Modeling sagebrush ecosystem in the Reynolds Creek Experimental Watershed for different CO2 and fire conditions,with the Ecosystem Demography (EDv2.2) model

Karun Pandit[a], Hamid Dasthi[a], Nancy Glenn[a], Alejandro N. Flores[a], Douglas J. Shinneman[b], and Andrew T. Hudak[c]

Acknowledgements
Boise Center Aerospace Laboratory (BCAL)
Lab for Ecohydrogy and Alternate Futuring (LEAF)

<u>Funding Agencies</u>
Joint Fire Science Program (JFSP)
NASA-TE
Western Wildland Environmental Threat Assessment Center (WWETAC)

[a]Department of Geosciences, Boise State University, Boise, ID
[b]U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Boise, ID
[c]U.S. Forest Service, Moscow, ID

Threats to sagebrush ecosystems

Sagebrush ecosystem in the Western U.S. affected by **wildfire frequency, climate change, and invasion from non-native species** like Cheatgrass (*Bromus tectorum*) resulting in altered vegetation composition, hydrological function (Schroeder et al., 2004, Connelly et al., 2004; McArthur and Plummer, 1978; Schlaepfer et al., 2014).

Image credit: Anna Roser

Restoration efforts

- **Restoration activities** like reducing flammable vegetation, transplanting sagebrush, seeding native grass (Chambers et al., 2014; McIver and Brunson, 2014)
- **Effectiveness** of these programs are largely **unexplored at regional scales**

Ecosystem dynamic models

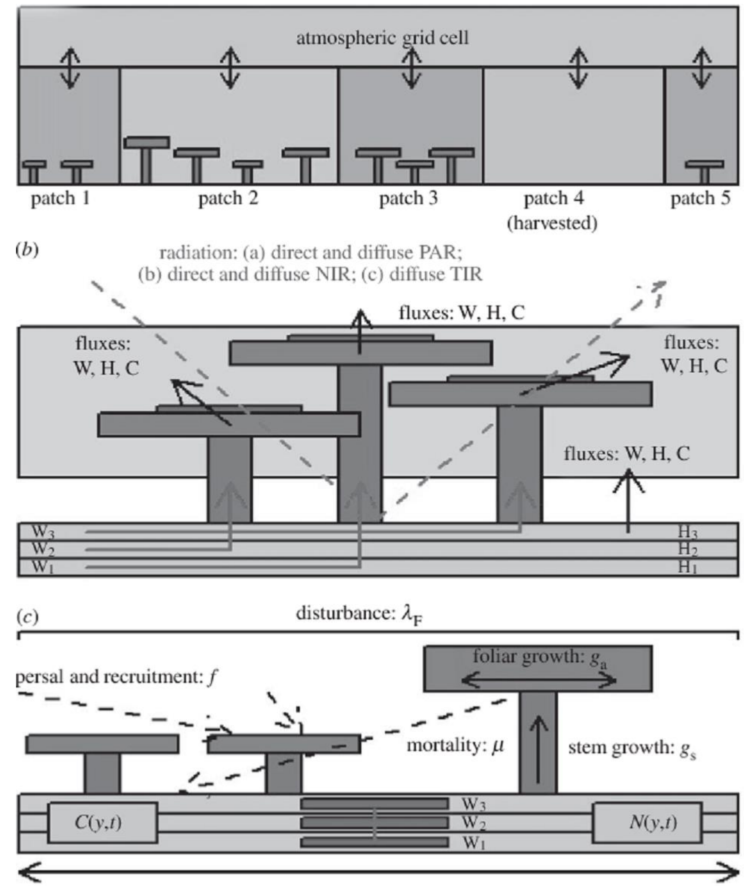
- widely used to estimate terrestrial vegetation composition and biomass over time and space
- efficiency over direct field measurements and their applicability to broader spatial scales (Dietze et al., 2014; Fisher et al., 2017)

General Questions

- Can we **explore the effects of disturbances and restoration** in sagebrush ecosystem at regional scales, using some **dynamic vegetation model** ? What would be the associated **uncertainties** ?

Ecosystem Demography (EDv2.2) model

- A **cohort based dynamic vegetation model** where land surface is composed of a series of gridded cells, that experiences meteorological forcing (Medvigy, 2009; Moorcroft et al., 2001)



EDv2.2 model structure and processes
(source: Medvigy et. al., 2009)

Specific questions

- parameterizing sagebrush (*Artemisia* spp) shrub PFT in ED model ?
- exploring the dynamics of sagebrush ecosystem at basin scale under different climate, vegetation, and fire scenarios?

