FINAL REPORT, JOINT FIRE SCIENCE PROGRAM AFP3-2003

Project Title: Climate drivers of fire & fuel in the Northern Rockies: Past, Present & Future

JFSP Project No.: 03-1-1-07

Project Locations: We collected data in the Northern Rocky Mountains including Idaho, Montana (west of the continental divide) and northeastern Wyoming on 12 national forests, 2 national parks and state and privately owned land (see appendix). Research was conducted at University of Idaho, Latah County, Moscow, ID, First Congressional District; Fire Science Laboratory and Aldo Leopold Wilderness Research Institute, Rocky Mountain Research Station, USDA Forest Service, Missoula, MT, First Congressional District.

Principal Investigators: Penelope Morgan, Emily Heyerdahl, Carol Miller, Matthew Rollins

Contact Information:

Contact Information:	Penelope Morgan	208-885-7507	pmorgan@uidaho.edu
	Emily K. Heyerdahl	406-829-6939	eheyerdahl@fs.fed.us
	Carol Miller	406 542-4198	cmiller04@fs.fed.us
	Matt Rollins	406-329-4960	mrollins@fs.fed.us

SUMMARY OF FINDINGS TO DATE

Polygon fire history for the northern Rocky Mountains: Accuracy, strengths, and limitations of digital fire perimeter data

- Modern fire regimes differ greatly across the diverse vegetation types and biophysical settings of the US Northern Rockies, including Idaho, Montana west of the Continental Divide, and Yellowstone National Park .Available polygon fire histories were acquired for 12 national forests and two national parks to build a digital Northern Rockies fire atlas.
- There was good agreement between National Interagency Fire Management Integrated Database (NIFMID) and the fire atlas over the period 1970 to 2003 in identifying four regional fire years (years of extensive burning) and four years of lowest fire activity.
- The fire atlas is a better reflection of large fires and fire years than those of lower extent and activity.
- The eleven regional fire years, identified as those years that exceeded the 90th percentile in fire extent from 1900 through 2003 in the fire atlas, accounted for 77% of all area burned in the region during the 20th century.
- Key limitations of the fire atlas that contributed to inaccuracies include changes in mapping standards, methods, and recording over time. However, this fire history is spatially explicit and complements existing fire history methods, such as tree-ring analysis.
- The existing interagency protocols can be improved by incorporating fire regime descriptors (e.g. severity), actual area burned, robust metadata, and standardized map projections and coordinate systems.

- The Northern Rockies fire atlas is a bridge between the past and present, helping us apply the lessons from fire scars and other fire proxies to the present and future. Although it contains some inaccuracies in fire locations and gaps in recording, it is: (i) the only spatially explicit record of fire for the entire 20th-century; (ii) consistent with both short fire records (e.g., NIFMID and satellite imagery) and long ones (e.g., tree rings); and (iii) contains records that are sufficiently accurate to reveal modern climate drivers of fire that are consistent with historical ones.
- The collection and preservation of fire atlas records should be a priority in other regions of North America.

Multi-season climate synchronized widespread forest fires throughout the 20th-century, Northern Rocky Mountains

- We identified climate during years of regionally synchronous forest fires in the US northern Rocky Mountains. We used annual fire extent from the Northern Rockies fire atlas that includes annual fire extent from nearly 13 million ha of forested land in Idaho and Montana west of the Continental Divide.
- We identified eleven regional fire years as those exceeding the 90th percentile in annual fire extent from 1900 to 2003 (>102,314 ha ha or ~1% of the atlas). These years were concentrated early and late in the 20th century (six from 1900 to 1934 and five from 1988 to 2003).
- Regional fire years occurred when warm springs were followed by dry summers, and during the positive phase of the Pacific Decadal Oscillation (PDO). Spring snowpacks were likely reduced during warm springs and when PDO was positive, resulting in longer fire seasons. However, El Niño-Southern Oscillation (ENSO) was not an important driver of regional fire years, in keeping with its weak effect on climate here, nor was climate in antecedent years. Consistent with these interannual results, the mid-20th century period lacking regional fire years (1935-1987) had generally cool springs, generally negative PDO, and a lack of extremely dry summers.
- These climate drivers of regionally synchronous fire are congruent with those of past fires in this region, suggesting a strong fire-year spring and summer climate signal despite major land-use change.
- Although every regional fire year burned across a range of forest types, relatively more low-elevation moist forest burned early in the 20^{th-}century, likely because increasingly warm springs have lead to reduced spring snowpack at high elevations and consequently to longer fire seasons there.
- We suggest that the late 20th-century increase in regional fire years in this region resulted from a combination of climate variation, climate change and land use. Given projections of future climate, the region is likely to experience larger and more severe fires in the future.
- This is the first use of fire atlases to examine the effect of climate on regionally synchronous fires.

