Vulnerability of US National Parks to Land Use and Climate Change and Variability

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Abstract

The US National Park Service (NPS) faces the challenge of maintaining ecosystem function and biodiversity within National Parks in the face of climate and land use change. New satellite and other technologies have increasingly allowed reconstruction for past decades of climate and land use at fine spatial scales and consequences for ecosystem processes such as NPP and fire risk. These reconstructions reveal high levels of spatial heterogeneity across the US in directions and magnitude of change in climate, NPP, fire risk, and stream flows. This study will harness these new data sets to better inform the NPS about threats to National Parks. The goal of this study is to assess park vulnerability to current and near-term future climate and land use based on detailed reconstructions and analyses of change and ecological response over the past 50-100 years. The study will include the 70 National Parks in the US that are relatively large in area (>35000 ha). The study will include the 70 National Parks in the US that are relatively large in area (>35000 ha). The study will define and include the larger ecosystem surrounding each park. Potential drivers (climate and land use), ecosystem response NPP, stream flow, fire risk, habitat area, and biodiversity response (representation of native species guilds, exotic species, species richness) will be quantified across the 70 national parks during the 1900s using NASA and other imagery, data, and models. Statistical patterns of association will used to evaluate the plausibility of cause and effect relationships between the potential drivers and response variables. The vulnerability of each of the parks to current and near-term future climate and land use change will be assessed based on the RAPPAM methodology. The results will be used to suggest to the NPS which parks are high priority for mitigation, and the primary issues that threaten the parks, and mitigation strategies.

Rationale

A central goal of the US National Park Service is to maintain ecological functioning and native species within National Parks. While the attention of park managers is often on important near-term challenges, they also face maintaining parks under long-term and broad-scale change in climate and land use in and around parks. Climate has warmed in many locations in the US over the last century and variability in temperature and precipitation have increased. In some National Parks, these changes in climate have lead to increased fire, more frequent low stream flows, and reduced net primary productivity (NPP). Similarly, some National Parks have experienced changes in land use on the surrounding lands. Increases in agriculture, rural homes, and cities have reduced the area of natural habitats around parks. Such land use changes in the lands around parks can have strong negative impacts on ecosystem function and biodiversity within parks.

Unfortunately, many park managers are not well aware of rates of change in climate and land use in their regions over the past century nor how these changes may be influencing park ecology. This is partially because tools for mapping change in climate, land use, and ecosystem processes have only become available in the last year or two at the finer spatial resolutions needed for park management. Initial analyses indicate that climate change and resulting ecosystem function varies in spatially complex ways. For example, spring temperature has increased at a rate of 5^{o}C/100 years in parts of the US and decreased at a rate of 2^{o}C/100 yrs in other places (Fig. 1).