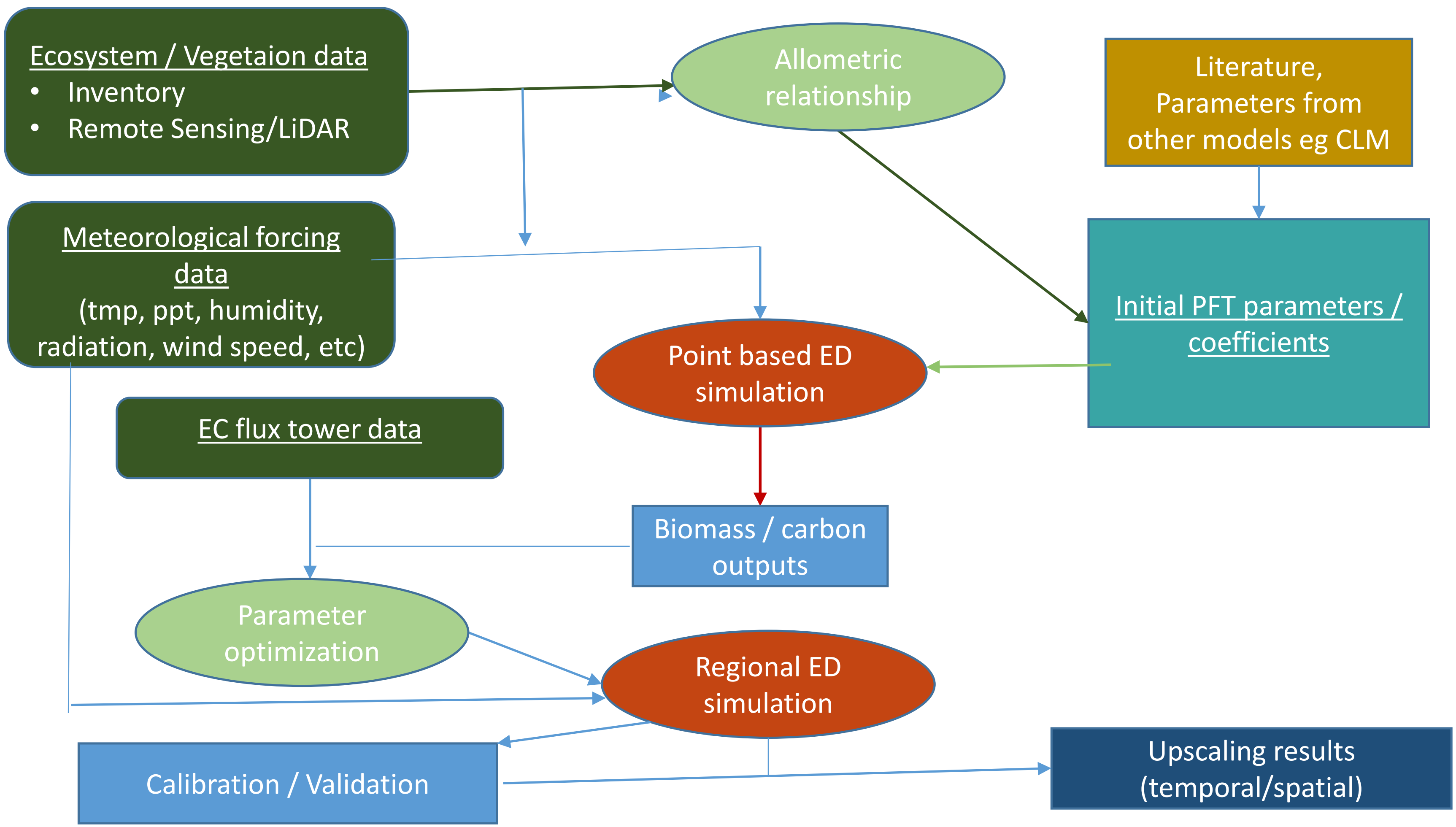


Fig. Major processes and inputs involved in modeling ecosystem dynamics using ED

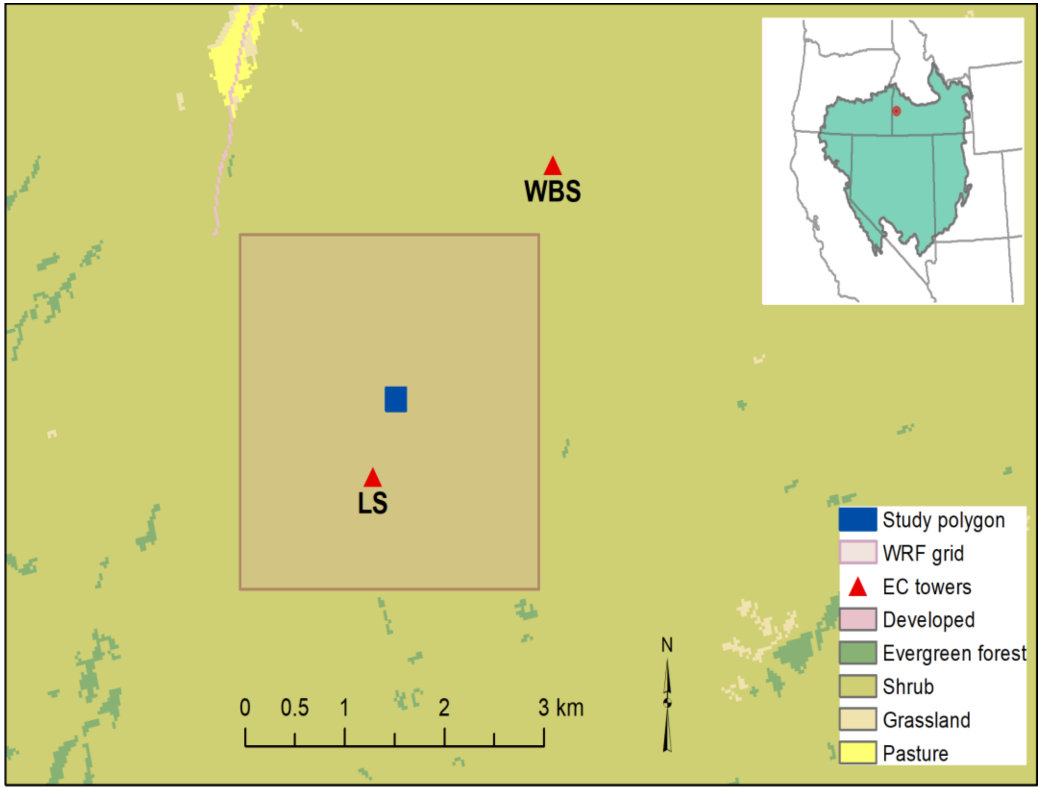
1. Sagebrush PFT parameterization

a. Initial parameterization

- field data (allometric relationships),
- literature,
- PFT parameters in ED/CLM and other land models