Multi-season climate synchronized widespread historical fires in dry forests (1630-1900), Northern Rockies, USA

- Our objectives were to identify the climate forcing of years of regionally synchronous fires in dry forests of the US Northern Rockies (Idaho and Montana west of the Continental Divide) from 1630 to 1900.
- We reconstructed fires from 9499 fire scars on 576 trees (mostly ponderosa pine, *Pinus ponderosa* P. & C. Lawson) at 21 sites and compared them to existing tree-ring reconstructions of climate (temperature and the Palmer Drought Severity Index) and large-scale climate patterns that affect modern spring climate in this region (El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO)).
- We identified 29 regional-fire years as those that exceeded the 90th percentile in number of sites with fire.
- Fires were remarkably widespread during regional fire years, including one year (1748) in which fires burned in what are today seven national forests and one site on state land.
- Spring and summer climate interacted in their effect on the occurrence of regional- and no-fire years, but not on the occurrence of local-fire years. Regional fire years were ones when warm springs were followed by warm/dry summers whereas years that lacked fire at any site were ones when cool springs were followed by cool/wet summers. Warm springs likely resulted in early melting of relatively shallow snowpacks and hence to a longer fire season whereas warm/dry summers resulted in lower fuel moisture during the fire season.
- Climate in prior years was not a significant driver of fire, likely because fuel loads are generally sufficient in all years to carry fire in dry forests of this region. Years lacking fire at any of our sites had a weak tendency to occur during La Niña years, which are associated with relatively cool/wet springs in this region, consistent with the relatively weak influence of ENSO on modern climate in this region.
- The PDO was not a significant driver of past regional-fire years, despite being a strong driver of modern spring climate and modern regional fires years in the Northern Rockies. Although variation in large-scale climate patterns is responsible for variation in spring climate, such climate also varies independent of such patterns.
- We suggest that the climate drivers of past fires that we identified for dry forests of the Northern Rockies were likely consistent with those in other forest types as well.

Comparison of fire scars, fire atlases, and satellite data in the northwestern United States

- We evaluated agreement in 20th-century fires recorded in digital fire atlases to those we reconstructed from fire scars collected systematically over a 611-ha site in Idaho.
    - Agreement was good for three fires.
    - Spatial agreement varied, but was best for the most recent fire (producer's accuracy = 69 and 94%; user's accuracy = 70 and 90% for 1924 and 1986 fires, respectively)
    - There was fair spatial agreement between perimeters in the fire atlas and fire perimeters interpreted using delta normalized burn ratio applied to pre- and post-fire satellite imagery for a 1986 fire (producer's accuracy = 92%; user's accuracy = 88%).
- In contrast, we found poor agreement between the fire-scar and fire-atlas records when we compared fire occurrence and extent of fires recorded in digital fire atlases to those reconstructed from fire-scarred trees at four sites sampled for another study in Washington.

- Despite their limitations, fire atlas data will continue to be the most readily available source of information on the extent of late 20th-century fires and remain a primary source of such information for the early 20th-century. Caution is warranted for fire-atlas usage without field validation, especially for local-scale applications.

