The Economic Impact of the 2013 Rim Fire on Natural Lands

EARTH ECONOMICS

Preliminary Assessment

Preliminary Assessment: The Economic Impact of the 2013 Rim Fire on Natural Lands
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REPORT PURPOSE AND BACKGROUND

Environmental benefits, or "ecosystem services," are benefits that humans receive from nature. This rapid assessment provides an economic valuation and analysis of the damage caused by the 2013 Rim Fire to the environmental benefits within the burn area.

The Federal government recognizes the economic value of natural systems. In 2013, the Federal Emergency Management Agency (FEMA) adopted Mitigation Policy FP-108-024-01, which provides explicit environmental benefit dollar values for use in all flood and hurricane disaster mitigation.[1]

Also in 2013, the President's Council on Environmental Quality approved a new Principles and Requirements for Investments in Water Resources, recognizing ecosystem service values in project benefit-cost analysis.[2]

In 2012, the US Forest Service adopted a new land management planning rule, governing 155 National Forests. The rule systematically incorporates ecosystem services into land management planning.[3]

This assessment was conducted while the fire was still burning. Some trees partially fire damaged and green in satellite imagery will suffer mortality within the next year, thus, this analysis represents an initial and conservative underestimate of fire damage.

This assessment also discusses important areas for future research including scientific analysis of the impact of fires on water supply, storage, quality, flow and temperature as well as economic valuation studies based on scientific data and sound valuation methods.

EXECUTIVE SUMMARY

Environmental benefits are the benefits humans receive from nature. In the first year after the Rim Fire, environmental benefit losses are estimated to range from $100 million to $736 million. These results are based on satellite data for the fire perimeter and tree damage accessed by Earth Economics on September 17, 2013, when the fire was 84% contained. Values for environmental benefits were based on peer-reviewed academic journal articles. Preliminary estimated losses (estimated while the fire was still burning) are for the first year after the fire and amount to nearly half of the annual value of environmental benefits provided within the Rim Fire perimeter before the fire. Table 1 summarizes the environmental benefits lost according to vegetation type.

TABLE 1 — TOTAL ENVIRONMENTAL BENEFITS LOST TO THE RIM FIRE IN THE FIRST YEAR POST-FIRE

Land Cover	Area (Acres)	Description	Low ($/year)	High ($/year)
Grassland and Meadow	20,201	Includes annual and perennial grasslands that dominate major regions around coniferous forests	$30,569,395	$69,202,212
Herbaceous Wetland	577	Includes wetlands dominated by herbaceous meadow vegetation; areas where total herbaceous wetland vegetation coverage is greater than 20%	$515,158	$20,284,851
Shrub	31,923	Riparian areas alongside riverine and wetland regions; exists through various altitudes	$541,959	$37,247,933
Lake	447	Contains areas dominated by shrubs less than 5 meters tall. This class includes chaparral shrubs and mixed montane shrubs	$93,926	$2,877,038
River	161	Includes areas of open water, generally with less than 25% cover of vegetation or soil	$4,073	$907,523
Riparian	190	Includes stream and creek systems and sometimes areas of open water	$47,071	$325,824
Forest (Broad Leaf and Mixed)	32,213	Includes a mixture of aspen, blue oak woodlands, and montane hardwoods that occur sporadically throughout National Parks Service and Forest Service lands	$5,098,191	$284,804,356
Forest (Coniferous)	168,941	Includes many conifer-dominated vegetation types such as Blue Oak-Foothill Pine, Closed-Cone Pine-Cypress, Douglas Fir, Jeffrey Pine, Lodgepole Pine, Ponderosa Pine, Red Fir, Sierran Mixed Conifer, and Mixed Montane Hardwoods Conifers	$63,147,300	$320,363,902
Total	*254,654*		*$100,017,074*	*$736,013,639*

This study provides monetary values for 10 out of 18 identified categories of environmental benefits (also called "ecosystem services") identified within the burn area. Eight categories of ecosystem services damaged by the fire have no estimated value in this study. A valuation of one or more environmental benefits for each of the eight land cover types burned by the fire was completed. The ten environmental benefits valued were: (1) air quality; (2) carbon sequestration; (3) moderation of extreme events; (4) Soil Retention; (5) biological control; (6) water regulation; (7) pollination; (8) habitat and biodiversity; (9) property and aesthetic values; and (10) recreational values. The eight land cover types were: (1) grassland/meadow; (2) herbaceous wetland; (3) shrub; (4) river; (5) lake; (6) riparian; (7) forest broad leaf and mixed forest; and (8) coniferous forest.

The $100 million to $736 million range represents the lower and upper boundaries for environmental benefit losses that were examined. Because only 10 environmental benefits were valued of 18 that were identified, this value range signifies a "below the basement" appraisal, an underestimate of the true range of damages. Highly valuable environmental benefits were not valued because: (1) Scientific data is lacking (fire impact on snow pack, for example); (2) primary valuation studies have not been conducted (soil retention by coniferous forests); or (3) existing valuation studies are not appropriate for this area.

Benefit Transfer Methodology was applied to estimate the total ecosystem service value loss before and after the Rim Fire. Benefit Transfer Methodology is a federally-accepted economic valuation methodology that utilizes local values where possible, and previous valuation studies of similar goods or services in comparable locations where local values are not available. These valuation studies each utilize one of eight primary valuation techniques, which include market pricing, cost avoidance, replacement cost, travel cost and contingent valuation. Inherent uncertainty exists, and because site specific studies for each environmental benefits would be cost and time prohibitive, the results of this valuation are provided as a range of high and low values per-acre, based on peer reviewed studies.

Satellite data for tree damage based on basal area losses was used to estimate burn damage. This approach can result in an underestimate of damage; previous fires have shown that trees still green during an initial satellite survey die later due to fire-related stress. As burn data is refined, this estimate will be improved.

The loss of environmental benefits is also estimated by land ownership category. Four land ownership categories were identified in the burn area: (1) Bureau of Land Management, (2) Private Lands, (3) Stanislaus National Forest, and (4) Yosemite National Park. **Direct damage to environmental benefits provided by Private Lands within the Rim Fire perimeter was estimated at $10 million to $62 million, or about 10% of the total year 1 post-fire damages.**

A supplemental analysis was used to estimate the economic value of stored carbon within the Rim Fire burn area both before and after the fire. US Forest Service data on the carbon content of different forest stand ages for each forest type, combined with pre-fire timber diameter size data and burn data, were used to compare pre-fire carbon storage with post-fire carbon storage. **The value of total carbon storage losses is estimated at $102 million to $797 million.**

In addition, private properties close to wildfires lose asset value (assessed property value) immediately after a wildfire. A supplemental analysis was conducted to estimate this loss of value, over and above the loss of environmental benefits. **Applying previous estimates from the economic literature to property values in selected zip codes near the Rim Fire, the fire-related private property value loss is estimated at between $49.7 million and $265 million.** These estimates imply (but do not include) associated declines in property taxes for local and state tax districts.

1. ENVIRONMENTAL BENEFITS AND ECONOMIC VALUATION

The Federal Government recognizes the economic value of natural systems (wetlands, forests, floodplains, green space) and working lands (commercial forest, ranch lands, agricultural lands). These benefits are called environmental benefits or ecosystem services. Environmental benefits can often be monetarily valued.

The USFS and NPS maintain vast natural assets that have economic value and a high rate of return for investments in healthy forests and ecosystems. Nationwide, the USFS manages 193 million acres of public land. Through visitor spending alone, Forest Service lands contribute more than $13 billion to the economy each year. These lands provide 20% of the country's clean water supply, a value estimated at $27 billion per year.[4]

The NPS maintains 84 million acres of public land, including 43 million acres of oceans, lakes and reservoirs, 85,049 miles of perennial rivers and streams, and 43,162 miles of shoreline.[5] A 2011 Michigan State University report showed that the American public receives $4 in economic value for each $1 invested in the NPS. In 2011, national parks generated $30.1 billion in economic activity and 252,000 jobs nationwide. Thirteen billion of that income went directly into predominantly rural communities within 60 miles of an NPS unit.[6] Moreover, for every million dollars invested in park construction and maintenance, 14 – 16 jobs are generated.

The Federal Emergency Management Agency (FEMA) in June 2013 adopted Mitigation Policy FP-108-024-01 providing dollar values for environmental benefits for use in all flood and hurricane mitigation. This policy was adopted because including environmental benefits in FEMA economic analysis helps meet the agency's mission to "prepare for, protect against, respond to, recover from and mitigate against all hazards."[7]

The President's Council on Environmental Quality recently updated the Principles and Requirements for Federal Investments in Water Resources, which recognizes ecosystem service values for federal project benefit cost analysis. The 2012 US Forest Service (USFS) Planning Rule for land management systematically includes ecosystem services with 72 references to the term. This rule governs 193 million acres of forests and grasslands, including 155 National Forests. Including the actual economic value of natural and working lands strengthens economic analysis, saves taxpayer money, improves investment decisions, and raises rates of return on investments and federal expenditures.

2. MAINTENANCE OF NATURAL CAPITAL AND THE RIM FIRE

Fires are an essential part of the ecology of the Sierra Nevada. Many plant species native to the north-central Sierra Nevada — including the Sequoia and Lodgepole Pine — tolerate, benefit from, or even promote fire. Native Americans used controlled burning as hunting and foraging aids, without causing significant damage to the greater ecosystems.[8] However, the Rim Fire, and fires like it, are highly damaging, tremendously costly, and becoming more common.

The expansion of human population and inhabited areas has also resulted in more human-caused fires.[9] Climatic changes resulting in earlier snowmelt and higher temperatures mean longer fire seasons – two months longer on the average – than in the 1970s.[10] Additionally, a past policy of aggressive fire suppression has built up fuel loads in many forests. Wildfires now burn twice as many acres per year than they did 40 years ago. On average, each year there are now seven times as many wildfires greater than 10,000 acres.[11]

There are forest management techniques that reduce the severity and size of wildfires while increasing biodiversity and better sustaining water production and quality. These techniques include thinning and controlled burns.[12] However, these actions all require sufficient funding for forest maintenance. Economic assets left unattended, usually result in economic losses. Forests require management – including capital, operational, and maintenance costs – to produce the high value suite of goods and services, such as water regulation and supply, biodiversity, timber, recreation, aesthetic value and other benefits that society depends upon. The USFS, National Park Service (NPS), private timber companies, water utilities, states, counties and private land owners all steward economically valuable natural assets that require sufficient operations and management funding to manage these assets. Often the benefits of these lands accrue to people living downstream. Benefits in the Tuolumne watershed include the role of healthy forests in producing high quality water for municipal and regional water supplies and irrigation.