b. Sensitivity and optimization

- point scale
- initial vegetation
- 15 years run
- forced with WRF meteorological data
- Calibrated and validated against GPP derived from flux tower data at two locations in Reynold Creek



b. Sensitivity and optimization

parameters selected were mostly related to ecophysiology and biomass allocation

Sensitivity Index was calculated as,

$$SI = \frac{GPP_{max} - GPPmi_{n}}{GPP_{max}}$$

Optimization was done with exhaustive search method

c. Validation

- GPP outputs from optimum parameters were compared with GPP from flux tower data
- Nash-Sutcliffe efficiency (NSE) score was used for interpretation (Nash and Sutcliffe, 1970)
- $NSE = 1 - \frac{\sum_{i=1}^{n}(O_i - P_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O})^2}$

where, O_i is observation, P_i is predicted value, $\bar{O}$ is mean of observation, and *n* is number of observations.

Parameter sensitivity - results

Parameters	Initial	Min	Max	SI
Specific Leaf Area (SLA) (m^2kg^{-1})	4.5	2	15	0.973*
V_{m0} ($\mu molm^{-2}s^{-1}$)	16.5	4	30	0.962*
Stomatal Slope	7	2	15	0.951*
Ratio of fine roots to leaves/ Q-ratio	3.2	0.4	12	0.801*
Fineroot Turnover rate (a^{-1})	0.33	0.1	2	0.787*
Leaf Turnover rate (a-1)	1	0.1	2	0.728
Growth respiration factor	0.33	0.11	0.66	0.718
Cuticular conductance ($\mu molm^{-2}s^{-1}$)	10^3	10^2	10^4	0.672
Water Conductance ($ms^{-1}kgCroot^{-1}$)	1.9×10^{-5}	1.9×10^{-6}	1.9×10^{-4}	0.227
Seedling mortality	0.95	0.25	0.99	0.007
Leaf width (m)	0.05	0.01	0.30	0.006
Storage turnover	0.624	0.50	0.95	0.003

Optimized parameters

Parameters	LS EC station			WBS EC station	
	Best case	Ensemble mean		Best case	Ensemble mean
V_{m0} (μmolm^{-2}s^{-1})	14.00	18.50		14.00	15.80
SLA (m^{2}kg^{-1})	6.00	7.95		6.00	7.50
Stomatal slope	10.00	7.60		10.00	8.60
Fine root turnover (a^{-1})	0.33	0.22		0.33	0.24
Q-ratio	3.20	2.64		3.20	1.94

