spectral mixture analysis at landscape (Landsat) and regional (MODIS) scales to determine fractional woody and grass cover. These data will be integrated into biogeochemical modeling and GIS analysis to assess NPP and carbon stocks under current and projected land management scenarios.

Project Goals: Our project goals are to expand our studies of woody encroachment to the Southwest in an effort to (1) understand the influence of land management history and climate on the biogeochemistry in these grassland/shrubland transitions, and (2) explore the impact of different policy scenarios that encourage or discourage woody plant abundance.

Activities for Year 1 (9/01/01 – 8/31/02)	**Comments on completion**
Image acquisition for TX and southwest (MODIS)	Near completion
Spectral mixture analyses for TX, validation exercises	Early stages
Initial TX NPP & C stock results from model-remote sensing links	Not yet begun
Soil analyses	Samples collected & cataloged
Technician for soil analyses upgraded to post-doc with funds from other sources	Candidates interviewed; offer made
TAMU Graduate student begins PhD; collect land use histories	Failure in finding student
ID of extensive sites throughout Southwest; focus on New Mexico	In progress

Gaps & Issues

Two of our PIs, Asner and Archer, changed institutions this year. Asner moved to the Carnegie Inst., Stanford, CA in Jan '02, shortly after the project funds arrived at Colorado. Due to complications in establishing a subcontract with Carnegie, Asner did not receive his funds until Jul '02. Archer's move to the University of Arizona (UA) took place Jun/Jul '02, disrupting some of the work in progress. It was decided that the PhD student should be recruited to start at UA rather than start at Texas A&M and mover to UA. A candidate initially offered the PhD assistantship in last spring subsequently withdrew her application in early summer.

Delays in recruiting a PhD student set back our acquisition of land use histories for Texas and the Southwest. However, we are currently exploring other, faster options, such as enlisting a current PhD student at Colorado or Stanford, or using a technician or post-doctoral associate.

Progress

Texas: Our analysis of changes in woody plant cover and aboveground carbon stocks between 1937 and 1999 in northern Texas shows cover increases of up to 500% in areas of no brush management. However, areas aggressively managed with herbicides, mechanical treatments or fire exhibit a wide range of woody cover changes relative to that present in 1937 (-75% to +280%), depending on soil type and time since last management action. Our data indicate that decadal accumulations of aboveground C by woody plants can quickly be lost via natural disturbances and land management practices (Figure 1). It will therefore be necessary to analyze imagery at a fairly high temporal frequency if the magnitude and extent of such losses are to be accurately assessed at regional scales. Moreover, explaining the causes for changes in ecosystem C pools evident on imagery will be contingent on the availability and accuracy of land-use records. We have a well-documented history of management at the La Copita Research Station in the Rio Grande Plains of south Texas. We have used this project period to acquire Landsat and management data to assess whether imagery will be useful in quantifying response to management practices and rates of woody plant recovery (Figure 2).

New Mexico: In semiarid ecosystems, multiyear rainfall anomalies can yield geographic shifts in grass-woody plant transitions. Significant drought (e.g.1950s) may have played an important role in the shrub invasion of the semiarid grasslands of New Mexico, even in the absence of grazing and fire suppression. We are studying the landscape structure and functional processes within the region of the Sevilleta NSF LTER Site in Central New Mexico to determine the relative influence of climate and land use on landscape properties. The region has experienced approximately three centuries of livestock grazing; the Sevilleta was removed from grazing in 1973 while the surrounding lands continue under ranching management. We are currently using spectral mixture analysis of remote sensing data to determine the structure of the vegetation patchiness at the interface between the Chihuahuan Desert and Great Plains Shortgrass Steppe biomes at the Sevilleta. We have unmixed over 40 images collected by NASA's AVIRIS at two different resolutions, 20m and 4m (Figure 3). We are in the process of characterizing the fractal structure of the patch mosaic and individual patches and their edges through percolation and multifractal analyses of cover fraction images (blue and black grama; creosote; soil). These analyses will help us to understand the scaling of edaphic and hydrologic constraints on landscape configuration and function, and will contribute to our studies of land management influences on net primary productivity and carbon stocks in these arid grasslands