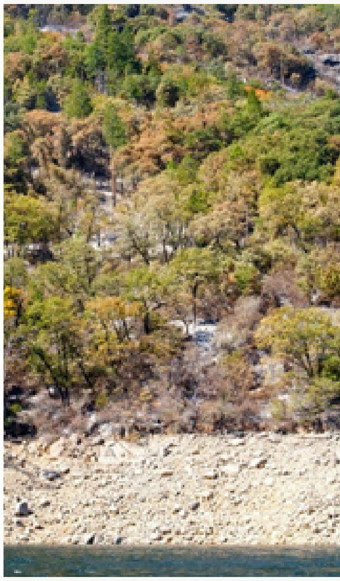
Fire can be beneficial in the maintenance of forested lands, leading to "healthy," diverse forests. Fire can also be ecologically destructive, depending on fire frequency, intensity, and the nature of vegetation communities subject to fire. More frequent, slower burning understory fires eliminate fuel build-up, liberate fire-activated seeds and do not burn deeply into the soil, while high intensity burns consume vegetation from tree crowns to roots, burning deep into the ground and damaging soils.

The Rim Fire demonstrated a range of fire effects. In vast areas of the Stanislaus National Forest, the Rim Fire severely and completely burned dense stands of pine and other vegetation. In the higher elevations within the National Forest and Yosemite National Park, and particularly around Hetch Hetchy Reservoir, the fire generally burned as a beneficial low intensity, slower-moving ground fire below the tree crowns due to the thinner forest stands and higher elevation granitic landscape. Within Yosemite National Park, fire behavior was at least partially influenced by the park's policy of allowing fires to burn when they do not threaten property or lives.

For example, in many ways the beneficial nature of the Rim Fire around Hetch Hetchy Reservoir likely provided for vegetation maintenance while protecting watershed function and water supplies. The NPS BAER Team report stated that "Given the highly dispersed nature of the burn within the [Hetch Hetchy] watershed and very small amounts of moderate and high soil burn severity, risk to Hetch Hetchy Reservoir from increased post-fire watershed response and erosion is negligible to low."[13] This highlights the importance of understanding the ecology and economics of forests, fires, climate change and federal and local investments in forest health and firefighting.

The above image shows the result of an intense burn in the Stanislaus National Forest.

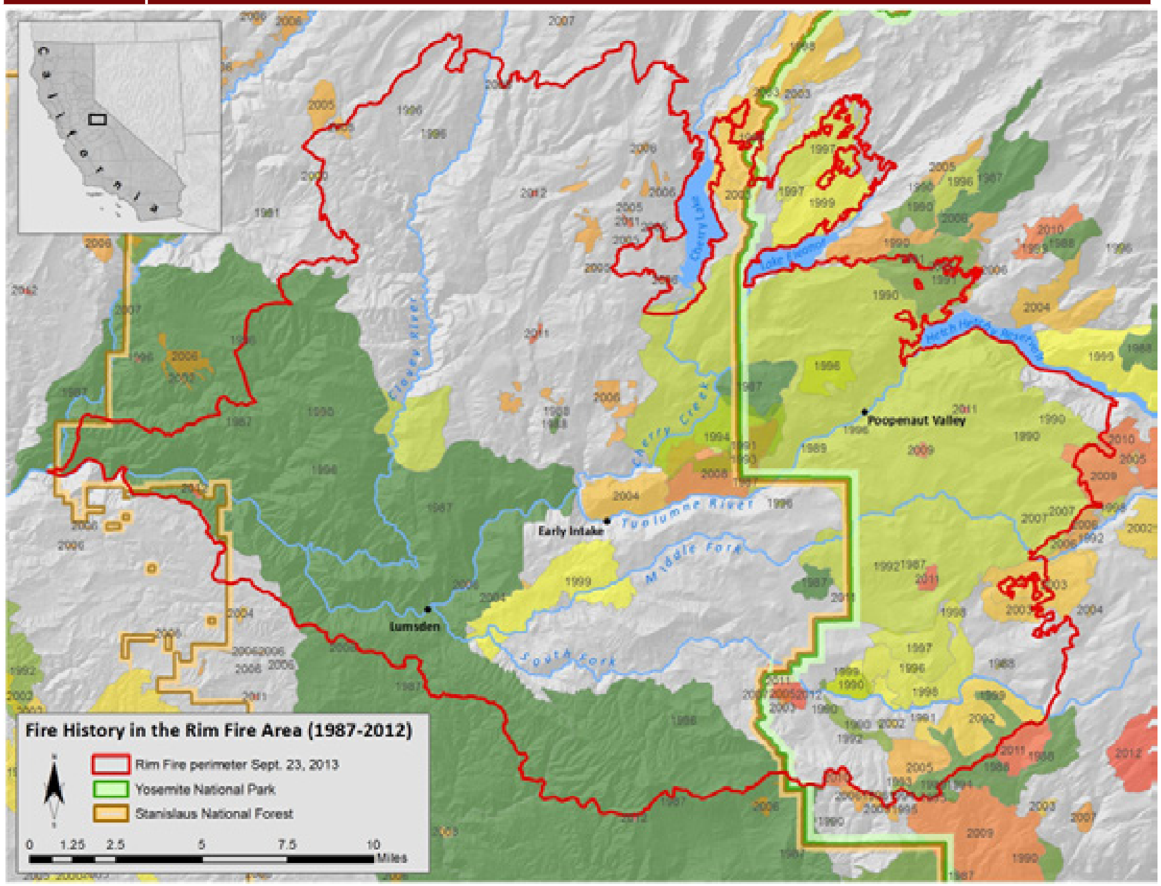
The image below shows a low intensity understory fire in the Hetch Hetchy watershed.



3. DESCRIPTION OF THE RIM FIRE BURN AREA

The Rim Fire burn area covered more than 256,000 acres (400 square miles) of land as of September 17, 2013, making the Rim Fire the third largest fire in California since reliable records began in 1932.[i] This was a fire of historic proportions. Burning approximately 232,800 acres of public land and 23,800 acres of privately owned land, the cost of fighting the Rim Fire as of this writing (with the fire still burning) has been pegged at $127.2 million. Figure 1 shows a series of historic fires in Yosemite National Park and Stanislaus National Forest, with historic fire areas and dates in relation to the Rim Fire outline.

FIGURE 1 | HISTORIC FIRES IN THE RIM FIRE REGION



Source: CAL FIRE[14]

The Rim Fire burned predominantly coniferous forests over granitic and metamorphic geology. In the Tuolumne watershed, high ridges and steep canyons collect runoff from the annual snowpack, which filters through meadows and forests,[15] providing water to meet the needs of communities and farms in the Sierras, Central Valley, and to users as far away as the San Francisco Bay area.

The Sierra Nevada – where the Yosemite, Sequoia, and Kings Canyon National Parks are located – receives up to 79 inches of precipitation per year. The Rim Fire burn area has two primary climatic regimes – mediterranean and highland – and a variety of vegetation zones, including alpine shrubs, wet meadows, dry meadows, grasslands, chaparral, and diverse forests of juniper, lodgepole pine, Jeffery pine, ponderosa pine, black oak, incense cedar, gray pine, aspen, red fir, white fir, blue oak, valley oak, willow, alders, sycamores, and cottonwoods.

[i] Update as of October 25, 2013: By the time it was 100% contained, the Rim Fire burn area covered 257,314 acres. http://www.fire.ca.gov/communications/downloads/fact_sheets/20LACRES.pdf

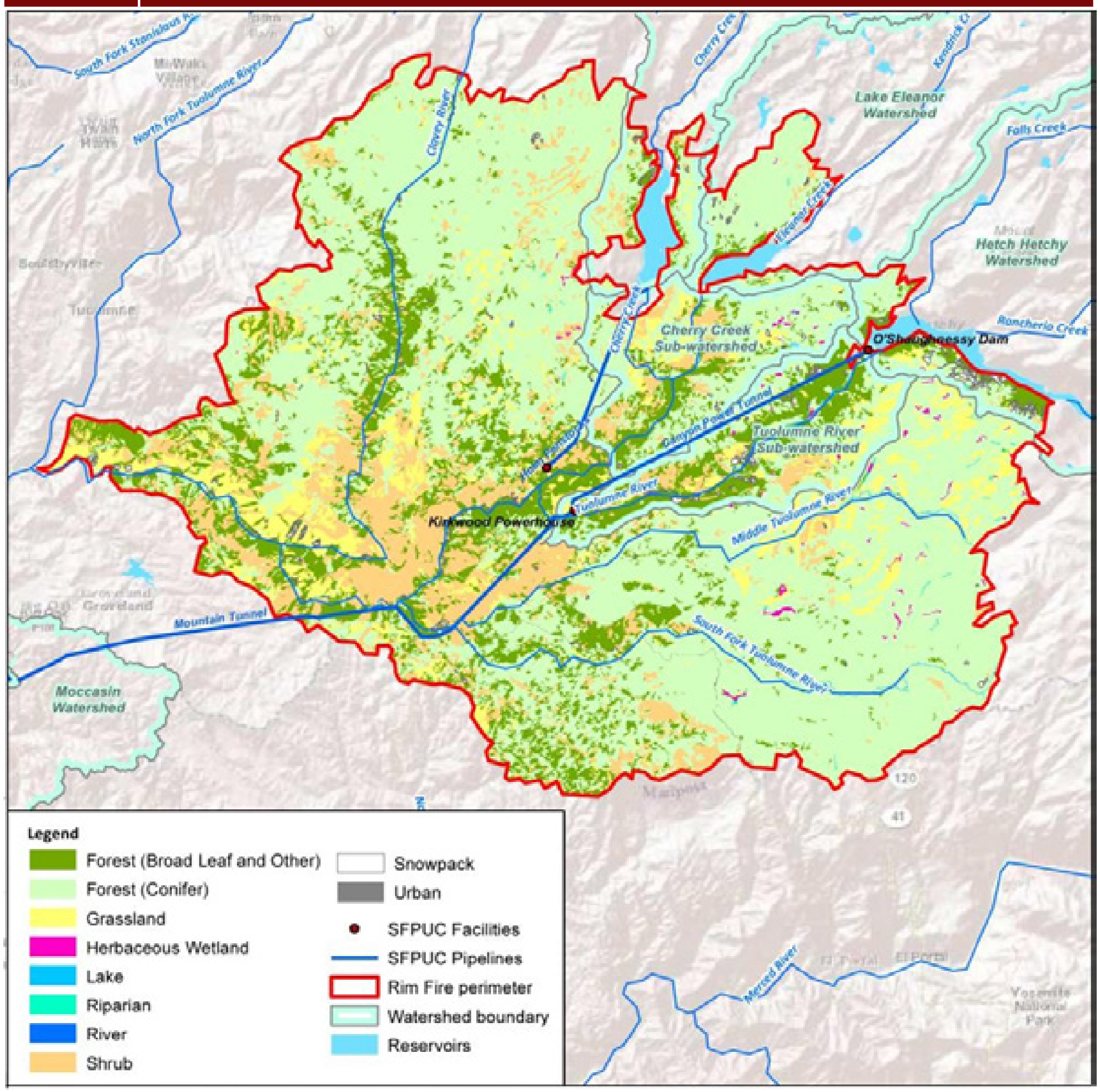
Water from the burn area both supplies the San Francisco Bay Area with water and the Central Valley of California with drinking and irrigation water. The San Francisco Bay Area is one of the country's most productive urban areas. The area generated a GDP of over $360 billion in 2012, the fastest real GDP growth of any major metropolitan area in the US.[16] The Central Valley of California is one of the country's most productive farming regions. The Central Valley contains 1% of the US farmlands, but produces 8% of the US agricultural output that totals to $13 billion[17] in food products annually.