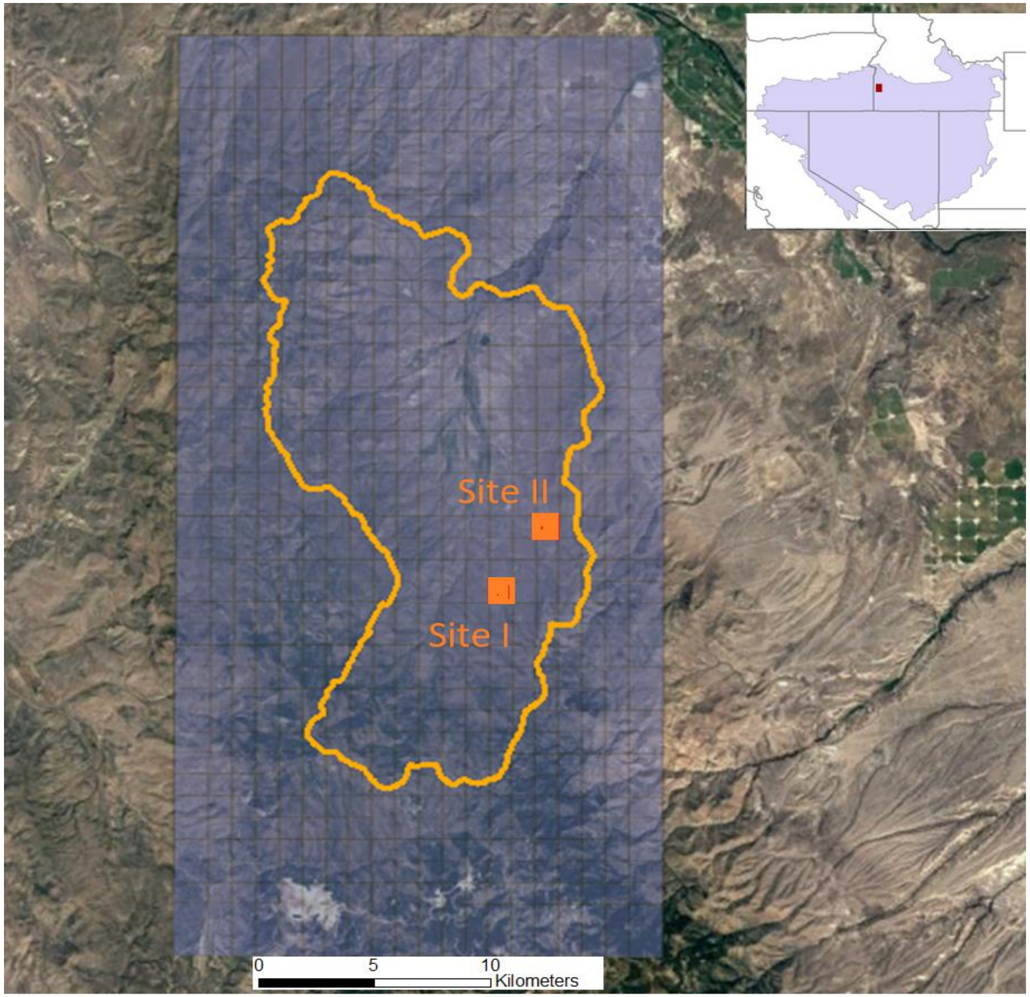
Summary

- With optimized parameters, ED predicted daily GPP quite well with some negative bias
- GPP during spring months were not captured well.
- Non-linear relationship between the parameters was not captured.

2. Exploring sagebrush ecosystem dynamics

Study Area

- Covers Reynold Creek Experimental Watershed
- 20 * 40 grid
- 1 Km resolution



Data

<u>Meterological forcing</u>

- Weather Research and Forecasting (WRF) model to subset required forcing data
- 1 km spatial resolution
- 3 hour temporal resolution
- Data from 1988 – 2016 used

Data

- Eddy Covariance tower data from two locations (Fellows et al., 2017)
  - GPP based on observation data