Southwest: Maps of potential maxiumum woody plant cover and biomass will be developed based on climatic/edaphic constraints. This map wil then be used as a baseline to assess how local and regional variation in land use practices (Fig. 1) might potentially affect carbon stocks. Regionalization of actual net primary production and carbon stocks will be accomplished using MODIS data linked to the Terraflux model. Figure 4 exemplifies the type of product we will generate. Progress on this product was not possible due to Asner's move to Carnegie and the late release of funds (end of funding period).

At this point, we have no **new findings** (requiring rapid communication), **new potential**, or complete **new products** to report.

Conclusions

Our work is developing in three directions: (1) continued focused study in Texas on impacts of land management history on woody plant encroachment; (2) extension to grassland/shrubland sites that represent more arid areas in the Southwest (e.g. Sevilleta, NM); and (3) MODIS-based studies of the Southwest regional productivity and carbon stocks. This year was spent preparing baseline products for grassland/shrubland analyses in New Mexico, and acquisition of south Texas imagery and land use histories for analysis of land management impacts and their detection. Delays in receipt of funding, in conjunction with logistical challenges associated with moves by Archer and Asner have injturrupted workflow somewhat; slow transfer of funds to Asner prohibited any movement on the MODIS/NPP product.

The second funding period will include: completion of soil analyses for model validation and interpretation, analysis of Sevilleta landscape configuration and its influence on biogeochemical processes, refinement of land-use and vegetation histories within the Texas study region, development of land-use scenarios defining different policy environments, and initiation of NPP and C stock estimates for focus areas (Texas and New Mexico sites).

Peer-reviewed publications

Asner, G.P., S.R. Archer, R.F. Hughes, J.N. Ansley, and C.A. Wessman. Net changes in regional woody vegetation cover and carbon storage in North Texas rangelands, 1937-1999. Submitted to *Global Change Biology*.

House, J, S Archer, D Breshears, RJ Scholes. 2002. Conundrums in mixed woody-herbaceous plant systems. Submitted to *Journal of Biogeogrphy*.

Hibbard, KA, DS Schimel, S Archer, D Ojima, W Parton. 2002. Integrating landscape structure and biogeochemistry: changes in carbon stocks accompanying grassland to woodland transitions. Submitted to *Ecological Applications***.**

Martin, R.E., G.P. Asner, R.J. Ansley, and A.R. Mosier. Effects of woody vegetation encroachment on soil nitrogen oxide emissions in a temperate savanna. Submitted to *Ecological Applications*.

Manuscripts in Preparation:

Bateson, C.A. and C.A. Wessman. Mapping biome transition zones in New Mexico. To be submitted to *Remote Sensing of Environment.*

Wu, X.B. and S.R. Archer. Scale-dependent influence of surface hydrologic features on vegetation patterns in savanna landscapes. To be submitted to *Landscape Ecology.*

Other Issues:

Archer is collaborating with other LCLUC/ Carbon Cycle project PIs in a Symposium on 'Land use change in rural America: rates, drivers, and consequences' at the Annual Meetings of the Ecological Soc. America in Tucson in August 2002.

We would like to request additional funds for Steve Archer to accommodate “losses” incurred as a result of his move to University of Arizona: (1) increased cost of travel to field sites, (2) salary and fringe benefit increase, and (3) increased stipend for PhD student. UA has agreed to honor the lower overhead of Texas A&M (45.5%). In total, these unanticipated additional costs are estimated at $30,000.