4. VALUATION OF ENVIRONMENTAL BENEFITS BEFORE THE RIM FIRE

4.1. Land Cover In The Rim Fire Burn Area

The total burned area of the Rim Fire was assigned to one of eight land cover types: grassland, herbaceous wetland, lakes, riparian, river, shrub, coniferous forest, and broadleaf/mixed forest. Figure 2 presents a map of land cover within the Rim Fire perimeter before the fire occurred. The Rim Fire perimeter is shown as of September 27, 2013 when the fire was about 84% contained, but still burning. A description of each land cover and its total acreage is provided in Table 2 with references to the base GIS layer. California's CALVEG data was the basis for this information.

FIGURE 2 | VEGETATION MAP BEFORE RIM FIRE



Source: San Francisco Public Utilities Commission, based on CALVEG data.

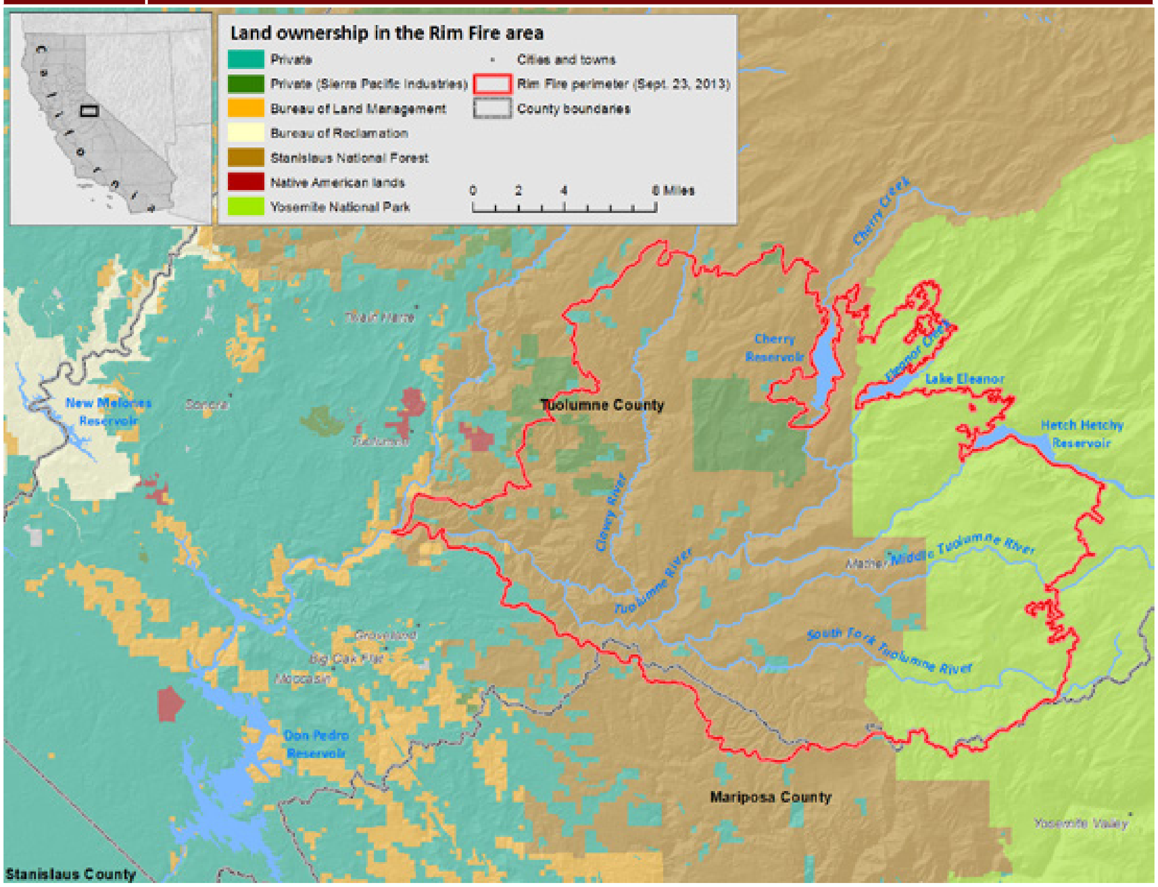
TABLE 2	LAND COVER DESCRIPTIONS AND ACREAGES IN THE RIM FIRE BURN AREA	
Land Cover	Acreage (Rounded to Nearest Acre)	Description and Layer(s) Used
Grassland/Meadow	20,201	Includes annual and perennial grasslands that dominate major regions around coniferous forests.
Herbaceous Wetland	577	Includes wetlands dominated by herbaceous meadow vegetation, areas where total herbaceous wetland vegetation coverage is greater than 20%.
Shrub	31,923	Contains areas dominated by shrubs less than 5 meters tall. This class includes chaparral shrubs and mixed montane shrubs.
River	161	Includes stream and creek systems and sometimes areas of open water.
Lake	447	Includes areas of open water, generally with less than 25% cover of vegetation or soil.
Riparian	190	Riparian areas alongside riverine and wetland regions; exists through various altitudes.
Forest (Broad Leaf and Mixed)	32,213	Includes a mixture of aspen, blue oak woodlands, and montane hardwoods that occur sporadically throughout National Parks Service and Forest Service lands.
Forest Coniferous	168,941	Include many conifer dominated vegetation types, such as Blue Oak-Foothill Pine, Closed-Cone Pine-Cypress, Douglas Fir, Jeffrey Pine, Lodgepole Pine, Ponderosa Pine, Red Fir, Sierran Mixed Conifer, and Mixed Montane Hardwoods Conifers.
Total Acres	*254,654**	

* Areas of land classed as “Urban” and “Barren” were not included in this analysis. Therefore the total area does not add up to 256,000 acres, as stated in Chapter 3.

4.2. Land Ownership in the Burned Area

It is important to see the fire in terms of land ownership as well as ecological impacts. While vegetative mapping shows the physical nature of plant communities, land ownership provides a different lens for understanding the Rim Fire. FEMA provides disaster assistance to private landowners, farmers and industry as well as state, county, city, utilities and other local tax jurisdictions, but provides no direct assistance to federal agencies. Figure 3 shows a map of private and public ownership boundaries related to the Rim Fire.

FIGURE 3 LAND OWNERSHIP IN THE RIM FIRE BURN AREA



Source: San Francisco Public Utilities Commission, using data from Bureau of Land Management

4.3. Valuation methodology

This study employed benefit transfer methodology (similar to a house or business appraisal) to derive the dollar values for each ecosystem service across each land cover type. Benefit transfer is used when the cost of conducting original studies on every ecosystem service for every vegetation type is cost or time prohibitive. It involves obtaining an estimate for the value of ecosystem services through the analysis of a group of studies, which have been previously completed to value similar ecosystem services in similar geographies and/or contexts. The transfer itself refers to the application of derived values and other information from the original study site to a new but sufficiently similar site, like a house or business "comparable" used for valuation appraisals.[18] As the "bedrock of practical policy analysis,"[19] benefit transfer has gained popularity in recent decades as decision-makers have sought timely and cost-effective ways to value ecosystem services and natural capital.[20]

Earth Economics maintains SERVES, the world's largest database of peer-reviewed ecosystem service valuation studies for use in benefit transfer and valuation research. Valuation techniques used to develop values in the database studies are well-accepted and derive from environmental and natural resource economics. As Figure 4 indicates, these techniques include direct market pricing, replacement cost, avoided cost, factor income method, travel cost, hedonic pricing and contingent valuation. Detailed information on the primary studies used in this benefit transfer is listed in Appendix 3.

FIGURE 4	VALUATION METHODS USED TO VALUE ECOSYSTEM SERVICES IN PRIMARY STUDIES
Avoided Cost (AC)	Services that allow society to avoid costs that would have been incurred in the absence of those services; e.g. storm protection provided by barrier islands avoids property damages along the coast.
Replacement Cost (RC)	Services that can be replaced with man-made systems; e.g. nutrient cycling waste treatment provided by wetlands can be replaced with costly treatment systems.
Factor income (FI)	Services that provide for the enhancement of incomes; e.g. water quality improvements increase commercial fisheries and the incomes of fishing communities.
Travel Cost (TC)	Service demand may require travel, which has costs that can reflect the implied value of the service; e.g. recreation areas can be valued at least by what visitors are willing to pay to travel to it, including the imputed value of their time.
Hedonic Pricing (HP)	Service demand may be reflected in the prices people will pay for associated goods, e.g. housing prices along the coastline tend to exceed the prices of inland homes.
Marginal Product Estimation (MP)	Service demand is generated in a dynamic modeling environment using a production function (Cobb-Douglas) to estimate the change in the value of outputs in response to a change in material inputs.
Contingent Valuation (CV)	Service demand may be elicited by posing hypothetical scenarios that involve some valuation of alternatives; e.g. people generally state that they are willing to pay for increased preservation of beaches and shoreline.
Group Valuation (GV)	This approach is based on principles of deliberative democracy and the assumption that public decision making should result, not from the aggregation of separately measured individual preferences, but from open public debate.

Adapted from Farber et al., 2006[21]

The greatest challenge to the valuation of environmental benefits is the lack of primary valuation studies. For example, despite the obvious and critical importance of aquifers to California's water supply, an economic valuation of aquifers in California has yet to be conducted. Similarly, not all ecosystem services identified as having economic value have been valued within the Rim Fire areas. Some land covers have few ecosystem services values available. For example, the land cover class "grassland" has only been valued for three ecosystem services: air quality, pollination, and aesthetic information. Yet areas with grasslands also provide biological control, flood risk reduction, and other important benefits.