Modeling scenarios

A. Vegetation dynamics

1. Bare earth (with default CO_2)
2. Initial vegetation (with default CO_2)
3. Increased CO_2 (with bare earth)

Simulated for 20 plus years

B. Disturbance with fire

Fire introduced after 25 years of bare earth simulation

Bare earth = 0.1 plants / m2 for shrub, C3 grass, and conifers

Initial vegetation = 0.25 plants/m2 of shrub and C3 grass

Default CO_2 = 370 ppm ambient CO_2

Increased CO_2 = 740 ppm ambient CO2

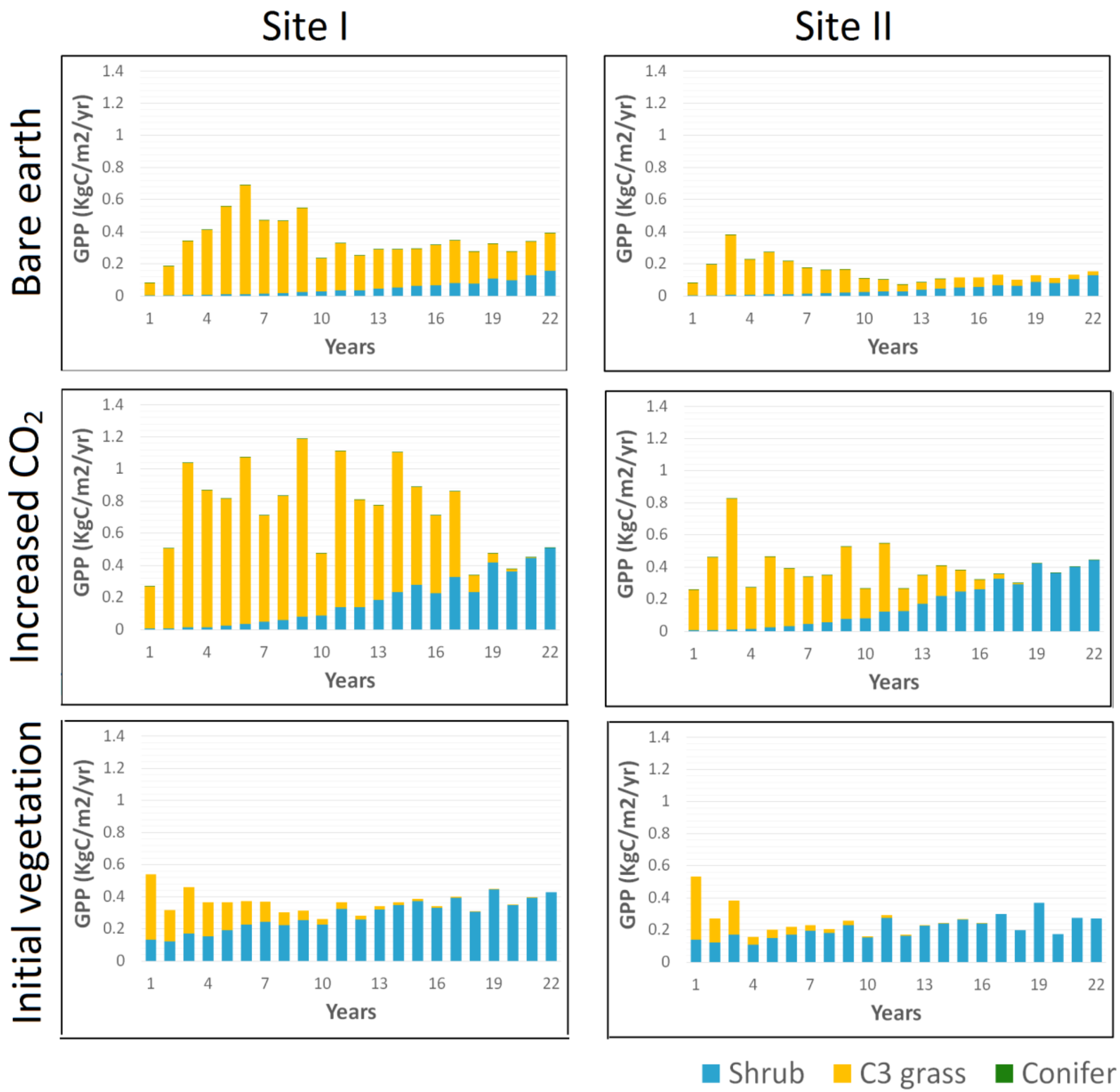
Results

There are some site specific variations

But, in general, similar PFT competition trends between sites

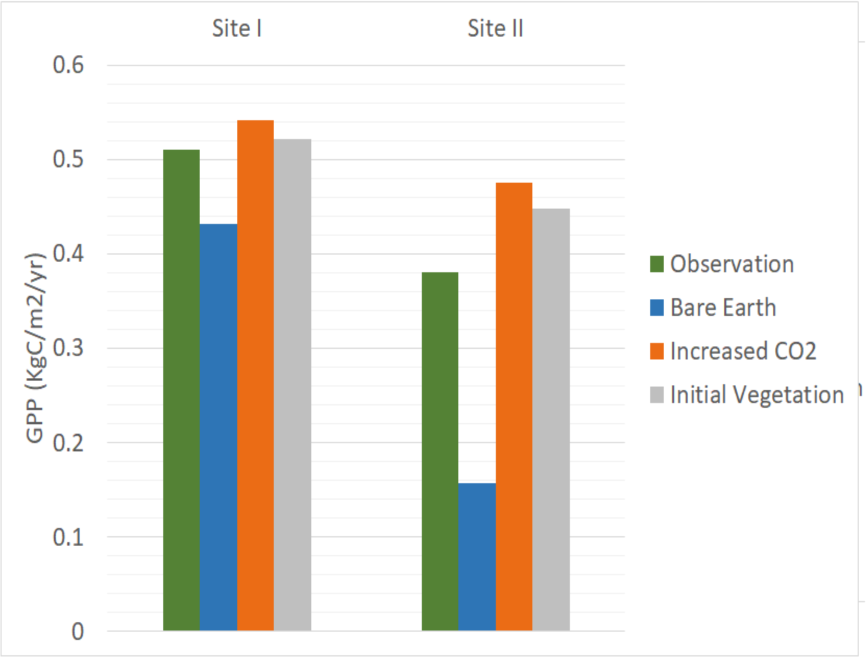
Shrub (sagebrush) PFT dominating

Increased CO2 – had increasing conifer species but at low magnitude

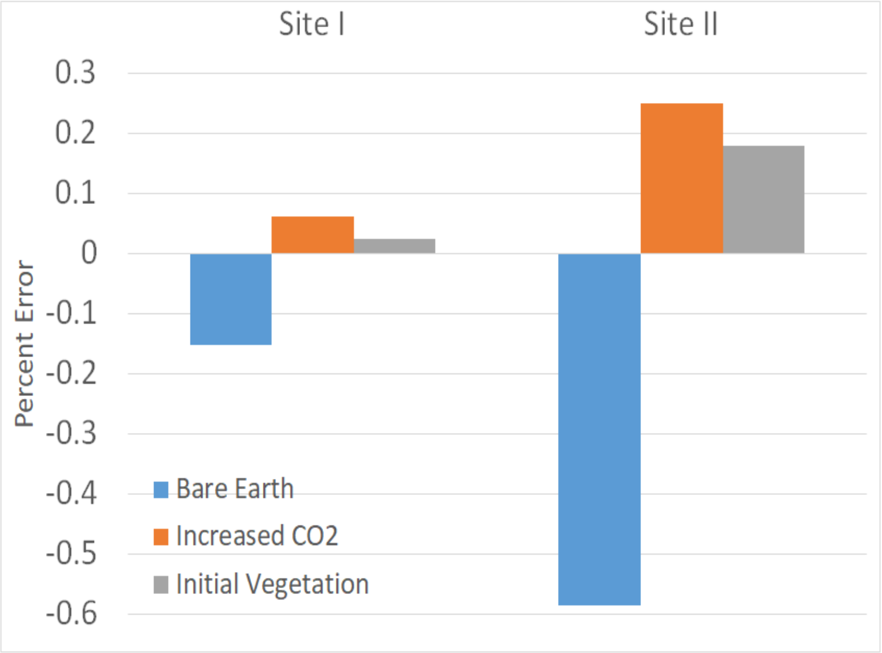


Comparison of simulated GPP (from final year) with EC tower observation

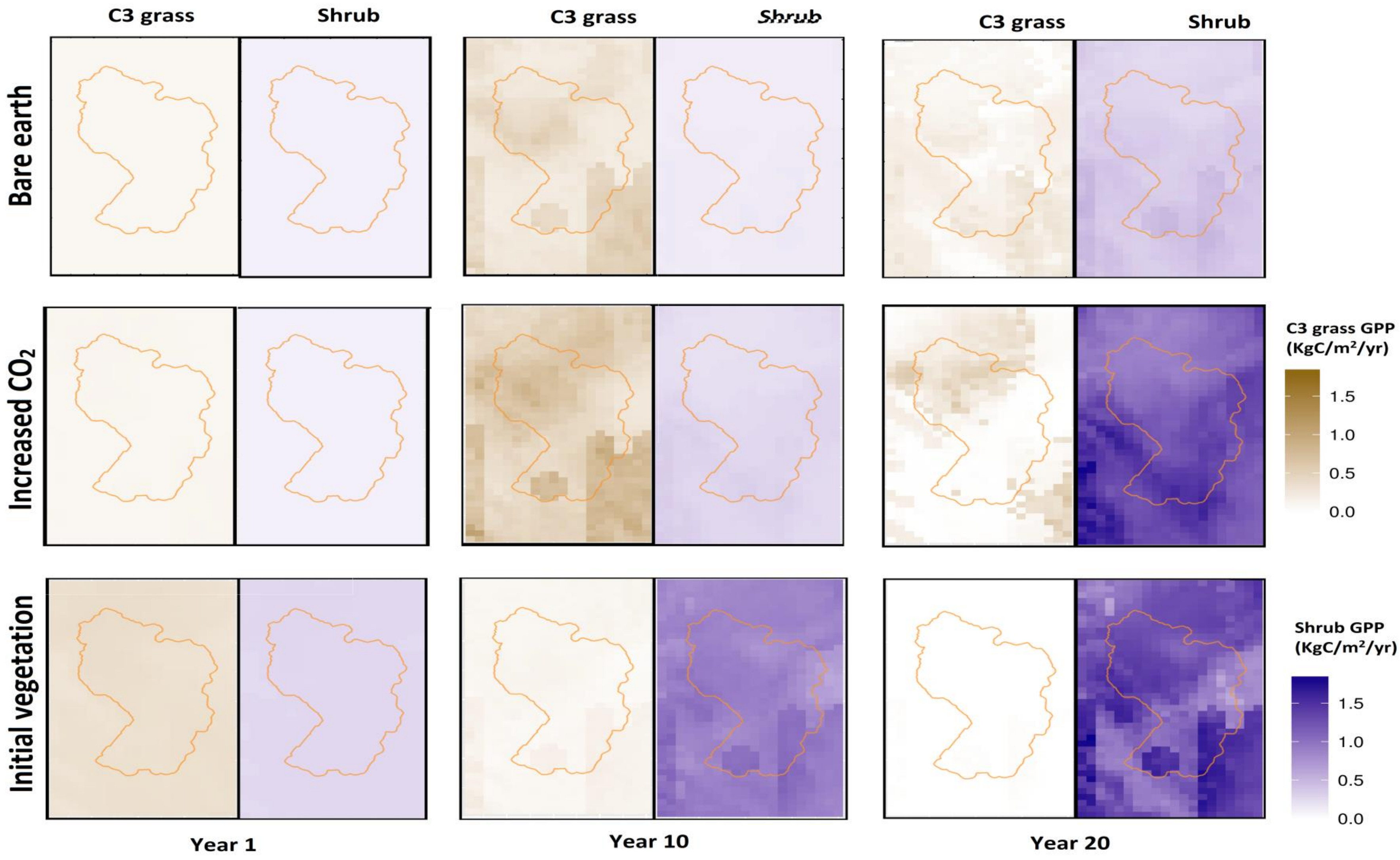
GPP (KgC/m2/yr)



