# Using Fire History for Assessing Current & Future Fire Hazards

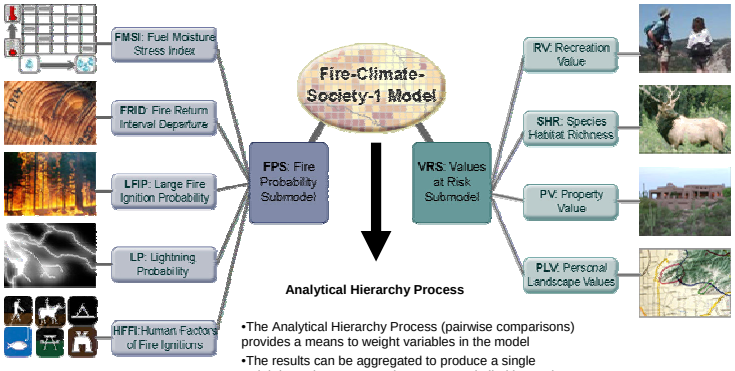
Thomas W. Swetnam[1], Michael Crimmins[2] and Barbara Morehouse,[3]
(1) Laboratory of Tree-Ring Research, University of Arizona, Tucson, AZ 85721, (2) Soil, Water & Environmental Sciences, University of Arizona, Tucson, AZ 85721
(3) Institute for the Study of Planet Earth, University of Arizona, Tucson, AZ 85721

## The Intersection of Fire, Climate and Society

Many forest and woodland ecosystems in western North America have undergone extreme changes during the past century, leading to increased hazard of high severity fires. In addition to forest structure and fuel changes, increased numbers of people living in these environments, and extreme droughts in recent years have led to extraordinary fire events, burning the largest areas in more than a century, destroying hundreds of homes and businesses, and damaging watersheds and habitats. Better management of forests and fire problems in the future, especially under changing climate conditions, will require the use of spatial/temporal analytical tools and datasets to map the current and anticipated fire hazards. We have developed a prototype tool for such analyses called "Wildfire Alternatives" (WALTER). We developed a "Fire-Climate-Society model (FCS-1) to integrates multiple spatial-temporal data layers to estimate fire risk and hazard.

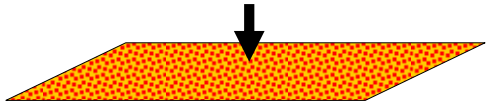
Unique aspects of the WALTER/FCS-1 approach are the integration of biophysical variables, historical and current fire and climate conditions, and social considerations. Additionally, the Analytical Hierarchy Process (AHP) is used to quantitatively weight and combine the multiple variables affecting fire hazard.

Photo courtesy of Julio Betancourt, USGS




**Analytical Hierarchy Process**

- The Analytical Hierarchy Process (pairwise comparisons) provides a means to weight variables in the model
- The results can be aggregated to produce a single weighting scheme, or used to compare similarities and differences in weighting patterns by type of evaluator



**Fire Risk Map**

## Climate and Fuel Moisture Stress

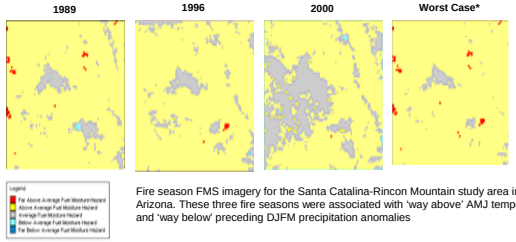
Annual Fire-Climate workshops organized under CLIMAS auspices highlighted the need for research that would integrate climate information into tools useful for strategic decision making. In FCS-1, climate information helps determine vegetation moisture conditions.

The Normalized Difference Vegetation Index (NDVI) derived from Advanced Very High Resolution Radiometer (AVHRR) imagery provides a proxy for vegetation moisture. NDVI products are converted into multi-temporal z-scores to produce vegetation moisture ratings that are comparable across the highly variable topography of the sky islands of the US Southwest.

Each fire-season (AMJ) composite fuel moisture stress (FMS) image in the period of record (1989-present) is available as an input layer to the FCS-1 model. Each seasonal image is linked to climate by a quintile ranking system. The concurrent AMJ temperature anomaly and preceding winter (DJFM) precipitation anomaly correlate most strongly with variability in the FMS imagery. These climate variables are used to classify the climate conditions associated with each fire season FMS image in the database. The information allows users to explore the connection between climate variability and fuel moisture stress and to relate seasonal climate forecast information to past conditions.

**Precipitation Quintiles (DJFM)**

| Temperature Quintiles (AMJ) | Way Below | Below | Normal | Above | Way Above |
|---|---|---|---|---|---|
| Way Above | 1989, 1996, 2000 | 1990, 1994, 2002 | 2003 | | |
| Above | | 1997 | | | 1992, 1993 |
| Normal | 1999 | | | | |
| Below | | | | | |
| Way Below | | | | | 1991, 1995, 1998 |

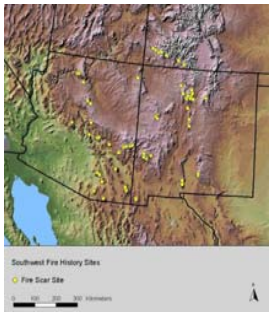



*The worst case scenario takes the highest fuel moisture hazard value from any of the available images relevant to this year to produce a new image comprised of highest values.