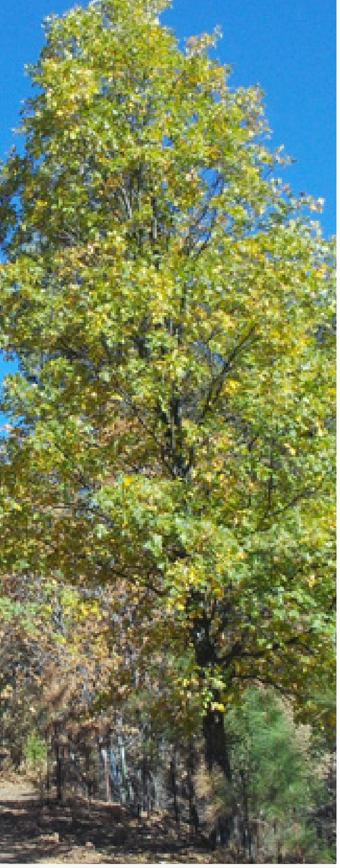
Table 3 provides a matrix that summarizes the suite of ecosystem services that were identified on each land cover within Rim Fire, and those for which values could be derived for this study. White boxes indicate that an ecosystem service is not present. Grey boxes show that an ecosystem service is present, but may not have an existing or appropriate economic valuation study to provide dollar values. Grey boxes marked with an "X" indicate ecosystem services that have dollar valuations. Orange boxes show that the ecosystem service is present and the economic value was derived from California.

A total of 10 ecosystem services were examined for value. Each of the eight land cover types in the Rim Fire burn area was valued for one or more ecosystem services. Within these, 37 ecosystem service/land cover type combinations were valued. Many identifiable ecosystem services with economic value in the burn area were not valued with dollar values due to a lack of data or absence of appropriate primary studies. As further primary studies are identified and added to the database, the accuracy of analysis for the Rim Fire area will improve.

TABLE 3 ECOSYSTEM SERVICES IDENTIFIED AND VALUED WITHIN THE RIM FIRE BURN AREA

	Grassland	Lake	River	Forest (Broad Leaf and Other)	Forest (Coniferous)	Shrub	Herbaceous Wetlands	Riparian
Food Provisioning								
Raw Materials								
Medicinal Resources								
Air Quality	X			X	X	X		
Climate Stability (Carbon Sequestration)	X			X	X	X	X	
Moderation of Extreme Events					X		X	X
Soil Retention								X
Biological Control				X	X			
Water Regulation				X	X			
Soil Formation								
Pollination	X				X	X	X	
Habitat and Biodiversity			X		X	X	X	X
Aesthetic Information	X		X	X				X
Recreation and Tourism		X	X	X	X	X	X	X
Science and Education								

Ecosystem service not produced by land cover	(blank)
Ecosystem service produced by land cover, no dollar value established	(grey)
Ecosystem service produced by land cover and dollar value(s) provided	X
Ecosystem service produced by land cover and dollar value(s) provided from California	X (orange)



4.4. Annual Value of Environmental Benefits Before the Rim Fire

Transferred values were converted to 2012 dollars per acre per year, representing the annual flow of value generated by a single ecosystem service on a specific land cover each year. Combining the available ecosystem service values (water regulation, habitat, recreation, etc.) for a single land cover yields a total value for that land cover in dollars per acre per year. The value of environmental benefits was compared before and after the Rim Fire, resulting in an estimate of benefits lost due to the fire. Tables 4 through 8 show the value of ecosystem services in $US per acre per year for each land cover before the Rim Fire occurred. The value of carbon sequestration and storage was calculated using a supplemental analysis, described in the following section.

TABLE 4 DOLLAR/ACRE ESTIMATES FOR AESTHETIC INFORMATION AND BIOLOGICAL CONTROL

	Aesthetic Information		Biological Control	
Land Cover	Low	High	Low	High
Grasslands	$1,952.99	$4,810.60		
Herbaceous Wetlands				
Lake				
Riparian	$251.38	$1,231.38		
River	$30.77	$12,270.48		
Shrub				
Forest (Broad Leaf and Mixed)			$1.82	$2.51
Forest Coniferous	$133.15	$11,221.80	$11.28	$11.28

TABLE 5 DOLLAR/ACRE ESTIMATES FOR MODERATION OF EXTREME EVENTS AND POLLINATION

	Moderation of extreme events		Pollination	
Land Cover	Low	High	Low	High
Grasslands			$420.20	$420.20
Herbaceous Wetlands	$1,698.13	$7,753.90		
Lake				
Riparian	$45.61	$63.07		
River				
Shrub			$6.89	$6.89
Forest (Broad Leaf and Mixed)				
Forest Coniferous	$670.93	$670.93	$71.72	$420.20

TABLE 6	DOLLAR/ACRE ESTIMATES FOR AIR QUALITY AND HABITAT AND NURSERY			
	Air Quality		Habitat and Nursery	
Land Cover	Low	High	Low	High
Grasslands	$10.79	$165.99		
Herbaceous Wetlands			$166.90	$54,659.05
Lake				
Riparian			$11.49	$52.64
River			$139.62	$3,037.09
Shrub	$6.43	$8.11	$0.64	$330.27
Forest (Broad Leaf and Mixed)	$18.29	$267.43		
Forest Coniferous	$12.85	$348.27	$0.95	$660.54

TABLE 7	DOLLAR/ACRE ESTIMATES FOR SOIL RETENTION AND WATER REGULATION			
	Soil Retention		Water Regulation	
Land Cover	Low	High	Low	High
Grasslands				
Herbaceous Wetlands				
Lake			$1,506.57	$1,506.57
Riparian	$223.11	$1,518.36		
River				
Shrub				
Forest (Broad Leaf and Mixed)			$54.55	$54.55
Forest Coniferous			$205.82	$205.82

TABLE 8	DOLLAR/ACRE ESTIMATES FOR RECREATION AND TOURISM	
	Dollar/Acre Estimates for Recreation and Tourism	
Land Cover	Low	High
Grasslands		
Herbaceous Wetlands	$43.92	$12,753.75
Lake	$26.06	$45,439.15
Riparian	$199.16	$2,192.74
River	$5.44	$23,871.30
Shrub	$15.89	$1,327.22
Forest (Broad Leaf and Mixed)	$2.31	$191.88
Forest Coniferous	$0.22	$2,623.12

The combined ecosystem service value for each land cover was multiplied by the area of that land cover within the Rim Fire perimeter. The results were summed across all land covers to arrive at a total annual value of ecosystem services for the Rim Fire burn area. Table 9 summarizes the value provided by selected ecosystem services across all land cover in the region before the fire. Table 9 includes the value and area of each land cover, and the estimated total annual value for all pre-burned lands.

TABLE 9	TOTAL ANNUAL ENVIRONMENTAL BENEFITS BEFORE THE RIM FIRE				
Land Cover Type	Acres	Low Annual $ Per Acre	High Annual $ Per Acre	Total Low Annual $	Total High Annual $
Grassland	20,201	2,384	5,397	48,158,109	109,019,089
Herbaceous Wetland	577	1,909	75,167	1,102,196	43,400,030
Lake	447	1,533	46,946	685,330	20,992,243
Riparian	191	731	5,058	139,255	963,924
River	161	176	39,179	28,253	6,295,734
Shrub	31,923	24	1,672	776,841	53,390,919
Forest (Broad Leaf and Mixed)	46,999	210	11,738	9,875,452	551,680,352
Forest Coniferous	154,156	974	4,940	150,110,548	761,552,764
Total	*254,654*			*210,875,983*	*1,547,295,054*

4.5. Carbon Storage Value Before the Rim Fire

Stored carbon biomass provides economic value by contributing to climate stability. In this study, the economic value of stored carbon within the Rim Fire burn area was calculated both before and after the Rim Fire.

Table 10 shows the acreage of different pre-fire plant communities within the Rim Fire burn area and an estimate for the total non-soil carbon biomass held within those communities. Table 10 represents the potential carbon sequestration for plant communities in the burn area if all vegetation were at maximum biomass. This data is based on the USFS data and sources for forest carbon for the forest types occurring in the Rim Fire burn area (see Appendix 1).

TABLE 10 CARBON BIOMASS OF RIM FIRE REGION BY LAND COVER

Plant Community*	Acreage**	Total Non-Soil Carbon Biomass (tC/acre)***
Aspen-Birch	32,080	74.83
Chaparrals	31,923	14.85 to 17.97
Douglas Fir	3,180	85.02
Lodgepole Pine	9,810	49.17
Mixed Conifer	123,938	111.86
Montane Riparian Meadows	20,778	64.75 to 76.89
Ponderosa Pine	30,138	51.76
Western Oak	2,008	105.50

*Based on collection of carbon stock data[22,23,24]
**Rounded to the nearest acre.
***Ranges were used when multiple references were available.

Table 11 provides dollar values per ton for stored carbon. The California Carbon Auction established a market value of $14.90/ton for carbon. The Stern Report examined the economic cost of releasing carbon into the atmosphere, including the social costs due to increased storm and drought.

TABLE 11 VALUES FOR CARBON SEQUESTRATION

Carbon Value ($/ton)	Source
$14.90	CA Carbon Auction[25]
$33.33 to $40	Stern Report (scenario: carbon reduction policy)[26]
$133.33	Stern Report (scenario: no carbon reduction policy)[27]

Table 12 provides high and low dollar values per acre for each type of plant community in the Rim Fire burn area, based on its non-soil carbon biomass potential and the economic value of storing one ton of carbon. The low value is based on the California Carbon Auction value of $14.90 per ton of carbon and the high value is based on the Stern Report high value of $133.33 per ton of carbon.

TABLE 12 TOTAL POTENTIAL VALUE OF NON-SOIL STORED CARBON BY LAND COVER

Plant Community	Total Non-Soil Carbon Biomass (tC/acre)*	Value per acre	
		Low	High
Aspen-Birch	74.83	$1,114.91	$8,480.08
Chaparrals	14.85 to 17.97	$221.27	$2,036.54
Douglas Fir	85.02	$1,266.87	$9,635.83
Lodgepole Pine	49.17	$732.62	$5,572.36
Mixed Conifer	111.86	$1,666.64	$12,676.55
Montane Riparian Meadows	64.75 to 76.89	$964.78	$8,713.94
Ponderosa Pine	51.76	$771.21	$5,865.89
Western Oak	105.50	$1,571.97	$11,956.50

* Non-soil carbon biomass estimates are based on plant communities aged between 90 and 125 years.

Much of the Stanislaus National Forest and private lands had been either logged or burned in previous fires prior to the Rim Fire. Thus, even before the Rim Fire, actual carbon storage was lower than total potential carbon storage in those forests. To adjust for actual forest age, tree diameter was used as a proxy to estimate carbon storage capacity across different areas of the Rim Fire burn area. Plant communities were assigned a “carbon stock capacity” coefficient based on the average tree diameter in those communities. For example, plant communities with an average tree diameter of 11-24 inches were estimated to hold 90% of the non-soil carbon biomass potential for that plant community (as described in Table 10). Table 13 summarizes the acreages of plant communities according to average tree diameter and carbon stock capacity in the Rim Fire burn area.

TABLE 13 TREE SIZE STATISTICS

Tree Diameter	Acreage	Percent of Total Acreage	Carbon Stock Capacity
< 1"	5,642	2.20%	5%
1 - 6"	11,967	4.66%	20%
6 - 11"	33,888	13.20%	45%
11 - 24"	107,589	41.92%	90%
> 24"	50,927	19.84%	100%
NA	46,630	18.17%	50%

Tables 14 and 15 show the value of carbon storage before the Rim Fire by land ownership and plant community type. The values were derived by multiplying the carbon storage value per acre of each plant community by the number of acres of each plant community (within each ownership category).