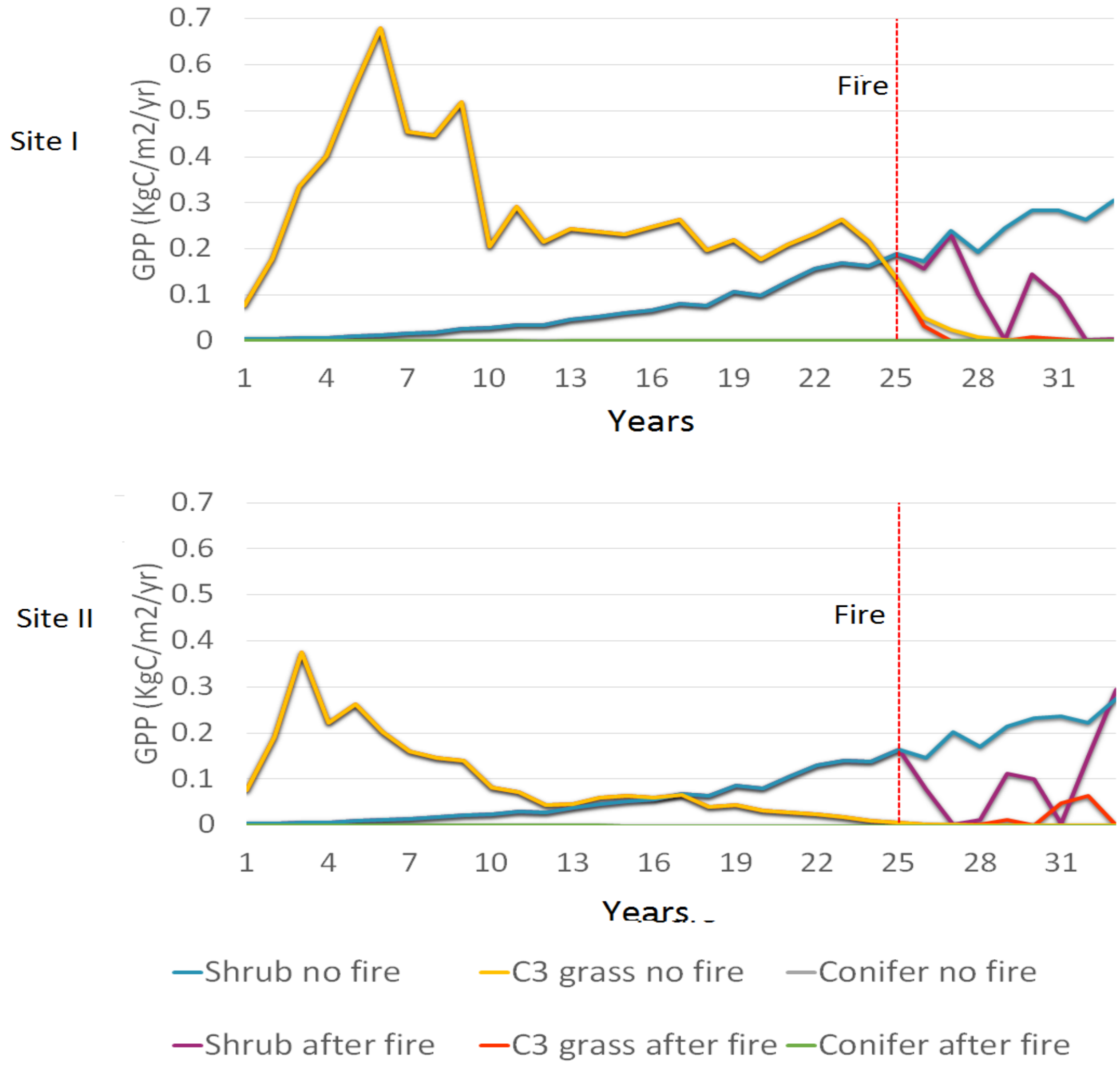
Percent Error



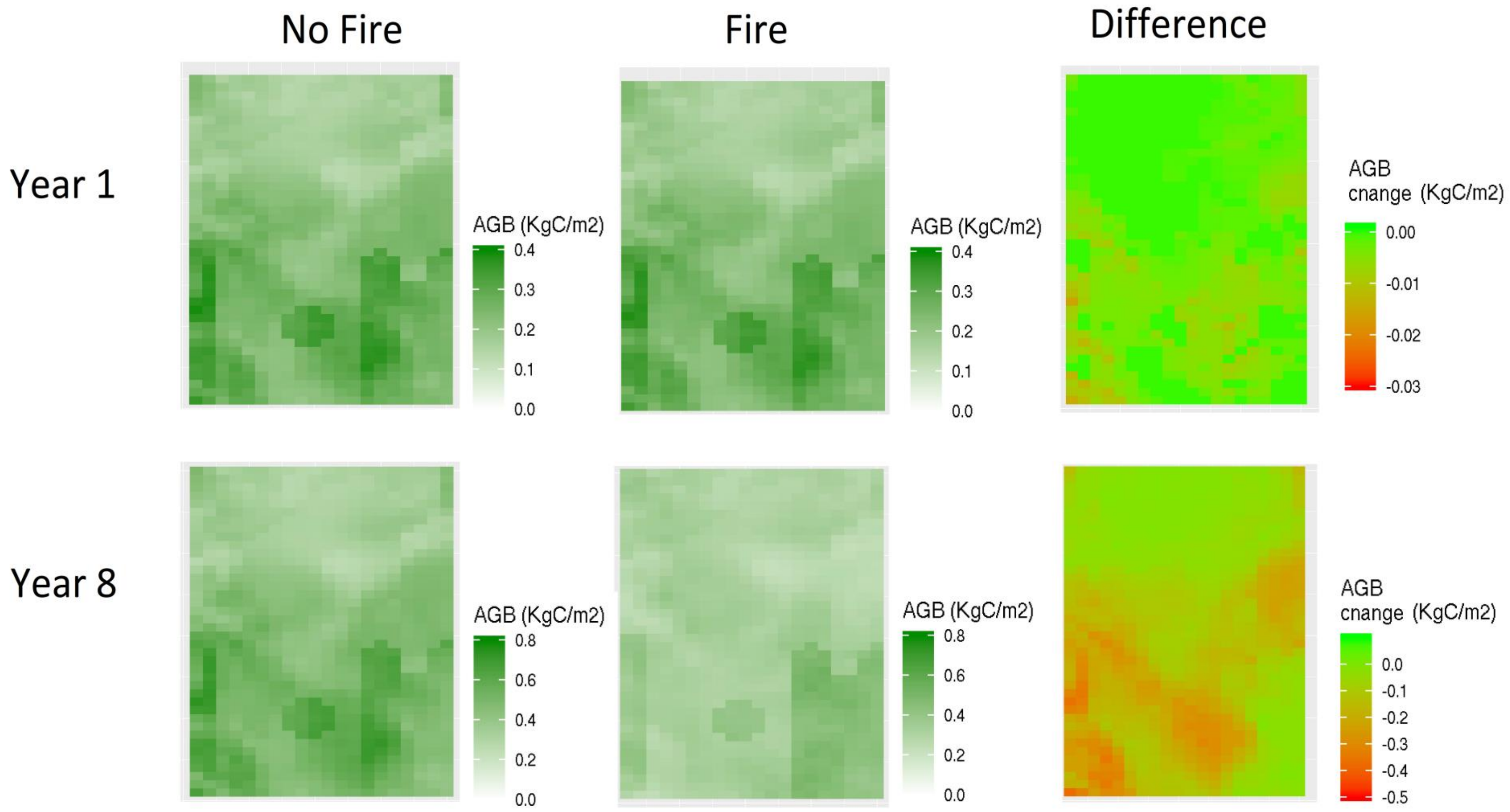
GPP (KgC/m2/yr) for C3 grass and Shrub



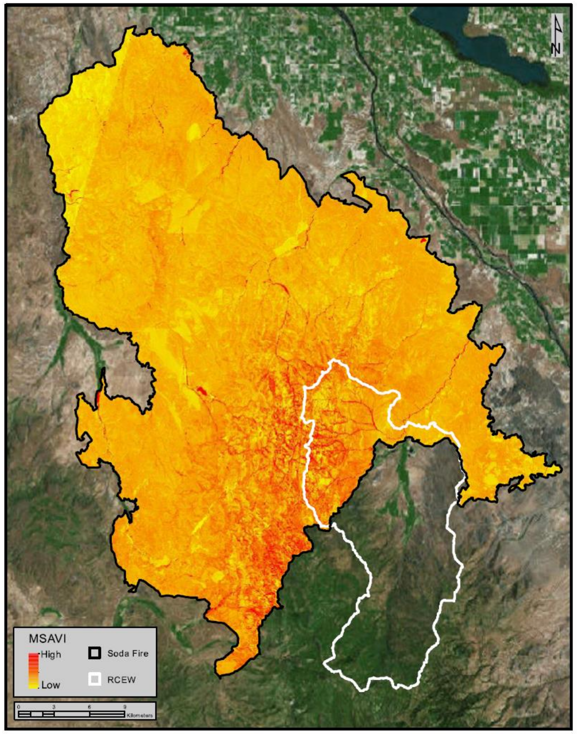
Introduction of fire



AGB (KgC/m2) for fire and no fire conditions

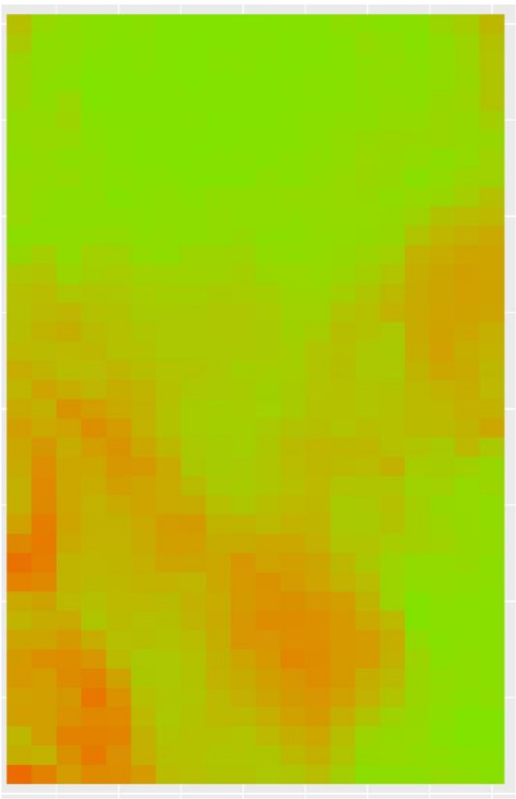


- Can we make some comparisons with actual fire incident at RCEW?
- 2015 Soda Fire

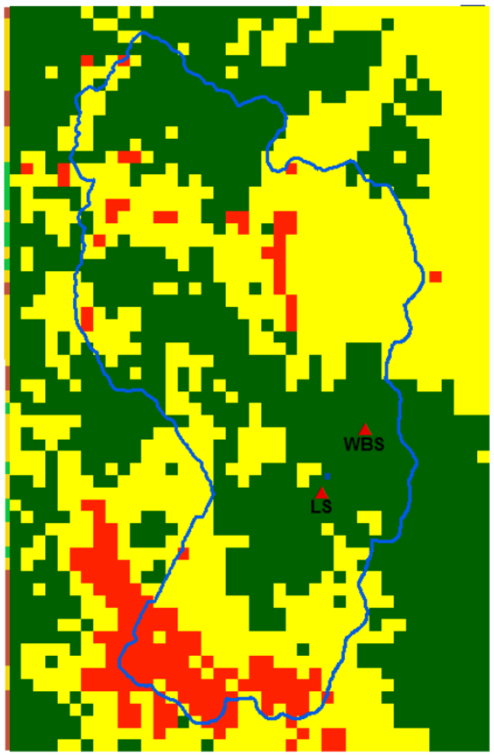


Poly, A., 2017

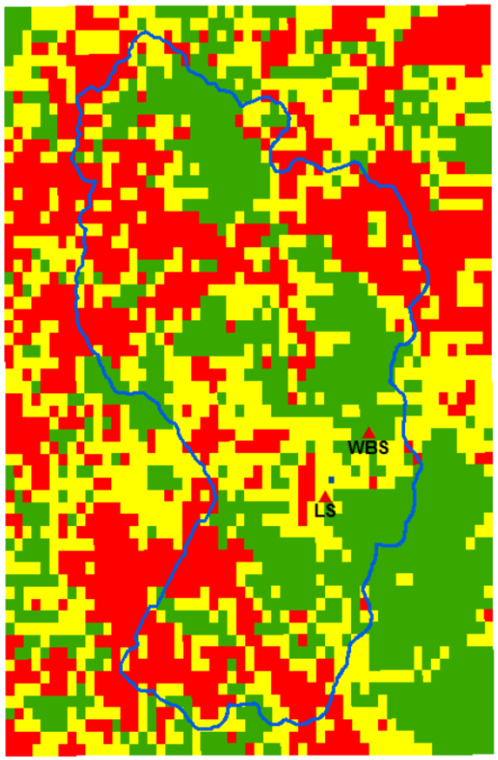
Comparison with information from Landsat data



Model output



Change in NDVI



change in GPP

Summary

- After 20 years we did not see coexistence of C3 grass and shrub
- Conifer could encroach some of the shrublands with increased CO_2
- Disturbance from fire is more evident after few years and shows some spatial pattern

Future work

- Compare results from PFT coverage with percent cover maps derived from hyper spectral images.
- Tweak C3 and conifer PFT parameters in ED2 to better model vegetation composition.
- Compare fire related disturbance with some observed data.

Thank You !