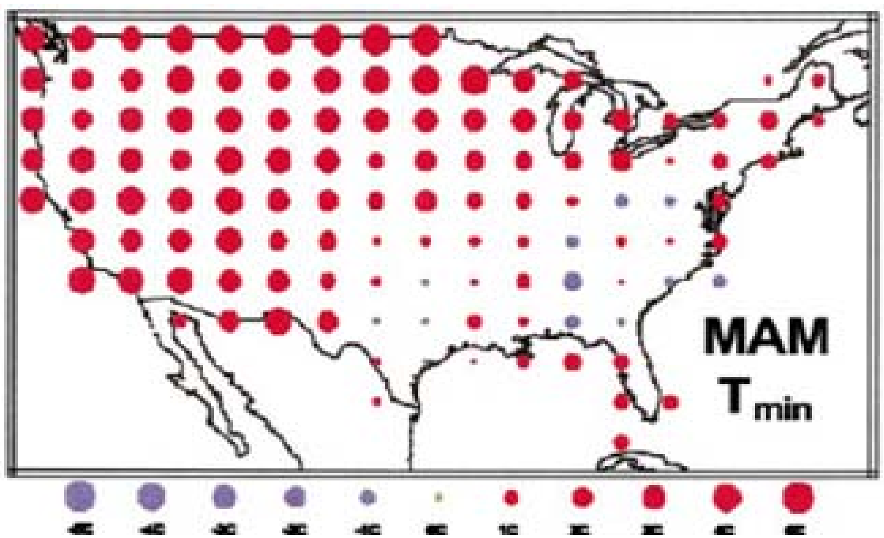


Figure 1. Spring (Mar-May) minimum temperature trends for 1950-2002. Red dots indicate increasing trends and blue dots indicate decreasing trends. The dot areas are proportional to the trend values [^{o}C (100 yr)$^{-1}$, with the largest equal to +-5^{o}C (100 yr)$^{-1}$. From Groisman et al. 2004

Similarly, percent change in NPP since 1982 across North America has ranged from +30% to -30% (Fig. 2). Land use change over the past 50 years has also varied across the US with many places increasing in population and some losing population. Thus, the regions encompassing some National Parks have undergone little change in climate or land use, some have changed only in climate or land use, and many have experienced rapid land use intensification and substantial change in climate.

Rationale

Park managers would greatly benefit from knowing past change in climate and land use and consequences for ecological processes and biodiversity. Resources for research and management are limited in the National Park Service and must be carefully allocated. Knowledge of the types and magnitudes of current and future threats would allow park managers to set long term strategies to mitigate the highest priority threats and tailor these strategies to the most important places in the landscape.

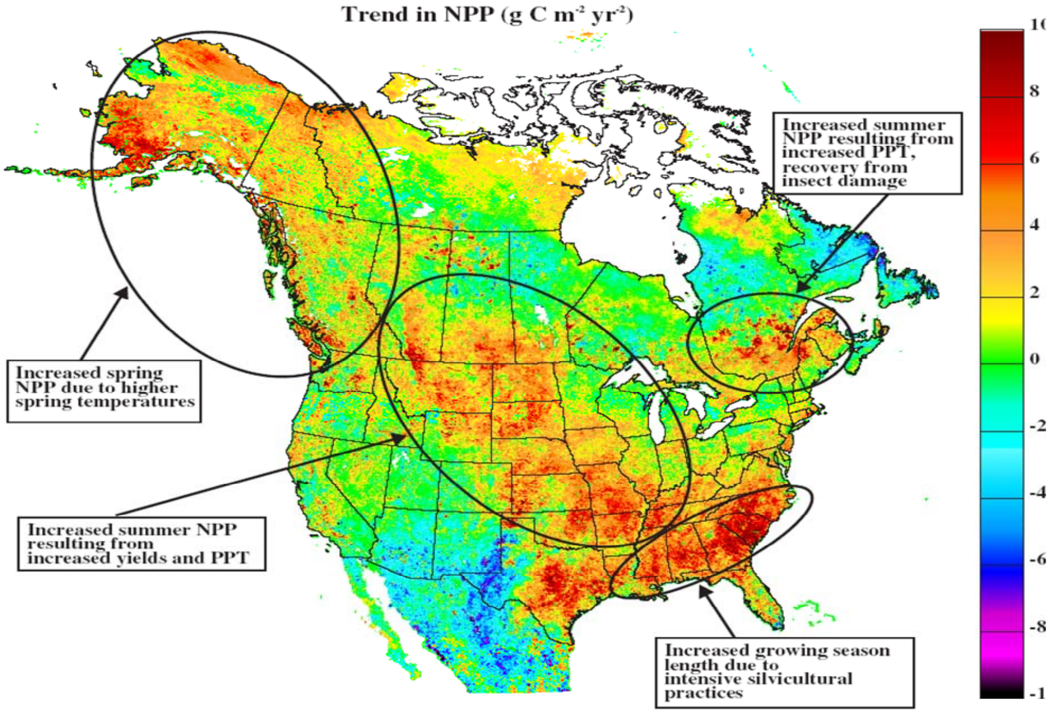
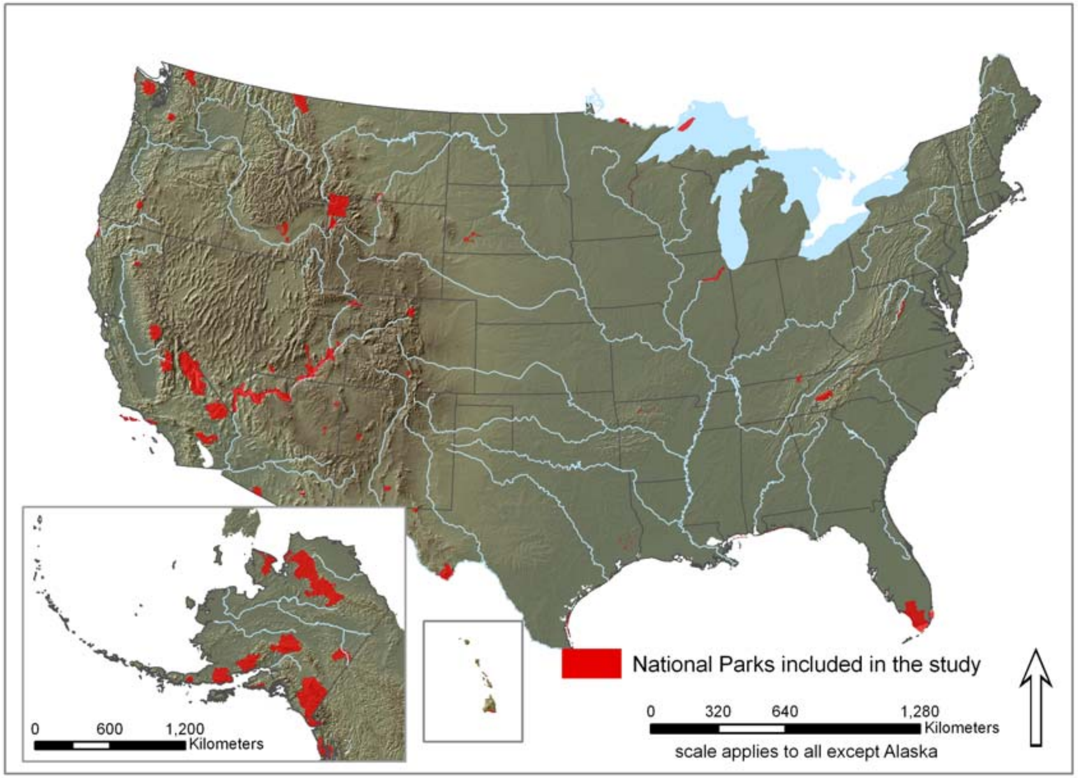