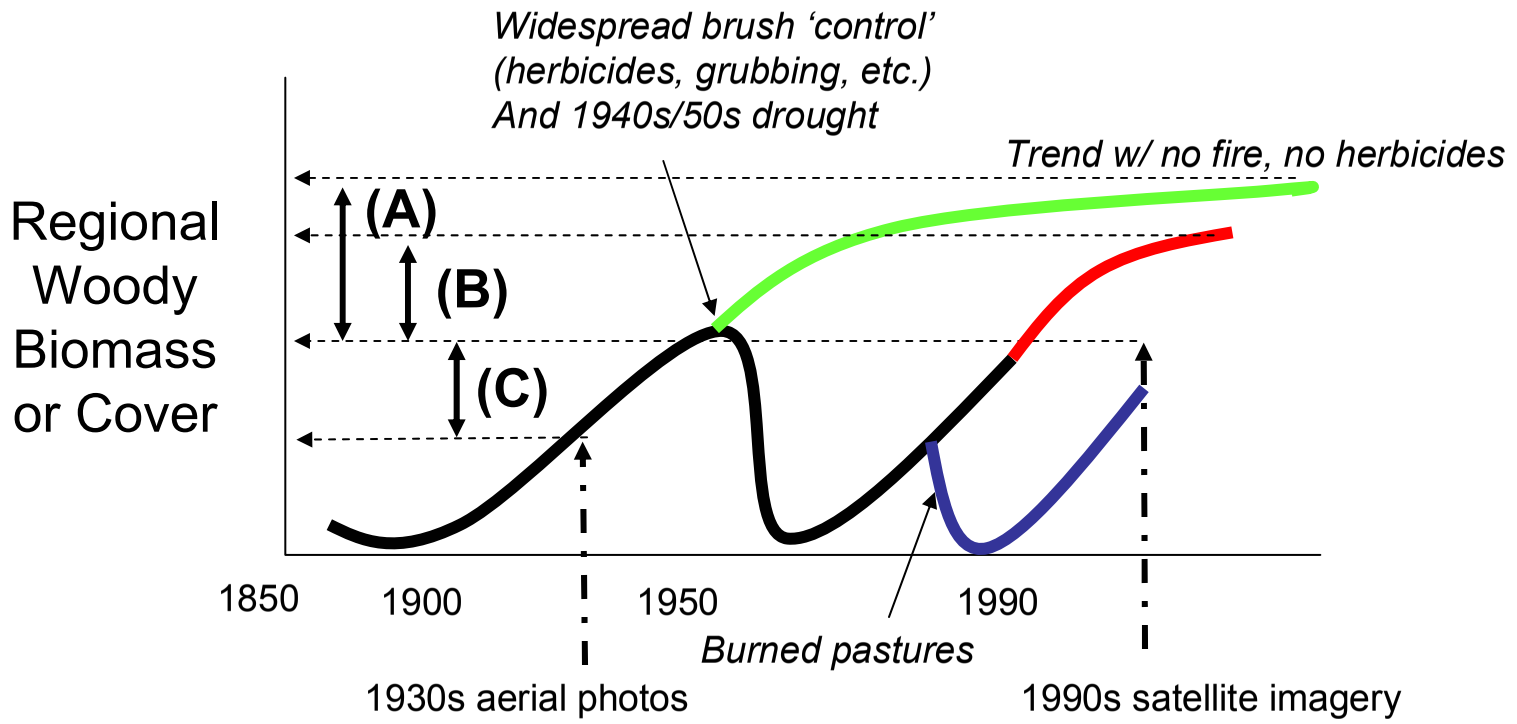

Figure 1. Woody plant aboveground biomass accumulation (A) with no management intervention, (B) interrupted by intensive clearing in the 1950s but no follow-up, and (C) clearing in 1950s and again in early 1990. Comparisons of woody cover in 1937 versus 1999 thus represent net, rather than absolute changes.