TABLE 14 VALUE OF CARBON STOCK PRE-RIM FIRE (1/2)

	BLM		Private	
Land Cover Type	Low	High	Low	High
Aspen-Birch	$19,919	$151,502	$1,415,659	$10,767,556
Chaparrals	$16,375	$150,720	$447,897	$4,122,479
Douglas Fir	$0	$0	$37,190	$282,870
Lodgepole Pine	$0	$0	$258,735	$1,967,946
Mixed Conifer	$58,645	$446,058	$18,705,133	$142,271,996
Montane Riparian Meadows	$5,531	$49,956	$2,327,837	$21,025,257
Ponderosa Pine	$0	$0	$4,743,567	$36,079,758
Western Oak	$2,059	$15,659	$458,012	$3,483,657
	$102,529	*$813,895*	*$28,394,029*	*$220,001,519*

TABLE 15 VALUE OF CARBON STOCK PRE-RIM FIRE (2/2)

	SNF		YNP	
Land Cover Type	Low	High	Low	High
Aspen-Birch	$26,040,318	$198,063,707	$8,290,576	$63,058,456
Chaparrals	$5,978,390	$55,025,558	$620,776	$5,713,674
Douglas Fir	$75,538	$574,548	$3,915,483	$29,781,322
Lodgepole Pine	$564,411	$4,292,934	$6,363,563	$48,401,520
Mixed Conifer	$116,096,138	$883,031,902	$71,700,744	$545,358,749
Montane Riparian Meadows	$11,319,715	$102,240,790	$6,393,109	$57,743,195
Ponderosa Pine	$15,267,984	$116,128,902	$3,231,561	$24,579,386
Western Oak	$1,717,070	$13,060,102	$980,389	$7,456,878
	$177,059,564	*$1,372,418,443*	*$101,496,203*	*$782,093,181*

4.6. Property Values Adjacent to the Rim Fire Burn Area

Fires reduce property values in nearby unburned areas. Studies from California and around the country have shown significant property value losses associated with forest fires due to factors such as an increased perception of fire risk by potential homebuyers, as well as a reduction in the amenity value of the forest.[28,29] An additional analysis was conducted on housing values in five zip codes within and adjacent to the Rim Fire burn area. Estimates of the average home and condominium values, as well as the number of properties within each zip code, were used to estimate the total property value potentially impacted by the Rim Fire. These estimates are summarized in Table 16.

Estimates for the decline in property value associated with the Rim Fire are calculated in the following section.

TABLE 16	PROPERTY VALUE WITHIN OR NEAR THE RIM FIRE BURN AREA		
Zip Code	Zillow Home Value Index* (August, 2013)	Homes & Condos per Zip Code[30]	Total Value per Zip Code
95321	$201,300	3,613	$727,296,900
95379	$150,000	1,831	$274,650,000
95346	$171,800	1,160	$199,288,000
95364	$325,000	720	$234,000,000
95335	$174,200	1,269	$221,059,800
		Total	*$ 1,656,294,700*

* Median value of all homes in a geographic area obtained from Zillow.com[31]

5. VALUATION OF ENVIRONMENTAL BENEFITS LOST TO THE RIM FIRE

After a severe fire event, the USFS conducts a Rapid Assessment of Vegetation Condition after Wildfire (RAVG), a process assessing forests fires within 30 days after containment of a wildfire that burns over 1,000 acres of National Forest System (NFS) land.[32] Using remote sensing tools, RAVG produces GIS data and maps of the Basal Area (BA) Loss within the fire perimeter. BA Loss measures the percent change in BA or tree cover (relative number of live trees on the site) from the pre-fire condition and is reported as four classes of percent change in tree cover as expressed in acres.

USFS produced a BA Loss estimate based on satellite data when the fire was more than 85% contained. Below, Table 17 shows the acreage for BA loss for each general land cover type.

Ecosystem service functions are impaired or enhanced by changes in land cover types or qualities. Forest areas, immediately after a fire, for example, have less biodiversity than an untouched forest. Within a few years, a burned area may have more biodiversity with pioneer species and greater light penetration, and then decline if a dense stand of similar aged trees grows without thinning. The relationship between BA Loss and ecosystem service function capacity requires further study. Each ecosystem will have different function losses and will regain (or not regain) those functions over time at different rates.

TABLE 17	ACREAGE OF VEGETATION TYPES CATEGORIZED BY BASAL AREA LOSS			
Land Cover	BA Loss (0%)	BA Loss (0-25%)	BA Loss (25-75%)	BA Loss (75-100%)
Grassland	2,019.93	2,808.54	3,232.60	12,139.65
Herbaceous Wetland	94.96	148.86	113.08	220.49
Lake	257.16	112.65	48.98	28.37
Riparian	63.36	49.25	26.69	51.27
River	89.97	39.29	22.63	8.80
Shrub	2,099.28	3,630.59	4,164.85	22,028.27
Forest (Broad Leaf and Mixed)	7,322.75	10,560.30	7,492.88	21,622.93
Forest Coniferous	40,058.04	35,464.05	23,669.01	54,964.46

The BA Loss is a coarse, rapid assessment of real fire damage to vegetation. The loss in ecosystem service function associated with that vegetative loss is also real, and in this study a necessarily coarse and rapid approximation was used, for disaster response purposes. Based on expert judgment, a coefficient was adopted to represent the loss of ecosystem services according to BA loss. Table 18 provides estimates of the decline in ecosystem service function and carbon storage capacity with each level of BA Loss.

TABLE 18	ECOSYSTEM SERVICE FUNCTION CAPACITY AT BASAL AREA LOSS	
BA Loss	Ecosystem Service Function Capacity	Carbon Storage Capacity
0%	100%	100%
0 - 25%	90%	90%
25 - 75%	50%	50%
75 - 100%	10%	10%

Overall, the losses of ecosystem services may be significantly larger. Fire history demonstrates that the BA Loss is larger than what an immediate post-fire analysis reveals. This is because many trees that are severely stressed by the fire are still green during the immediate post-fire BA Loss survey, but they do die eventually, thereby expanding the actual BA Loss area and further reducing ecosystem service function.

The loss of carbon storage should be considered additive to timber value because the carbon value is not included in the timber value. Timber values were not estimated in this study, but may be estimated separately by California agencies and private timber owners.

Post-fire ecosystem service benefits were estimated by multiplying the Function Capacity coefficients associated with the BA Loss with the ecosystem service values provided in Table 9. By subtracting the post-fire estimate of ecosystem service benefits from the pre-fire ecosystem service benefits, a loss in environmental benefit value for the first year after the fire can be estimated. Tables 19 and 20 show the reduced value of each ecosystem service by land cover type and BA loss category.

TABLE 19 ANNUAL VALUE OF ECOSYSTEM SERVICES LOST DUE TO RIM FIRE BY BASAL AREA LOSS (1/2)

	Acres BA Loss (0%)		Acres BA Loss (0-25%)	
Land Cover	Low	High	Low	High
Grassland	$0	$0	$669,550	$1,515,709
Herbaceous Wetland	$0	$0	$28,416	$1,118,898
Lake	$0	$0	$17,266	$528,865
Riparian	$0	$0	$3,599	$24,911
River	$0	$0	$691	$153,932
Shrub	$0	$0	$8,835	$607,213
Forest Broad Leaf	$0	$0	$221,894	$12,395,856
Forest Coniferous	$0	$0	$3,453,348	$17,519,801
	$0	*$0*	*$4,403,598*	*$33,865,184*

TABLE 20 ANNUAL VALUE OF ECOSYSTEM SERVICES LOST DUE TO RIM FIRE BY BASAL AREA LOSS (2/2)

	Acres BA Loss (25-75%)		Acres BA Loss (75-100%)	
Land Cover	Low	High	Low	High
Grassland	$3,853,222	$8,722,825	$26,046,624	$58,963,678
Herbaceous Wetland	$107,927	$4,249,738	$378,815	$14,916,216
Lake	$37,531	$1,149,609	$39,129	$1,198,564
Riparian	$9,751	$67,495	$33,721	$233,419
River	$1,990	$443,403	$1,392	$310,188
Shrub	$50,676	$3,482,840	$482,449	$33,157,881
Forest Broad Leaf	$787,206	$43,976,311	$4,089,091	$228,432,188
Forest Coniferous	$11,523,971	$58,464,328	$48,169,980	$244,379,773
	$16,372,274	*$120,556,548*	*$79,241,202*	*$581,591,906*

TABLE 21 TOTAL RIM FIRE FIRST-YEAR ECOSYSTEM SERVICE VALUES LOST BY LAND COVER

Land Cover	Low	High
Grassland	$30,569,395	$69,202,212
Herbaceous Wetland	$515,158	$20,284,851
Lake	$93,926	$2,877,038
Riparian	$47,071	$325,824
River	$4,073	$907,523
Shrub	$541,959	$37,247,933
Forest Broad Leaf	$5,098,191	$284,804,356
Forest Coniferous	$63,147,300	$320,363,902
	$100,017,074	*$736,013,639*

BA losses were summed for each land cover to arrive at the estimated first-year losses of ecosystem service goods and services caused by the Rim Fire. Table 21 shows these estimated losses by land cover type.

Table 22 shows the ecosystem service losses due to the Rim Fire by ecosystem service.

TABLE 22 TOTAL ANNUAL ECOSYSTEM SERVICES LOST TO THE RIM FIRE BY ECOSYSTEM SERVICE

Ecosystem Service	Low	High
Aesthetic Information	$28,290,426	$334,324,867
Biological Control	$775,534	$792,153
Moderation of Extreme Events	$43,970,557	$45,605,922
Air Purification	$1,558,478	$31,382,368
Habitat and Biodiversity	$125,029	$65,015,130
Pollination	$10,069,509	$32,791,479
Recreation and Tourism	$450,299	$211,241,045
Soil Retention	$14,371	$97,805
Waste Treatment	$14,762,870	$14,762,870
	$100,017,074	***$736,013,639***

5.1. Environmental Benefits Lost to the Rim Fire by Land Ownership

The losses of environmental benefits across the landscape were sustained on both public and private lands. Areas in the Stanislaus National Forest, Yosemite National Park, Bureau of Land Management, private forestlands, and other private lands were burned over. The USFS has provided immediate post-fire estimates of the BA Loss as well as the vegetation cover type for each of the ownership areas within the Rim Fire. This enabled the calculations of the loss of value for each land ownership class across land cover types and ecosystem services.

Table 23 shows the acreage within the Rim Fire burn area by land ownership agency or group.