Landscape consequences of changing fire regimes in the Northern Rockies

- TELSA was determined to be an appropriate landscape simulation tool for exploring consequences of changing climate-driven fire regimes on landscape structure and composition.
- Fire atlas data proved to be suitable for deriving fire size distributions and burned area index with which to parameterize the TELSA model.
- Simulation experiments were completed for two of four landscapes in the northern Rockies (35,822 ha Dahlonega watershed on the Salmon-Challis National Forest and 49,559 ha Bear and Elk Creek watersheds on the Boise National Forest). Experiments involved varying different components of the fire regime (e.g., frequency of extreme fire years, size of fires in extreme years, and area burned in normal years).
    - Extreme fire years were simulated as years in which fires were larger and more severe. Increasing the frequency of these extreme fire years in the TELSA simulations allowed us to anticipate consequences of an increase in drought conditions in the northern Rockies.
    - Increasing the area burned during normal years in TELSA simulations allowed us to anticipate consequences of increasing wildland fire use (WFU) on these landscapes.
- Increasing the frequency of extreme fire years has a similar effect on landscape composition as increasing the area burned during typical years.
- For most fire regimes simulated, the amount of older forest (>200 years) declines from current levels on these landscapes. This is the case for even the baseline fire regime we derived from the 1900-2003 fire atlas, supporting the idea that current landscape conditions are an artifact of fire exclusion.

DELIVERABLES
We have included copies of most of these on the enclosed CD. We indicate those not included (---) because they are available on the project web site, because they have not yet been completed, or because they are not available for inclusion on the CD.

Proposed	Delivered	Status	File Name on CD
Progress Reports for JFSP and RJVA	On accompanying CD: two progress reports and a final report for JFSP; work plan, two progress reports, and a final report for RJVA between USDA Forest Service and University of Idaho	Submitted on time	JFSPAnnualReport03-1-1-07_Aug2005 JFSPAnnualReport03-1-1-07_Feb2004 Morgan_JFSP03-1-1-07_FinalReport RJVA_Climate_Workplan_May 04 RJVA_Climate_Progress_July 04 RJVA_Climate_Progress_Feb05 FinalReport_FireClimate-RJVA
Website	http://frames.nbii.gov, Fire regimes and climate drivers in the Northern Rockies	Posted in 2004 and updated yearly	---
Electronic project brochures	Distributed widely via email to scientists and land managers across the Northern Rockies	2 completed (Sep 2005 and Mar 2006), 1 planned for fall 2006	Project_Flyer.pdf
Assemble fire-atlas data from 11 national forests	We assembled digital polygon perimeters from 12 national forests and 2 national parks.	Done	---
Crossdate fire scars from 15 sites	We crossdated 9803 fire scars on 576 trees from 21 sites.	Done	---

Crossdate fire scars and tree-establishment dates from 1 gridded site to compare to fire atlas	We crossdated fire scars and obtained tree establishment dates on 1 grid of 49 plots.	Done	---
2 Master of Science theses	(1) Shapiro, L.B. 2006. Historical fire records: comparison of fire scars, fire atlases, and satellite data in the northwestern United States. M.S. thesis. Moscow, ID: University of Idaho. 57 p. (2) Gibson, C.E. 2006. A Northern Rocky Mountain polygon fire history: Accuracy, limitations, strengths, applications, and recommended protocol of digital fire perimeter data. M.S. thesis. Moscow, ID: University of Idaho. 35 p.	Both theses were successfully defended in May 2006	(1) ThesisShapiro_May2006 (2) ThesisGibson_May2006
5 peer-reviewed journal articles	(1) Gibson, C.E, P. Morgan, and C. Miller. Polygon fire history for the northern Rocky Mountains: Accuracy, strengths, and limitations of digital fire perimeter data. International Journal of Wildland Fire (2) Morgan, P., E.K. Heyerdahl, and C.E. Gibson. Multi-season climate synchronized widespread forest fires throughout the 20th-century, Northern Rocky Mountains. Ecology. (3) Heyerdahl, E.K., P. Morgan, and J.P. Riser II. Multi-season climate synchronized widespread historical fires in dry forests (1630-1900),	Final drafts ready for submission in September 2006 for manuscripts 1 to 4. Final draft of manuscript 5 planned for December 2006 after two additional landscapes are modeled (Selway basin on the Nez Perce and Clearwater National Forests and	Abstracts only: (1) Gibsonetal.InPrep.AtlasStrength.Abstract (2) Morganetal.Submitted.Ecology.abstract (3) Heyerdahletal.Submitted.Ecology.abstract

