FOREST RESTORATION IN THE SIERRA NEVADA OF CALIFORNIA: INTEGRATING ECONOMIC AND ENVIRONMENTAL ANALYSES FOR MANAGEMENT DIRECTION.

Dominic Roques, Roques Wildland Resources, 1921 Bonita Ave., Berkeley,

California 94704 - *roqueswild@vdn.com*

Thomas Gaman, East-West Forestry Associates, PO Box 276, Inverness,

California 94937 - *tgaman@forestdata.com*

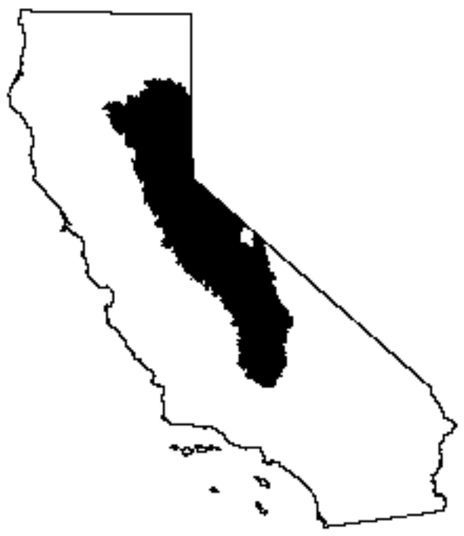
Abstract: The authors develop a methodology for a landscape based economic analysis that recognizes three forms of capital (financial, natural, and social). These factors are woven together via a spatial analysis to identify and prioritize forest restoration needs in the Sierra Nevada of California. The economic assessment offers a comprehensive view of the enterprise of forest restoration. We examine the costs, potential benefits, and realistic funding mechanisms for addressing impacts on forest biodiversity from urbanization, suppression of the natural fire regime, and construction of roads through riparian areas. The spatial analysis is conducted using a Geographic Information System (GIS) constructed for this project encompassing the 31 watersheds of the Sierra Nevada, comprising over 20 million acres, using 1:100,000 and 1:24000 digital coverages. The true complexity of the restoration challenge in the region is abundantly clear where maps reveal the intersection of public and private ownerships, encroaching human settlement, fire frequency, and riparian impacts in each basin. This process can be effectively used on a regional level in selecting, prioritizing, scaling, and funding appropriate restoration projects to match a local community's capacity to exploit the investment of financial capital. Using prescribed fire, mechanical treatments and road closure, we estimate that there is a minimum of $374 million in restorable resource impacts in the twenty million acre project area.

Keywords: Sierra Nevada Economic GIS

Introduction and Goals

The Sierra Nevada Ecosystem Project (SNEP), funded by Congress and completed in 1996, funded a team of over 50 researchers to assemble baseline data on the condition of the Sierra Nevada. SNEP scientists, however, made no effort to infer or coordinate any management direction based on the studies of its scientists. The Sierra Nevada Conservation Framework, currently underway in late 1999, is an effort on the part of the US Forest Service to identify the issues and to update the Forest Plans for the ten Sierra Nevada national forests. However, no comprehensive analysis of planning or restoration needs has been undertaken by any agency.

Regions of the Sierra Nevada



NORTHERN REGION

NORTH CENTRAL REGION

SOUTH CENTRAL REGION

EAST SIDE REGION

SOUTHWESTERN REGION

HONEY-EAGLE LAKES
NORTH FORK FEATHER
MILL-BIG CHICO
E. BRANCH OF N. FORK FEATHER
MIDDLE FORK FEATHER
BUTTE
YUBA
TRUCKEE
BEAR
NORTH FORK AMERICAN
LAKE TAHOE BASIN
SOUTH FORK AMERICAN
CARSON
COSUMNES
MOKELUMNE
STANISLAUS
WALKER
CALAVERAS
TUOLUMNE
MONO BASIN
MERCED
CROWLEY LAKE
CHOWCHILLA-FRESNO
SAN JOAQUIN
KINGS
KAWEAH
OWENS LAKE
KERN
TULE
MOJAVE

The principal goals of this independently funded study are to provide a science-based interpretation of restoration needs based on SNEP, and then to explore the economic implications of pursuing restoration of Sierra Nevada forests. This paper summarizes that effort. The full report can be downloaded in Adobe Acrobat format at www.forestdata.com.