TABLE 23 ACREAGE BY LAND OWNERSHIP

Owner of Land	Total Acres
Bureau of Land Management (BLM)	135
Private	23,799
Stanislaus National Forest (SNF)	153,648
Yosemite National Park (YNP)	77,072
Grand Total	*254,654*

For each of these ownership categories, GIS data enabled a calculation of the acreages for eight land cover types within the Rim Fire burn area. From this data, the pre- and post-burn ecosystem services values for were estimated, resulting in the ecosystem service value losses within each land cover type, by ownership category.

Tables 24 and 25 show the minimum and maximum estimates of the pre-burn value of the ecosystem services lost in first year after Rim Fire for each land cover type by land ownership.

Tables 26 and 27 show ecosystem service value lost due to the Rim Fire by ecosystem service across the land ownership classes.

TABLE 24 TOTAL FIRST POST FIRE YEAR ECOSYSTEM SERVICE LOST BY LAND OWNERSHIP AND LAND COVER (1/2)

	BLM		Private	
Land Cover	Low	High	Low	High
Grassland	$3,658	$8,281	$2,407,599	$5,450,262
Herbaceous Wetland	$0	$0	$95,653	$3,766,441
Lake	$0	$0	$364	$11,136
Riparian	$0	$0	$12,911	$89,368
River	$2	$484	$8	$1,743
Shrub	$1,007	$69,212	$27,067	$1,860,278
Forest Broad Leaf	$2,120	$118,459	$258,574	$14,444,903
Forest Coniferous	$16,670	$84,573	$7,181,769	$36,435,120
	$23,458	*$281,009*	*$9,983,944*	*$62,059,250*

TABLE 25 TOTAL FIRST POST FIRE YEAR ECOSYSTEM SERVICE LOST BY LAND OWNERSHIP AND LAND COVER (2/2)

	SNF		YNP	
Land Cover	Low	High	Low	High
Grassland	$16,279,052	$36,852,100	$11,879,086	$26,891,569
Herbaceous Wetland	$24,798	$976,435	$394,707	$15,541,975
Lake	$4,772	$146,166	$88,791	$2,719,735
Riparian	$2,337	$16,174	$31,824	$220,283
River	$2,619	$583,588	$1,444	$321,709
Shrub	$462,728	$31,802,472	$51,158	$3,515,971
Forest Broad Leaf	$4,078,323	$227,830,664	$759,174	$42,410,330
Forest Coniferous	$32,086,521	$162,783,890	$23,862,340	$121,060,320
	$52,941,149	*$460,991,488*	*$37,068,522*	*$212,681,892*

TABLE 26 — TOTAL ANNUAL ECOSYSTEM SERVICES LOST BY LAND OWNERSHIP AND ECOSYSTEM SERVICE (1/2)

	BLM		Private	
Ecosystem Service	Low	High	Low	High
Aesthetic Information	$4,341	$120,781	$2,140,636	$18,690,033
Biological Control	$211	$218	$85,415	$86,258
Moderation of Extreme Events	$11,486	$11,486	$5,034,232	$5,337,983
Air Purification	$687	$9,251	$135,311	$3,074,310
Habitat and Biodiversity	$45	$25,013	$16,302	$7,978,953
Pollination	$1,929	$8,124	$954,822	$3,531,162
Recreation and Tourism	$685	$102,061	$27,837	$21,748,279
Soil Retention	$0	$0	$3,942	$26,826
Waste Treatment	$4,074	$4,074	$1,585,447	$1,585,447
	$23,458	***$281,009***	***$9,983,944***	***$62,059,250***

TABLE 27 — TOTAL FIRST POST FIRE YEAR ECOSYSTEM SERVICE LOST BY LAND OWNERSHIP AND ECOSYSTEM SERVICE (2/2)

	SNF		YNP	
Ecosystem Service	Low	High	Low	High
Aesthetic Information	$15,921,656	$250,844,325	$10,223,793	$64,669,728
Biological Control	$406,974	$420,269	$282,934	$285,408
Moderation of Extreme Events	$22,130,256	$22,208,978	$16,794,582	$18,047,475
Air Purification	$974,288	$17,954,063	$448,192	$10,344,744
Habitat and Biodiversity	$47,869	$28,801,151	$60,813	$28,210,014
Pollination	$5,258,616	$16,846,630	$3,854,141	$12,405,564
Recreation and Tourism	$355,414	$116,065,857	$66,363	$73,324,848
Soil Retention	$713	$4,855	$9,716	$66,124
Waste Treatment	$7,845,361	$7,845,361	$5,327,988	$5,327,988
	$52,941,149	***$460,991,488***	***$37,068,522***	***$212,681,892***

5.2. Carbon Storage Value Lost to the Rim Fire

Tables 28 and 29 show low and high estimates of the carbon storage value lost by land cover across the four land ownership classes. Total carbon storage losses are estimated at $102 million to $797 million.

TABLE 28 CARBON STORAGE LOST BY LAND COVER AND LAND OWNERSHIP

	BLM		Private	
Land Cover Type	Low	High	Low	High
Aspen-Birch	$4,985	$37,915	$466,311	$3,546,777
Chaparrals	$6,743	$62,064	$181,240	$1,668,147
Douglas Fir	$0	$0	$378	$2,876
Lodgepole Pine	$0	$0	$86,633	$658,932
Mixed Conifer	$25,142	$191,233	$6,211,438	$47,244,449
Montane Riparian Meadows	$1,090	$9,847	$753,122	$6,802,277
Ponderosa Pine	$0	$0	$1,561,224	$11,874,734
Western Oak	$758	$5,766	$77,796	$591,721
	$38,719	*$306,825*	*$9,338,142*	*$72,389,913*

TABLE 29 CARBON STORAGE LOST BY LAND COVER AND LAND OWNERSHIP

	SNF		YNP	
Land Cover Type	Low	High	Low	High
Aspen-Birch	$10,859,965	$82,601,334	$2,419,439	$18,402,354
Chaparrals	$3,098,397	$28,517,884	$342,548	$3,152,838
Douglas Fir	$4,438	$33,754	$1,147,756	$8,729,880
Lodgepole Pine	$245,673	$1,868,598	$1,732,824	$13,179,925
Mixed Conifer	$34,915,402	$265,567,956	$21,766,041	$165,553,387
Montane Riparian Meadows	$4,860,773	$43,902,982	$3,687,153	$33,302,735
Ponderosa Pine	$5,551,090	$42,221,815	$1,578,446	$12,005,727
Western Oak	$522,911	$3,977,281	$250,306	$1,903,839
	$60,058,649	*$468,691,604*	*$32,924,515*	*$256,230,686*

5.3. Property Value Lost due to the Rim Fire

Fires cause home values to decline where the homes are near a burn area. Three studies provide California-based values and values outside of California showing the degree of house value declines related to wildfires. Property values in California were shown to decline between 3% and 16% following a fire. This literature and the values associated with each study (high and low) are shown in Table 30.

Using the average housing values for zip codes within or bordering the Rim Fire from Table 14, and the low and high home value declines from Table 30, total private property value reductions due to the Rim Fire were estimated and are provided in Table 29. Distance from the fire or viewshed of the fire influences the value decline.[39]

Table 31 shows substantial property value loss within Tuolumne County, which may be reflected in property assessment reductions and declines in property tax receipts for the County, State, and other tax districts.

5.4. Value Ranges

The range in values represents an appraisal of the natural capital value provided and lost by Yosemite National Park, the Stanislaus National Forest, Bureau of Land Management and private lands within the Rim Fire area. The range provided is wide, but will narrow as more detailed analysis of key ecosystem services, land cover types, and spatial mapping of the fire's damage is completed.

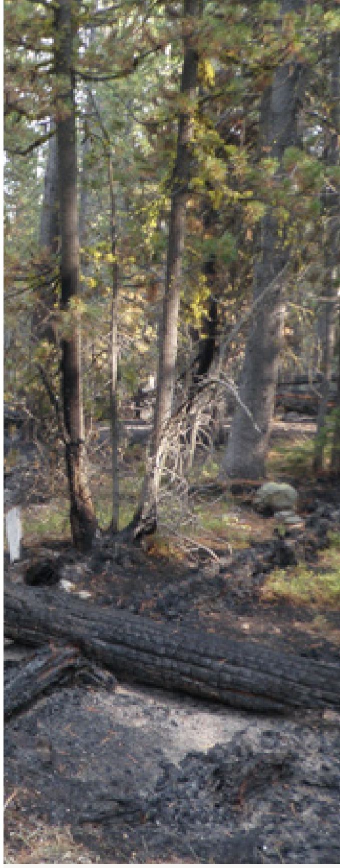


TABLE 30 LITERATURE DEMONSTRATING THE IMPACT ON PROPERTY VALUES DUE TO A WILDFIRE

Decline in Housing Value	Source
3.00%	Price-Waterhouse Coopers, 2001[33]
7.60%	Stetler, et al. 2010[34]
11.00%	Price-Waterhouse Coopers, 2001[35]
13.70%	Stetler, et al. 2010[36]
15.00%	Loomis, J. 2004[37]
16.00%	Loomis, J. 2004[38]

TABLE 31 PROPERTY VALUE REDUCTION DUE TO THE RIM FIRE

	Property Value Lost to Fire	
Total Value per Zip Code	Low	High
$727,296,900	$21,818,907	$116,367,504
$274,650,000	$8,239,500	$43,944,000
$199,288,000	$5,978,640	$31,886,080
$234,000,000	$7,020,000	$37,440,000
$221,059,800	$6,631,794	$35,369,568
$1,656,294,700	*$49,688,841*	*$265,007,152*

The low end of the ecosystem service ranges in this study can be considered as "below the basement" baseline value, an underestimate of the true value, because while up to 20 known ecosystem services for each land cover were identified, only between 2 - 10 of the services could be valued for each land cover type. Due to a lack of valuation studies, some highly valuable ecosystem services were not valued. For example, the storage value of ice and snowpack – which is critically valuable for water supply, energy generation, and timing of water release in the dry summer – is not included.

6. CONCLUSIONS

The immediate damage caused by the Rim Fire is estimated at between $100 million and $736 million to environmental benefits for the first year after the fire. This is based on satellite data for the fire perimeter and tree damage that were accessed by Earth Economics on September 17, 2013 when the fire was 84% contained. These estimated losses for the first year after the fire amount to nearly half of the pre-fire annual value. These are preliminary values that were developed while the fire was still burning. The fire burn perimeter was then estimated at over 250,000 acres, but both the burn area and subsequent damages have grown larger. The range in values represents the lowest and highest appropriate values in the academic peer reviewed literature for each category of environmental benefit. This is an appraisal of natural capital before and after the Rim Fire, similar to a house appraisal before and after a fire or flood.