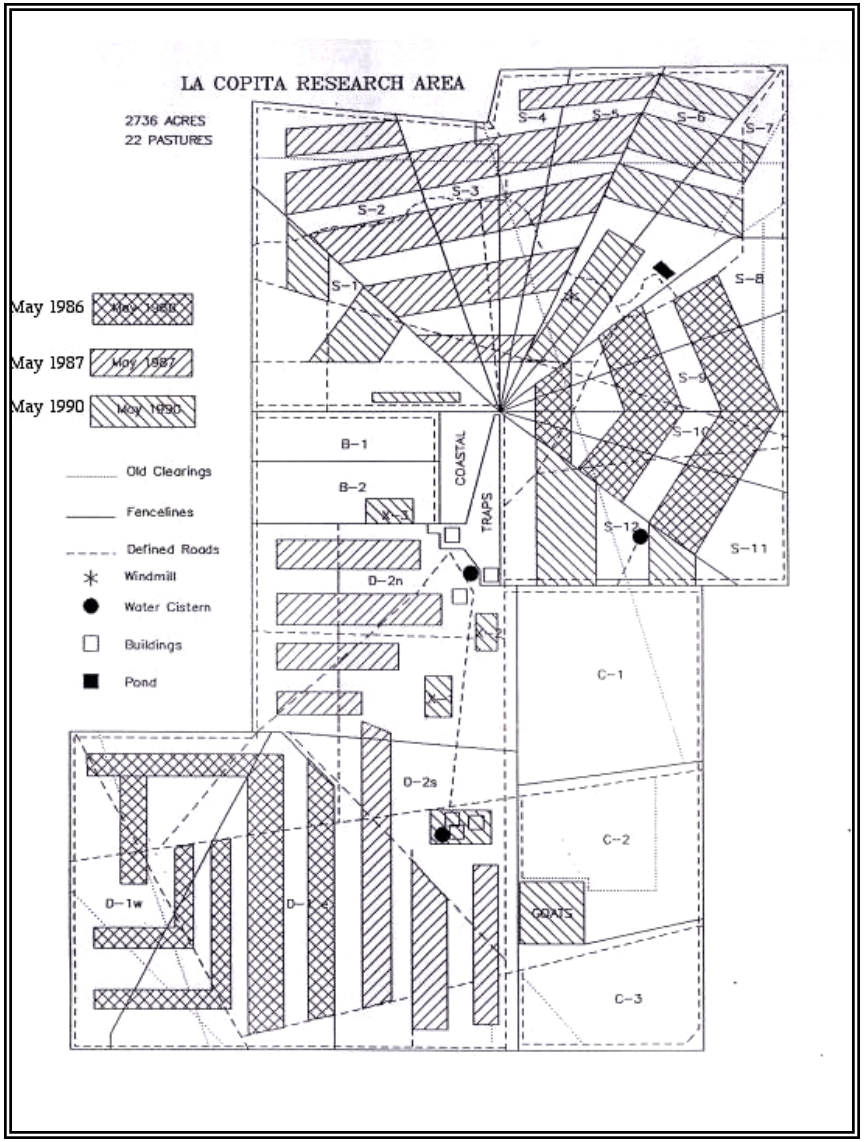

Figure 2. Map of management treatments on La Copita Research Area, Texas. Herbicide treatments were applied to designated areas in the years 1986 (hatch), 1987 (slash from right), 1990 (slash from left) (Left). Management treatment patterns overlay a pre-treatment, baseline Landsat Thematic image from 5 October 1985. (Right)