Indicators of Restoration Need

In searching through SNEP for indices for our analysis, we identified three primary stressors on forest ecosystems which have impacted Sierra Nevada forests to the point where restoration is needed and justified:

1. road-building in forest riparian environments.
2. suppression of natural fire regimes, and
3. urbanization and human settlement.

Riparian areas. There are a number of reasons that road building in forest riparian environments is a significant stressor of natural systems. Road building leads to the direct loss of acreage of riparian areas. The direct loss of large trees causes increased insolation, increasing water temperatures, and reduced the structural complexity of riparian and aquatic environments and a reduced supply of large woody debris. Ensuing reduced base flows and increased peak flows in streams and rivers further accelerate downstream sedimentation and flooding.

Fire suppression. The Sierra Nevada is a fire-adapted system. Suppression of natural fires throughout the 20th century has resulted in increasing shade tolerant understory growth of white fir and incense cedar in Sierra forests and has altered fuel profiles. Live and dead fuels in today's conifer forests are more abundant and continuous than before. In and around urban wildland interface areas the increased ladder fuels and fuel loads contribute to the likelihood of ignition of large, uncontrollable and costly fires. While in need of large-scale management and restoration efforts, most such areas are not now suited to the direct reintroduction of fire. They lend themselves to costly, higher-impact manual and mechanical treatments. We were interested in determining the extent of the problem and the cost of defending the rapidly urbanizing Sierra Nevada from catastrophic fire.

Urbanization. There are a variety of reasons that increased residential density has had impacts on Sierra forests. Larger numbers of people spending time in an area proportionately increases fire ignition frequency. Runoff of precipitation from roads, buildings and compacted areas in settled forest areas is greater than runoff from undeveloped forest. Concentrated channels of water are the primary source of surface erosion. Grading and road construction contributes heavily to mass wasting landslides and other erosive slope failures. There is also an observed decline in wildlife species diversity along gradients of increasing urbanization, with some well-adapted urban species increasing in abundance. Induced dominance of understory vegetation by

opportunistic shade-intolerant species creates increases fuel loading. While we did not assess the direct costs and benefits of urbanization in our report, we were able to provide some data on the opportunity costs in terms of impacts on natural forests.

Discussion of Spatial Analysis

A spatial analysis that identifies and quantifies areas likely to be candidates for restoration is required for the economic assessment to be founded on factual information about conditions throughout the diverse Sierra landscape. A Geographic Information System (GIS) database was constructed for this project from digital files obtained through the Sierra Nevada Ecosystem Project (SNEP) and other sources. In all we obtained 25 digital coverages characterizing Sierra Nevada forests, watersheds, preserves, history, roads, waterbodies, ownerships, biodiversity, rare species, archaeology and other features. These coverages were generally based on 1:24000 scale 7.5 minute quadrangles and in all require over 500 megabytes of hard disk space. Analysis was performed primarily using PC-ArcInfo and ArcView 3.0.

When we examine large landscapes with an eye toward solving environmental problems, the watershed presents itself as a uniquely valuable unit on which to base a wide array of analyses. Therefore we chose the 31 major "CalWater 2.0" river basins of the Sierra Nevada as the primary geographic units for our analyses. CalWater is a set of standardized watershed boundaries, nested into larger previously standardized watersheds, meeting standardized delineation criteria (Brandow, 1994). Because of the hierarchical nature of Calwater, our data does support the further subdivision of these watersheds into hydrologic sub-areas. This information establishes the first spatially-explicit estimates of regional forest restoration needs ever reported and will significantly advance conservation management, planning and research efforts underway throughout the region.