This study provides the monetary value of 10 out of 18 environmental benefits or ecosystem services that were identified within the burn area as having economic value. One or more ecosystem services were valued for each of the eight land cover types that were burned by the fire. The natural benefits valued include air quality, carbon sequestration, moderation of extreme events, soil retention, biological control, water regulation, pollination, habitat and biodiversity, property and aesthetic values and recreational values. The land cover types include: grassland/meadow, herbaceous wetland, shrub, river, lake, riparian, forest broad leaf and mixed forest, and coniferous forest.

A benefit transfer methodology was applied to estimate the total ecosystem service value loss before and after the Rim Fire. Benefit Transfer Methodology is a federally-accepted economic valuation methodology that utilizes previous valuation studies of similar goods or services in comparable locations. These valuation studies each utilize one of eight primary valuation techniques, which include market pricing, cost avoidance, replacement costs, travel cost and contingent valuation. Inherent uncertainty exists, and because site specific studies for each ecosystem services would be cost prohibitive, the results of this valuation are characterized as a range of high and low values per-acre, based on the summation of up to 10 ecosystem service values across different vegetation types.

The Rim Fire impacted private and public assets, most significantly forests. This includes the Stanislaus National Forest, Yosemite National Park, private timberlands and Bureau of Land Management forestlands. National disaster declarations are based upon damage to non-federal lands and assets. The loss of environmental benefits is also estimated by land ownership category. Four land ownership categories were identified in the burn area: (1) Bureau of Land Management, (2) Private Lands, (3) Stanislaus National Forest, and (4) Yosemite National Park.

Environmental benefit losses for Private Lands within the Rim Fire perimeter was estimated at $10 million to $62 million, or about 10% of the total year 1 post-fire damages.

In addition, private properties close to wildfires lose asset value (assessed property value) immediately after a wildfire. A supplemental analysis was conducted to estimate this loss of value, over and above the loss of environmental benefits. **Applying previous estimates from the economic literature to property values in selected zip codes near the Rim Fire, the fire-related private property value loss is estimated at between $49.7 million and $265 million.** These estimates imply (but do not include) associated declines in property taxes for local and state tax districts.

The Federal government recognizes the economic value of natural systems. The Federal Emergency Management Agency (FEMA) adopted Mitigation Policy FP-108-024-01, which provides explicit environmental benefits (ecosystem service) dollar values for use in all flood and hurricane disaster mitigation. This improvement in economic analysis saves significant amounts of taxpayer money. FEMA also conducted an analysis that showed 300% to 1,500% rate of return on one class of flood mitigation projects.

In 2013, the President's Council on Environmental Quality also approved a new Principles and Requirements for Investments in Water Resources recognizing ecosystem service values in project benefit cost analysis. Also, the 2012 USFS has a new land-management planning rule, governing 155 National Forests, systematically includes ecosystem services with 72 ecosystem service references.

7. FUTURE RESEARCH

This is a rapid assessment and valid for inclusion with the other estimates of Rim Fire disaster damages. However, these estimates should be considered preliminary findings. The analysis can be improved as further data about the Rim Fire becomes available.

Fires are becoming more common, larger and more costly. It is critically important to develop the economic analysis to value the fires that are beneficial to overall ecosystem health and to the long-run health of highly valuable services such as timber and water supply, carbon sequestration and recreation. Some recommendations for improvements are included below.

7.1. Improvement of California Ecosystem Service Values

This draft analysis provides a first cut at valuation of ecosystem services for the burn area. More than 30 additional ecosystem service values, which are not included in this analysis, such as snowpack storage value, have no primary studies in California. Louisiana has more primary ecosystem service valuations than California, though the population and geography are significantly smaller, and is using those valuations in Mississippi River Delta to secure a larger scale of restoration ($50 billion). Other studies that are critical to economic development in California and the country include the impact of fire on water supply, quality, release timing, flow and temperature. Studies on soil retention for coniferous and broad leaf forests is highly valuable for water quality, reservoir storage space, slope stability and landslide prevention. Values for recreation in the Sierra Nevada are clearly higher than most mountainous areas in the country and need to be more closely calculated. These include hiking, biking, boating, swimming, hunting, fishing, bird watching, rafting, rafting kayaking, and more.

7.2. Incorporation of Historical Fires and Stand Age Data

Including the stand age, or tree girth as proxies for stand age, was roughly accomplished in this report. With more time, the inclusion of available data on stand age and tree girth will refine the analysis of this part of the study. In addition, each ecosystem service changes at different rates in service delivery with stand age and diversity. Understanding the science and economics of stand age on ecosystem service values can improve the pre and post fire estimate of ecosystem services. In addition, to calculate the impact on these benefits across time including a recovery curve for forests and their associated ecosystem services would provide a better estimate of future ecosystem flow impacts. It could also help in the calculation of a rate of return for investments in planting and restoration. Another aspect is including tree species diversity with stand age.

7.3. Impact on Water Supply, Quality, Timing and Reliability

Water is becoming a sharper constraint on development and ecosystem health in California. Because most of the precipitation in California falls in the north and east, resulting in little water for the rest of the state, the heavily populated south, west and arid Central Valley require water transfers. Californians have been willing to pay for increased reliability in water supplies and conservation for curbing demand.

Fire has a direct impact on water production and timing, though this impact has not been sufficiently studied. Due to the interplay between built capital and natural capital, the impact of fire may differ significantly between watersheds in California. It is almost certainly worth many tens of billions of dollars to improve our understanding of the science and economics of fires and their impacts on water, provided this is reflected in policy.

Rivers, streams and lakes provide a suite of valuable services to people and economies. This includes water conveyance, cooling, water regulation, and supply of water for drinking, irrigation, industry, salmon habitat and recreational opportunities. However, most of these services depend on the volume, timing and quality of the rivers. Once the Rim Fire's impact on the watershed is better understood, local biophysical and economic data, along with Benefit Transfer Methodology can be used to better measure the impacts on a range of water-dependent ecosystem services.

The value for Californians of avoiding water shortages can also justify greater resources for forest management and restoration. A study for the California Urban Water Agencies (CUWA) in 1994 demonstrates the importance of this issue. Respondents to a contingent valuation survey administered to CUWA service areas in California were willing to pay large amounts to avoid even the smallest shortage scenarios. Willingness to pay to avoid water shortages ranged from $11.60 to $16.90 per month. These results also indicated that the respondents were willing to pay more in order to avoid larger or more frequent shortages.

7.4. Impact on Snowpack and Groundwater

The storage value of ice and snowpack, critically valuable for both water supply and energy generation, is not considered in this report. The Sierra Nevada ice and snowpack stores water in the wet winter and releases it in the late spring and early summer, providing value for drinking, agricultural and industrial water, hydroelectric power, flood control, recreation and salmon habitat. This study did not place a dollar value on the water storage value of snowpack, or the impacts of the Rim Fire on Sierra Nevada snowpack. One method for estimating the value of snow pack would be to utilize a replacement cost – the cost of replacing snowpack with additional manmade storage facilities (e.g. in $/acre foot of storage capacity).

7.5. Hydrophobic Soils

One impact of a large fire is that the ash and soot creates a hydrophobic soil crust, which repels water, resulting in creating faster runoff and less water infiltration for later release from soils or infiltration into groundwater. This problem has caused tremendous costs in other areas, such as the eastern slope of the Rocky Mountains. There should be primary valuation studies completed on the physical influence of post-fire hydrophobic soils and the economic consequences of these physical impacts, but to date none exist.

7.6. Impact on Recreation

The Stanislaus National Forest and Yosemite National Park draw millions of visitors each year, many for recreational activities as diverse as hiking, hunting, fishing, water activities, bicycling and horse riding.[40] However, the Rim Fire has closed many areas of both parks to recreational activities. The Earth Economics database contains hundreds of values specific to recreational activities on federal lands. Once the impact of the Rim Fire on recreational visitor numbers becomes better known, estimates of the damage to the local economy and businesses could be calculated.

7.7. Impact on Air Quality and Human Health

Damage to human health due to the scale of this forest fire and air pollution could be calculated as a further damage from the fire. This will require further data collection on the smoke plume and impacts on human health in communities close to the fire and in the Central Valley.

Advancing these areas of research would better equip local governments, utilities, counties, the State of California and federal agencies like the USFS and FEMA in setting both damage estimates for fires and investments which reduce fire impacts. For example, one study notes that: "A cost of illness estimate is $9.50 per exposed person per day. However, theory and empirical research consistently find that this measure largely underestimates the true economic cost of health effects from exposure to a pollutant in that it ignores the cost of defensive actions taken as well as disutility. For the first time, the defensive behavior method is applied to calculate the willingness to pay for a reduction in one wildfire smoke induced symptom day, which is estimated to be $84.42 per exposed person per day."[41]

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APPENDIX A. ADDITIONAL CARBON TABLES

Table A shows the land cover type, acreage, carbon stock classification-type and combined land cover classifications that were adapted for this report for carbon stock value calculations. The WHR Land Cover taxonomy is an adaptation of CALVEG as constructed by the USFS.[42]

TABLE A | LAND COVER TAXONOMY CONVERSION

WHR Land Cover Type	Acreage	Carbon Stock Literature	EE Land Cover Type
Annual Grassland	11,842.08	Montane Riparian Meadows	Grassland
Aspen	18.98	Aspen-Birch	Forest (Broad Leaf and Other)
Barren	1,879.33	N/A	Snowpack
Blue Oak Woodland	133.29	Oak-Hickory	Forest (Broad Leaf and Other)
Blue Oak-Foothill Pine	1,875.35	Oak-Pine	Forest (Conifer)
Chamise-Redshank Chaparral	45.17	Chaparrals	Shrub
Closed-Cone Pine-Cypress	24.22	Oak-Gum-Cypress	Forest (Conifer)
Douglas Fir	129.29	Douglas-Fir	Forest (Conifer)
Jeffrey Pine	8,840.73	Loblolly-Shortleaf Pine	Forest (Conifer)
Lacustrine (lake)	944.61	N/A	Lake
Lodgepole Pine	21,367.14	Lodgepole Pine	Forest (Conifer)
Mixed Chaparral	10,510.67	Chaparrals	Shrub
Montane Chaparral	32,061.05	Chaparrals	Shrub
Montane Hardwood	14,785.54	Elm-Ash-Cottonwood	Forest (Broad Leaf and Other)
Montane Hardwood-Conifer	190.57	Mixed Conifer	Forest (Broad Leaf and Other)
Montane Riparian	8,358.63	N/A	Riparian
Perennial Grassland	30,138.34	Montane Riparian Meadows	Grassland
Ponderosa Pine	3,050.38	Ponderosa Pine	Forest (Conifer)
Red fir	160.69	Douglas-Fir	Forest (Conifer)
Riverine	105,711.59	N/A	River
Sierran Mixed Conifer	1,175.87	Mixed Conifer	Forest (Conifer)
Subalpine Conifer	110.73	Mixed Conifer	Forest (Conifer)
Urban	577.38	N/A	Urban
Wet Meadow	2,265.18	Montane Riparian Meadows	Herbaceous Wetland
White fir	447.16	Mixed Conifer	Forest (Conifer)

Source: United States Forest Service. 2009. CALVEG/CWHR Xwalk.