Fire season FMS imagery for the Santa Catalina-Rincon Mountain study area in southeastern Arizona. These three fire seasons were associated with 'way above' AMJ temperature anomalies and 'way below' preceding DJFM precipitation anomalies

## Paleo-Fire & Climate

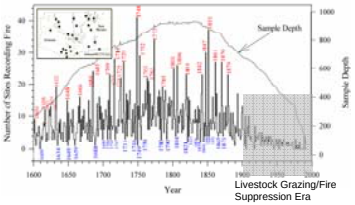
Extensive tree-ring reconstructions of fire and climate histories spanning the past three centuries provide insight on inter-annual to decadal-scale climate drivers of fire occurrence and hazard. Lagging patterns of wet/dry conditions and the El Nino-Southern Oscillation have been especially important in the Southwestern US. These insights from the paleo record have led to testing and confirmation with modern observations, and subsequent use of the climate-fire patterns in forecasting.




The fire-scar chronology network in southwestern North America currently includes about 110 sites.

Most sites 10-100 ha, some >1000 ha. Typical sample sizes ≈ 10-50 fire scarred trees, hundreds in a few cases.

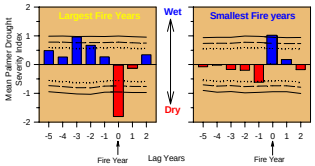
The SW fire history network represents the collective effort of many people and institutions over more than 3 decades.




The Southwestern US network of fire scar sites shows a high degree of regional fire synchrony – and as expected, the largest and smallest fire years are well correlated with dry and wet years, respectively.

In addition to current year dry conditions, large fire years are also associated with one to several prior years of wet conditions. Smallest fire years show the opposite pattern.

The importance of fine fuel production, e.g., grasses and tree needles – is reflected in these patterns.

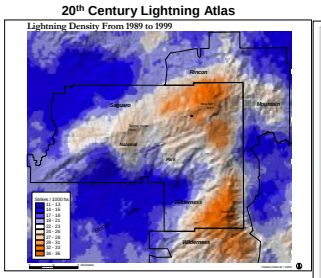



## Modern Fire & Climate

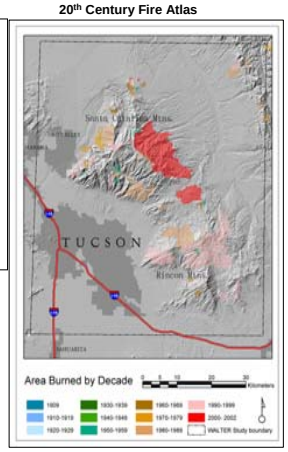
The fire history component of FCS-1 is designed to answer two basic questions: (1) Based on historical information, what are the spatial and temporal patterns of human-caused ignitions and naturally caused fire ignitions? (2) What factors influence these patterns? GIS-based modeling of fire history data provides an essential bridge that allows a combination of human dimensions and natural science components in the integrated model. Such spatial database development and mapping facilitates analysis of the relative contribution of humans and natural events to fire regimes in different ecosystems, and allows analysis at different time and spatial scales. These data layers are integrated directly into the FCS-1 model.

**20th Century Lightning Atlas**

Historical lightning strike data, collected by the National Lightning Detection Network, is synthesized into strike density maps as a proxy for ignition probability.




**20th Century Fire Atlas**




**Fire Return Interval Departure**

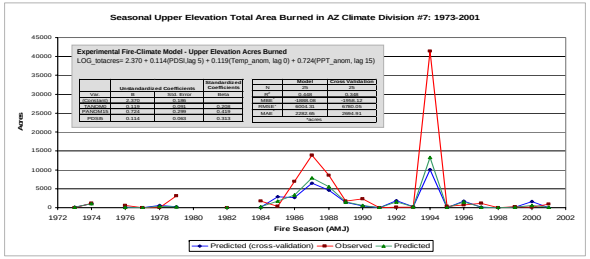
An index of the historical interval between fires for each vegetation type, and the years that have elapsed since the last fire.

$$\text{FRID} = \frac{\text{(Years since last fire - Natural Fire Return Interval )}}{\text{Natural Fire Return Interval}}$$

## Supplemental Guidance Tools

Several additional web-based modules are available on the WALTER site to assist users in weighting input variables for the FCS-1 model and to provide focused information that pertains to the intersections between wildfire, climate, and society. Modules include an experimental regression based forecast model that uses antecedent climate conditions to forecast upcoming wildfire season activity, policy analysis decision trees, fire history mapping tools, reference lists, and links to external sources of information.

**Fire-Climate Regression Modeling**




## Summary

- Paleo and modern fire and climate histories are useful for discovering important climate drivers of fire occurrence, and these can be useful in planning and forecasting models.
- The WALTER/FCS-1 approach includes fire-climate patterns from historical analysis, along with many other biophysical and social variables to develop maps of fire risk. These kinds of tools are needed for guiding forest restoration efforts, developing Community Wildfire Protection Plans, and for anticipating locations and times when fire/climate-related hazards will be highest.
- As climate changes, we will need WALTER-like tools that are dynamical, i.e., that allow for real time and near-real time data on climate and other conditions that alter fire hazard and risk. Hence, integration of both historical and current information will be increasingly important.

## Acknowledgements

We thank the other principal investigators and contributing scientists of the WALTER project, which include Gary Christopherson, Andrew Comrie, Barron Orr, Jonathan Overpeck, and Steve Yool, all of the University of Arizona. We also thank the many staff and students of the Institute of the Study of Planet Earth, Office of Arid lands Studies, Laboratory of Tree-Ring Research, and Department of Geography & Regional Development. The WALTER project was funded by the US EPA STAR Program. Fire history research was supported in part by the USDA Forest Service, US Geological Survey, National Park Service, and National Science Foundation grants to T.W. Swetnam.

**Corresponding Author Contact Information:**
Thomas W. Swetnam
Laboratory of Tree-Ring Research
The University of Arizona
Tucson, AZ 85721
tswetnam@ltrr.arizona.edu

**http://walter.arizona.edu**