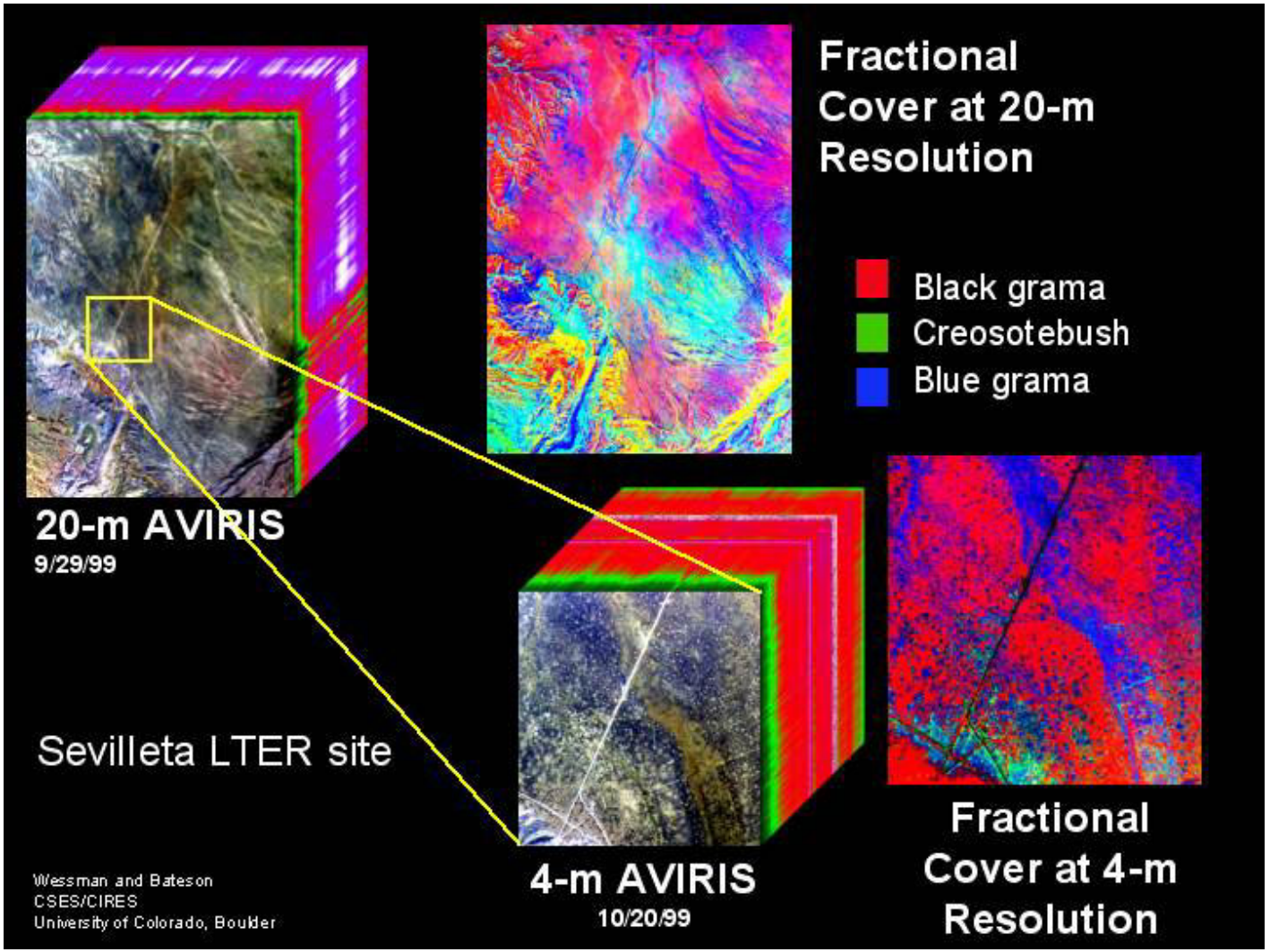

Figure 3. AVIRIS data cubes at 20-m and 4-m resolution show the reflectance variations ranging from bright caliche soils on the roads and around the kangeroo rat mounds (only visible on the 4-m resolution imagery) to darker areas of green vegetation (creosote) and black grama. Fractional cover images are the composite of the fractional cover of three landscape components "unmixed" from the original data: black grama (red), creosotebush (green), and blue grama (blue).