	Northern Rockies, USA. Ecology. (4) Shapiro, L.B., E.K. Heyerdahl, and P. Morgan. Comparison of fire scars, fire atlases, and satellite data in the northwestern United States. Canadian Journal of Forest Research. (5) Miller, C. Landscape consequences of changing fire regimes in the northern Rockies. To be submitted to Landscape Ecology or Fire Ecology (December 2006).	the Danaher creek drainage on the Flathead National Forest).	(4) Shapiroetal.InPrep.Comparison.Abstract (5) ---
Present results at 3 national professional conferences	(1) Morgan, P., Heyerdahl, E.K., Miller, C.M., Gibson, C.E., Shapiro, L.B., and Riser, J.P. 2006. Climate drivers of fire in the northern Rocky Mountains: Past, present, and future. First Fire Behavior and Fuels Conference, Fuels Management – How to Measure Success [online], 27-30 March, Portland, Oreg. Available from: http://www.iawfonline.org/fuels/program.shtml [cited 11April 2006]. (2) Heyerdahl, E.K. and J.P. Riser II. 2005. "Climate drivers of historical surface fires in the Northern Rocky Mountains, USA: Preliminary results." Fire history and climate synthesis in western North America. Flagstaff, Arizona (5/1-5/3/05). (3) Heyerdahl, E.K., P. Morgan, Carly Gibson, and James P. Riser II. Climate drivers of regional fire years in the US Northern Rockies: past and present. Abstract accepted for presentation at the 3rd International Fire Ecology and Management	Two are done. Three will be presented in Nov 2006	Abstracts only for items 2-4: (1) Abstract: Morganetal.2006.FuelsConferencePosterAbstract Poster: fuels06_poster_2_ette (2) --- (3) Abstract submitted, poster not yet finalized (4) Gibsonetal.AFEAbstract_May2006 (5) MillerAFEAbstract_May2006

	Congress. San Diego, CA (11/13-17/06). (4) Gibson, C., L. Shapiro, P. Morgan, E. Heyerdahl, and C. Miller. Twentieth century northern Rocky Mountain fire records and their relation to fire scars on trees. Abstract accepted for presentation at the 3rd International Fire Ecology and Management Congress. San Diego, CA (11/13-17/06). (5) Miller, C. Is Wildland Fire Use enough for wilderness, and if not, then what? Abstract accepted for presentation at the 3rd International Fire Ecology and Management Congress. San Diego, CA (11/13-17/06).		
Participate in "Fire in the West" conference and organize one for the Northern Rockies	Rather than adding another workshop for managers to attend, we decided to travel to them and make presentations, giving us the option of using an existing workshop where we can present our research, or having small focused meetings at local offices.	One complete in spring 2006 on Boise National Forest. Four planned for fall 2006 and spring 2007	---
Publicly archive data collected	(1) Fire-atlas data will be archived on the FRAMES website (http://www.nbii.gov) (2) Fire-scar data will be archived with the International Multiproxy Paleofire Database (http://www.ncdc.noaa.gov/paleo/impd/ paleofire.html)	Both sets of data will be archived after journal articles are accepted for publication (anticipated in fall 2006)	---

New items not proposed but partially funded by JFSP	(1) Short reports on local historical fire regimes for each fire-scar site, to be presented at workshops in fall 2006 and spring 2007 (2) Flyer on how to recognize old trees (3) Project PIs participatedin two North American Dendroecological Fieldweeks, one in 2003 and one in 2005, in part to collect fire-scar samples from additional sites (4) Outreach letter written to land managers when we were assembling data for the fire atlas		(1) --- (2) How_to_Recognize_Old_Trees.pdf (3) --- (4) atlas_outreachLTRFeb304

APPENDIX 1: PROJECT LOCATIONS

		Type of data			
State	Land owner	20th century: fire atlas	Fire history sites	Gridded fire history	Landscape modeling
Idaho	Boise National Forest	X	3	1 site	x
Idaho	Caribou-Targhee National Forest	X			
Idaho	Clearwater National Forest	X			x
Idaho	Idaho Panhandle National Forest	X			
Idaho	Nez Perce National Forest	X	2		x
Idaho	Payette National Forest	X	1		
Idaho	Salmon-Challis National Forest	X	1		x
Idaho	Sawtooth National Forest	X			
Idaho	privately owned land		1		
Montana	Bitterroot National Forest	X	2		
Montana	Flathead National Forest	X	2		x
Montana	Glacier National Park	X			
Montana	Kootenai National Forest	X	3		
Montana	Lolo National Forest	X	3		
Montana	University of Montana		1		
Montana	Plum Creek Timber, Inc.		1		
Montana	State of Montana		1		
Wyoming	Yellowstone National Park	X			