Table 1: Primary River Basins of the Sierra Nevada

SUBREGION	ACRES
NORTH	
Mill-Big Chico-Butte Creeks	658,454
North Fork Feather	783,417
East Branch North Fork Feather	656,980
Middle Fork Feather	871,789
Honey-Eagle Lakes	1,422,459
	4,393,100

NORTH CENTRAL		
Yuba	842,731	
North Fork American-Bear River	928,961	
South Fork American-Consumnes	946,790	
Truckee	274,344	
Lake Tahoe Basin (CA only)	325,337	
		3,318,164
SOUTH CENTRAL		
Mokelumne	506,179	
Stanislaus-Calaveras	873,314	
Tuolumne	1,055,720	
Merced	699,089	
		3,134,301
SOUTH		
Chowchilla-Fresno	597,713	
San Joaquin	1,098,744	
Kings	1,159,038	
Kaweah	552,532	
Tule	639,779	
Kern	1,751,590	
		5,799,396
EAST SIDE		
Carson	290,058	
Walker	584,272	
Mono Basin	430,589	
Crowley Lake	1,188,401	
Owens Lake	876,319	

Mojave	609,566	
		3,979,206
TOTAL ALL RIVER BASINS		**20,624,166**

Source: CalWater, Version 2.0.

Using the spatial data, we identified the density in each basin at which forest roads have been built in riparian zones. The 150' riparian buffer zones were mapped using the GIS system using criteria selected by Kondolf et al. in SNEP. We calculated the road distance in riparian zones for each basin. In each watershed we also identified the degree of human settlement, based on 1990 census data presented by Tim Duane in SNEP. We explicitly mapped land ownership, and derived land protection status based on information provided by Davis and Stoms of UC Santa Barbara. Based on work by David Sapsis of California Dept. of Forestry and Fire Protection, also in SNEP, we derived the "fire return interval" for the entire range of the Sierra Nevada. Contrary to popular belief, very little of the overall Sierra is threatened by the spectre of disastrous wildfire, but those areas affected are located in the foothill urbanizing areas. High forest fuels also threaten old growth forests on National Park Service lands in the Southwestern and South Central Sierras.

For a discussion of the methodology and for details on numerical and geographic analyses, interested readers are encouraged to consult our website www.forestdata.com.

Table 2: Land Ownership in the Sierra Nevada

LAND OWNERSHIP	ACRES	PERCENT OF TOTAL
Private	6,705,506	33%
State	190,594	1%
USDA Forest Service	8,672,735	42%
Bureau of Land Management	2,242,491	11%
National Park Service	1,644,225	8%
Other Public	521,208	3%
Lakes	453,105	2%

Source: USDA-Forest Service

Finding and Results

Roads in Riparian Areas. In the Sierra Nevada there is a minimum of 2,000 miles of forest roads located in sensitive riparian areas (within 150 feet of water). The North Central Basins (North Fk American/Bear, South Fk American/Consumnes, Stanislaus/Calaveras) have greatest occurrence of roads in such areas. Overall the Feather River Basin has most miles of mapped forest roads within 150 feet of a watercourse of any single river basin

Fire Suppression. We identified areas by fire return interval. Almost 77% of all acres in the 1-100 Year Fire Return Interval are private; 30% of acres with 1-100 Year FRI are broadleaf forests (tanoak, madrone, bay, black oak and associates); 24% with 100-250 Year FRI are oak woodland. The distribution of candidate areas for high priority fuel management is concentrated in the North Central and Southwest Basins, as shown on the accompanying map.

Urbanizing Forestlands. The data show that the decrease in crown canopy cover from residential development is greatest single threat to Sierra Nevada forests. Over 50% of settled forest lands are in the mixed conifer zone occurring in a broad band between 2,500 and 6,000 ft. elevation in central Sierra Nevada. Also there has been 18,000 acres of ponderosa pine canopy loss region-wide; 21,273 acres of oak woodland canopy within the study area had been lost (in addition to other areas in the foothills and central valley of California). Over 51,000 acres of forest canopy has been lost in the North Fork American and Bear River watersheds due to urbanization. Private lands in North Central and South Central Sierra Nevada are most at risk.

Economic Analysis

Having established the baseline indices of extent of restoration needs, we proceeded to examine the costs of forest restoration, potential sources of funding for restoration, and the potential for restoration to stimulate local economies. These issues are addressed in the context of key Sierra Nevada economic indicators. The indicators reveal a region in transition toward greater economic diversification. The quality of life in the region supports the trend toward diversity by attracting the social capital that supports enterprise. Forest restoration will be essential to preserving the quality of life in the region. Our report identifies areas where priority restoration strategies may be applied. This analysis is regional in scope. It yields findings which complement- rather than substitute for local assessments of forest restoration needs. Table 3 indicates the estimated costs of restoration efforts by region.