Figure 2. Percentage increase in NPP (1982–1998), computed by multiplying the linear trend at each location by the number of years in the time period (17), then dividing by the 1982 NPP. Modified from Hicke et al. 2002.

Study Area



The study includes the 70 National Parks in the US that are relatively large in area (>35000 ha) (Fig. 2). These parks are large enough to have adequate ecological function and are widely distributed relative to climate and land use gradients. Included in the analysis will be areas around each park that are selected to encompass the larger ecosystem that the park is embedded within.

Objectives

The goal of this study is to assess park vulnerability to current and near-term future climate and land use based on detailed reconstructions and analyses of change and ecological response over the past century. Assuming that change over the next 2-3 decades is likely to be heavily correlated with change in past decades, the results of the study will help to guide management to mitigate the most serious vulnerabilities. Specific objectives are:

1. Quantify change in land use and climate (mean and variability), ecosystem response (NPP, stream flow, habitat area) and biodiversity (representation of native species guilds, exotic species, species richness) during 1900-2003 (coarse spatial resolution) and 1982-2003 (fine spatial resolution).

2. Evaluate statistical patterns of association between land use and climate, ecosystem function, and biodiversity as a means of validating vulnerability indices.

3. Evaluate the vulnerability of parks to current and near-term future land use and climate based on past change and ecosystem and biodiversity response.

4. Derive guidelines for mitigating the primary vulnerabilities of each park.

Methods

The study will focus on past change in and around parks as a basis for assessing vulnerability to current and near-future conditions.