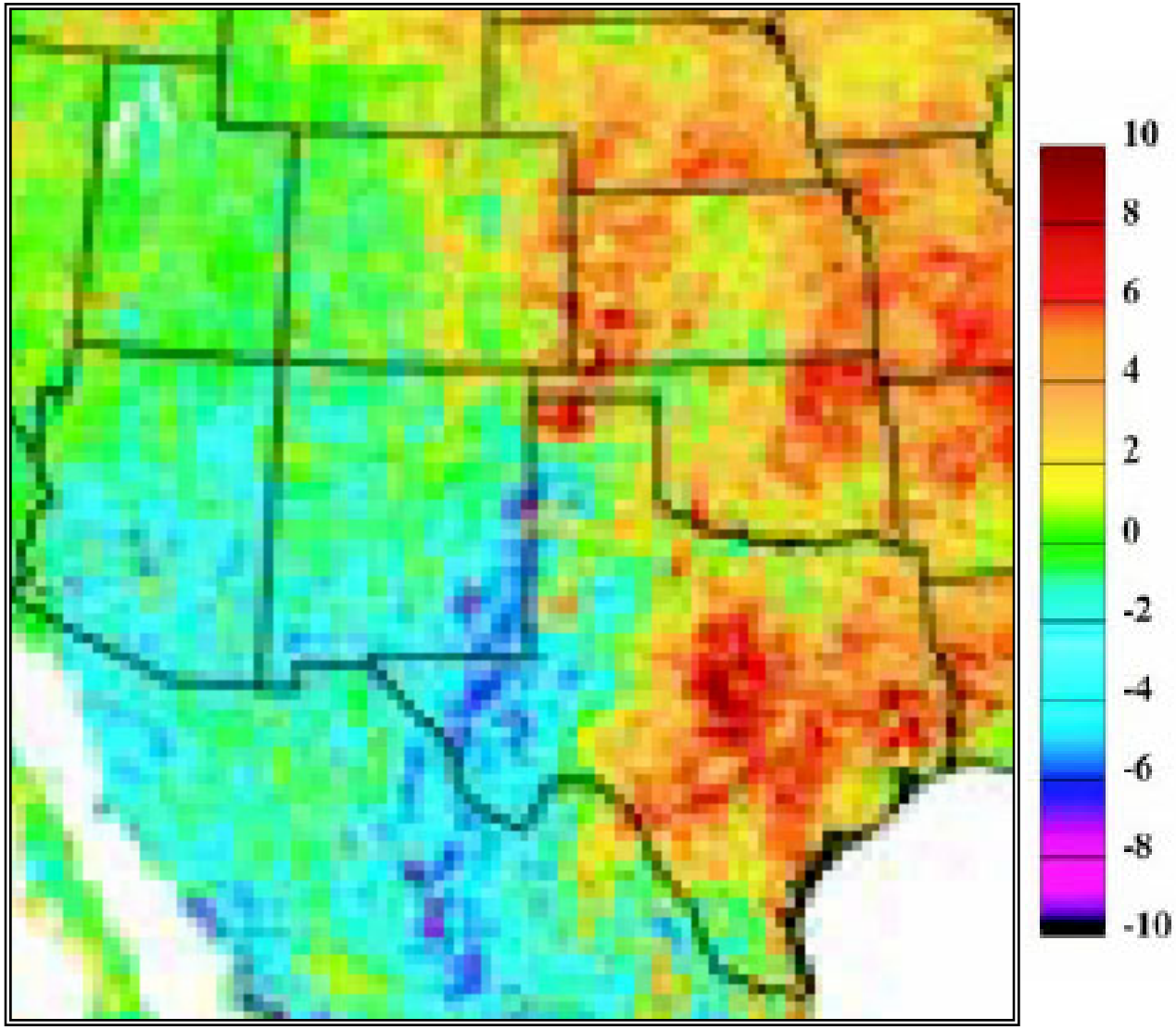

Figure 4. Trends in annual net primary productivity ($g/m^2/yr$) for the Southwest USA computed using the CASA model driven by the AVHRR NDVI 8 km product (1982 to 1998). Note large increases in ANPP in southern Texas and variable responses throughout the Southwest, even at 8km resolution, indicate loss in productivity perhaps through desertification processes. (Figure from Hicke J.A., G.P. Asner, J. Randerson, S. Los, S. Birdsey, C.J. Tucker, and C.B. Field. 2002. Satellite-derived increases in net primary productivity across North America, 1982–1998. *Geophysical Research Letters* 29(10):10,1029/2001 GL013578.)