Given the current structure of the resource economy of the Sierra Nevada, funding for restoration cannot be self-generating. Water is the only natural resource product that could be expected to pay for a significant portion of the costs. Additionally, the federal and state governments cannot be expected to provide funding for anything but the most localized efforts. With few exceptions, we expect fundraising for restoration to be pursued on a case by case basis, by local groups operating at the watershed level. Forest restoration will be integrated with broader watershed

restoration goals raising overall costs substantially. The cost estimates generated in the report broadly characterize the cost of the forest restoration portion of protecting the Sierra Nevada environment. While not comprehensive they give a good sense of the scale of the investment which will be required and point to the need to diversify funding sources.

Table 3 -- Restoration Costs

Estimated Costs of Addressing Immediate Fuel Management Needs in the Sierra Nevada

(THOUSANDS OF DOLLARS)

River Basins	--------Burning in Wildlands-------- Prescribed Management Fire	Prescribed Natural Fire	Under Burning	----Mechanical Treatments----- Intermix Urban Forests	Wildlands	Long-Term Monitoring Intermix Urban Forests	Wildlands	TOTAL FUEL MANAGEMENT COST
North	2324	5165	6197	3241	25822	243	2582	45574
North Central	3844	8544	10253	43151	42720	3236	4272	116020
South Central	2835	6300	7560	20501	31502	1537	3150	73385
Southwest	3711	8248	9897	8307	41240	623	4124	76150
East	899	1998	2398	508	9993	38	999	16833
TOTAL (Thousands of $$)								**327962**

Estimated Costs of Addressing Impacts of Roads in Riparian Areas of the Sierra Nevada

	Asssessment	Decommission	Improve Drainage	Sediment Reduction	Reforestation (5 ac/mile restored)	Fencing	Long-term maintenance	TOTAL ROAD RESTORATION COST
North	185	3898	1667	5362	368	125	133	11738
North Central	184	3859	1651	5309	364	124	132	11623
South Central	153	3212	1374	4419	303	103	108	9672
Southwest	163	3425	1465	4712	323	110	117	10315
East	57	1202	514	1654	113	38	41	3619
TOTAL (Thousands of $$)								**46967**

Grand Total -- Rangewide Roads and Fuel Treatments (thousands of dollars) 374929

LITERATURE CITED

Brandow, Clay, 1995. CALWATER: A Standardized Set of California Watersheds.

Davis, Frank W., Stoms, David M., Sierran Vegetation: A Gap Alalysis, in *Sierra Nevada Ecosystem Project, Final Report to Congress, vol. II, Assessments and Scientific Basis for Management Options* (Davis: University of California, Centers for Water and Wildland Resources, 1996).

Duane, Timothy P., Human Settlement, 1850-2040, in *Sierra Nevada Ecosystem Project, Final Report to Congress, vol. II, Assessments and Scientific Basis for Management Options* (Davis: University of California, Centers for Water and Wildland Resources, 1996).

Kondolf, G. Marthia, Richard Kattelmann, Michael Embury and Don Erman, Status of Riparian Habitat, in *Sierra Nevada Ecosystem Project, Final Report to Congress, vol. III, Assessments, Commissioned Reports, and Background Information* (Davis: University of California, Centers for Water and Wildland Resources, 1996).

Salwasser, Hal. 1998. Sierra Nevada Science Review, USDA-FS Pacific Southwest Research Station, Berkeley.

Sapsis, David, et al., 1996. An Assessment of Current Risks, Fuels, and Potential Fire Behavior in the Sierra Nevada, in *Sierra Nevada Ecosystem Project, Final Report to Congress, vol. III, Assessments, Commissioned Reports, and Background Information* (Davis: University of California, Centers for Water and Wildland Resources, 1996).

ABOUT THE AUTHORS

Tom Gaman is principal of East-West Forestry Assoicates, consulting foresters, in Inverness, California.

Dominic Roques is a natural resource economist with the California Department of Water Resources, Sacramento, California.