Potential drivers (climate and land use), ecosystem response, and biodiversity response will be quantified across the 70 national parks (Table 1). This will be done for all parks for 1900-2003 at a .5ox.5o resolution. For parks experiencing rapid change analyses will also be done for 1982-2003 at a 1-km resolution.

Statistical patterns of association will used to evaluate the plausibility of cause and effect relationships between the potential drivers and response variables (Table 2).

The vulnerability of each of the parks to current and near-term future climate and land use change will be assessed based on the RAPPAM methodology.

The results will be used to suggest to the NPS which parks are high priority for mitigation, and the primary issues that threaten the parks, and mitigation strategies.

Key Data Layers

Table 1. Description of key data layers to be used in the study.

Theme/Variable	Data Source	Spatial Resolution	Time Period and Interval
Climate			
PPT, TEMP, RH, Radiation	VEMAP (Kittell 1997)	$.5^o x .5^o$	1900-2003 annual
	DAYMET (Thornton et al. 1997)	1 km	1982-2003 annual
Land Use			
Human pop density	US Census	Census block	1940-2003 decadal
Land Allocation	Protected Areas Data (DellaSala 2001)	1:100,000	2000
Roads	U.S. Census TIGER data		1940-2003 decadal
Land use type based on housing density	Spatially Explicit Regional Growth Model (Theobald 2005)	100 m	1940-2003 decadal
Cover type	USGS NLCD (Vogelmann et al. 2001, Homer et al. 2004)	30 m	1992, 2001
Ecosystem			
Stream flow	USGS (http://water.usgs.gov)		1910-2003 annual
Natural habitat area	From home density (Gude et al. 2005)	1 km	1940-2003 decadal
Keetch-Byram Drought Index	DAYMET (Groisman et al. 2004	Effective ecosystem	1900-2003 fire season
NPP	Biome BGC (White et al. 2000)	1 km	1900-2003 ave annual
Biodiversity			
Potential species richness	Currie (2001)	2.5° x 2.5°	1900-2003 annual
Species at risk	Global cons status (NatureServe)		Current
Vertebrate Guilds	NPS expert opinion for trophic, seral stage, mig, exotic guilds		Current

Rationale

Table 2. Tests of hypothesized relationships between land use and climate and indices of biodiversity.

Driver/Mechanism	Ecosystem response	Biodiversity response	Tests
Land Use			
Effective Size	Natural habitat area	Fewer species based on area	Proportion of species at risk or extinct
		Change in trophic structure	Proportion of species at risk or extinct at each trophic level
	Loss of dynamic steady state equilibrium	Greater variability in seral stage specialists	Proportion of species at risk or extinct in each seral stage guild
Ecological Flows	Less natural disturbance entering park	Fewer early seral species	Proportion of species at risk or extinct in early seral stage guild
	Altered hydrological flows	Loss of native fish, increased exotic fish, increased exotic riparian plants	Proportion of native fish at risk or extinct, proportion exotic fish in community
Movement routes	Altered herbivory	Fewer migratory species	Abundances of migratory species Proportion of migratory species at risk or extinct
Edge effects		Fewer natives More exotic species, weeds, diseases	Proportion of native species at risk or extinct Proportion of exotic species
Climate mean and variability			
Extreme climate events	Extreme disturbance events (fire, floods)	Increased variability in abundance and distribution of species limited by climate/ disturbance	Proportion of species at risk or extinct within climate and disturbance sensitive guilds
Climate means	Change in NPP	Predicted species richness based on NPP	Number of species not at risk

Expected Outcomes

- Index of vulnerability to past and potential near future global change for 70 US national parks.
- Analysis of influence of past land use and climate change on native and exotic species fluxes in national parks.
- Guidelines on management strategies to mitigate highest priority global changes for 70 US national parks.
- Maps of land use histories in and around each national park for 1940-2000.

Status

The study is delayed a year due to difficulty recruiting outstanding graduate students. However, recruitment is now completed and one Ph.D. student will begin at Montana State University in June and one at the University of Montana in July.

Acknowledgements

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