APPENDIX B. ECOSYSTEM SERVICE LOSSES IN PRIVATE LANDS

TABLE B	VALUE LOST IN PRIVATE LANDS BY LAND COVER	
	Private	
Land Cover	Low	High
Grassland	$2,407,599	$5,450,262
Herbaceous Wetland	$95,653	$3,766,441
Lake	$364	$11,136
Riparian	$12,911	$89,368
River	$8	$1,743
Shrub	$27,067	$1,860,278
Forest (Broad Leaf and Mixed)	$258,574	$14,444,903
Forest Coniferous	$7,181,769	$36,435,120
	$9,983,944	***$62,059,250***

TABLE C	VALUE LOST IN PRIVATE LANDS BY ECOSYSTEM SERVICE	
	Private	
Ecosystem Service	Low	High
Aesthetic Information	$2,140,636	$18,690,033
Biological Control	$85,415	$86,258
Moderation of Extreme Events	$5,034,232	$5,337,983
Air Purification	$135,311	$3,074,310
Habitat and Biodiversity	$16,302	$7,978,953
Pollination	$954,822	$3,531,162
Recreation and Tourism	$27,837	$21,748,279
Soil Retention	$3,942	$26,826
Waste Treatment	$1,585,447	$1,585,447
	$9,983,944	***$62,059,250***

APPENDIX C. ECOSYSTEM SERVICE VALUES REFERENCE TABLE

All dollar values, adjusted to 2012 dollars, in this report are provided with land cover, ecosystem service, article reference, and dollar values derived.

Land Cover	Ecosystem Service	Author(s) (Primary)	Minimum ($/acre/year)	Maximum ($/acre/year)
Forest (Broad Leaf and Mixed)	Aesthetic Information	Thompson, R., et al.	$133.15	$11,221.80
	Biological Control	Pimentel et al. (1996)	$2.51	$2.51
		Pimentel et al. (1996)	$1.82	$1.82
	Air Quality	Mates. W., Reyes, J.	$60.57	$267.43
		Pimentel et al. (1996)	$18.29	$18.29
	Recreation and Tourism	Bennett, R., et. al.	$191.88	$191.88
		Maxwell, S.	$139.47	$185.97
		Prince, R. and Ahmed, E.	$91.09	$115.69
		Prince, R. and Ahmed, E.	$2.31	$2.94
		Shafer, E. L., et al.	$3.10	$3.10
		Shafer, E. L., et al.	$101.14	$101.14
	Waste Treatment	Pimentel et al. (1996)	$54.55	$54.55
Forest Coniferous	Biological Control	Wilson, S. J.	$11.28	$11.28
	Disturbance Regulation	Wilson, S. J.	$670.93	$670.93
	Air Quality	Costanza, R., et al.	$12.85	$16.20
		Wilson, S. J.	$348.27	$348.27
		Wilson, S. J.	$14.82	$14.82
		Wilson, S. J.	$163.53	$163.53
	Habitat and Biodiversity	Costanza, R., et al.	$1.28	$660.54
		Haener, M. K. and Adamowicz, W. L.	$0.95	$6.52
	Pollination	Costanza, R., et al.	$71.72	$322.11
		Wilson, S. J.	$420.20	$420.20
		Wilson, S. J.	$233.18	$233.18
	Recreation and Tourism	Boxall, P. C., et al.	$0.22	$0.22
		Costanza, R., et al.	$0.44	$2,623.12
		Shafer, E. L., et al.	$560.58	$560.58
		Wilson, S. J.	$126.85	$126.85

	Waste Treatment	Wilson, S. J.	$205.82	$205.82
Grasslands	Aesthetic Information	Mazzotta, M.	$1,952.99	$3,676.22
		Opaluch, R.J. et al.	$4,810.60	$4,810.60
	Air Quality	Wilson, S. J.	$165.99	$165.99
		Wilson, S. J.	$10.79	$10.79
	Pollination	Wilson, S. J.	$420.20	$420.20
Herbaceous Wetlands	Disturbance Regulation	Leschine et al.	$1,698.13	$7,753.91
		Leschine et al.	$1,971.38	$6,271.80
		Thibodeau, F. R. and Ostro, B. D.	$7,577.99	$7,577.99
	Habitat and Biodiversity	Pate, J. and Loomis, J.	$54,659.05	$54,659.05
		Woodward, R., and Wui, Y.	$166.90	$1,723.41
	Recreation and Tourism	Jaworski and Raphael 1981	$212.18	$1,625.48
		Thibodeau, F. R. and Ostro, B. D.	$711.35	$12,753.75
		Woodward, R., and Wui, Y.	$166.90	$2,357.62
		Woodward, R., and Wui, Y.	$43.92	$346.09
		Woodward, R., and Wui, Y.	$927.59	$4,887.40
Lake	Recreation and Tourism	Burt, O. R. and Brewer, D.	$2,630.49	$2,816.16
		Cordell, H. K. and Bergstrom, J. C.	$995.25	$1,959.03
		Eiswerth, M.E., et al.	$67.63	$12,915.84
		Kealy, M. J. and Bishop, R. C.	$26.06	$39.09
		Mullen, J. K. and Menz, F. C.	$302.05	$302.05
		Piper, S.	$643.09	$643.09
		Ribaudo, M. and Epp, D. J.	$1,751.98	$2,006.44
		Wade, W.W., McCollister, G.M., McCann, R.J., Johns, G.M.	$975.32	$45,439.15
		Ward, F. A., et al.	$4,684.45	$4,684.45
	Waste Treatment	Bouwes, N. W. and Scheider, R.	$1,506.57	$1,506.57

Riparian	Aesthetic Information	Qiu et al.	$251.38	$1,231.38
	Disturbance Regulation	Zavaleta, E.	$45.61	$63.07
	Habitat and Biodiversity	Knowler, D. J. et al.	$11.49	$52.64
	Recreation and Tourism	Lant, C. L. and Tobin, G.	$199.16	$2,192.74
	Soil Retention	Rein, F. A.	$1,518.36	$1,518.36
		Rein, F. A.	$223.11	$223.11
River	Aesthetic Information	Kulshreshtha, S. N. and Gillies, J. A.	$30.77	$849.67
		Sanders, L. D., et al.	$12,270.48	$12,270.48
	Habitat and Biodiversity	Berrens, R. P., et al.	$2,388.22	$2,388.22
		Wu, J. Skelton-Groth, K.	$139.62	$3,037.09
	Recreation and Tourism	Bowker, J. M., et al.	$5,015.05	$12,052.96
		Duffield, J. W., et al.	$1,785.66	$18,411.74
		Everard and Jevons	$5.44	$5.44
		Everard and Jevons	$15.45	$15.45
		Greenley, D., et al.	$21.65	$21.65
		Loomis J.B.	$23,871.30	$23,871.30
		Mathews, L. G., et al.	$14,277.52	$14,277.52
		Mullen, J. K. and Menz, F. C.	$432.83	$432.83
		Sanders, L. D., et al.	$2,868.43	$2,868.43
		Shafer, E. L., et al.	$4,620.17	$4,620.17
		Shafer, E. L., et al.	$17,646.43	$17,646.43
Shrub	Air Quality	Costanza, R., et al.	$6.43	$8.11
	Habitat and Biodiversity	Costanza, R., et al.	$0.64	$330.27
	Pollination	Costanza, R., et al.	$1.37	$6.89
	Recreation and Tourism	Bennett, R., et. al.	$191.88	$191.88
		Costanza, R., et al.	$15.89	$1,327.22

APPENDIX D. VALUATION STUDIES USED

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APPENDIX E. STUDY LIMITATIONS AND CAVEATS

Study limitations can be grouped into three categories: 1) lack of information, 2) benefit transfer limitations, and 3) improvements with modeling and spatial data.

The greatest gap in the valuation of ecosystem services is the lack of values for ecosystem services identified as present and impacted. Of the 137 ecosystem service/land cover type combinations, which were identified as valuable within the Rim Fire burn area, only 37 actually had monetary values attached. For 100 values, no value could be calculated. In some cases the science is not established, for example the loss or gain of water supply due to fire. In other cases, the science is present, but there is no economic analysis showing the value of the service, for example it is known that coniferous forests prevent soil erosion, but there is no economic valuation associated with that benefit. Finally, economic analysis may have been conducted, but it may not be appropriate to transfer the dollar values.

Because the actual valuation studies are so few compared to the known ecosystem services present, the current valuation should be considered a significant underestimate of the actual value of ecosystem service provided by the Rim Fire burn area. A FEMA memorandum on the "Cost Effectiveness Determinations for Acquisitions and Elevations in Special Flood Hazard Areas" from August 2013 provides the result of an analysis of 11,000 acquisition and elevation projects showing a 300% – 1,500% rate of return on mitigation projects.[43] Once ecosystem services are included, then the economic benefits of policies that affect natural systems, like the floodplain become apparent.

The second class of limitations involves benefit transfer analysis. Every ecosystem is unique, so per-acre values derived from other locations may not fully reflect local values. This is true for all house, business and asset appraisals, or for calculations in the GDP (all new cars sold for the same price have the same GDP value regardless of the actual value the car provides). For example, although a number of the valuation studies used in this analysis were conducted in California, none were conducted in Tuolumne County.

Ecosystem services are generally increasing in value more quickly than most other economic assets. Because there is a lag in publishing values, services such as water regulation, storm protection, or erosion control are often more valuable. For example, after every hurricane with greater dollar damages, the value of wetland buffering increases. As both the frequency and intensity of hurricanes has increased, wetland buffering values have increased, always outpacing valuation studies.

Burn area and ecosystem health are difficult to estimate and just as basal loss was estimated in quartiles, so were elements of ecosystem health; this could be greatly improved with stronger scientific grounding and more economic research.

Within the burn area, the National Park Service has a more detailed GIS coverage than GIS data covering private and USFS lands only for a subset of the burn area. However, in this study, US Forest burn data was used because it was consistent across the entire burn area of the Rim Fire.

Finally, improvements in ecosystem service valuation with modeling and spatial data is very exciting, but could not be utilized within the short timeframe (three weeks) of this report. This is a static, partial equilibrium framework that ignores many of the dynamics and interdependencies of the economy and natural systems. Dynamic systems modeling is being developed but is too time and resource intensive for application. Modeling can also include better analysis of uncertainty, sensitivity analysis, and modeling of each ecosystem service and the recovery path under different regrowth or restoration scenarios. Under a three-year National Science Foundation Grant lead by Dr. Ferdinando Villa, Earth Economics with the University of Vermont and Conservation International was able to model ecosystem service changes with landscape changes. This included the value of aesthetic and property values based on the line of sight to aesthetic resources. This would be valuable with the Rim Fire for better understanding the impact on private property values.

Overall, this study provides a robust, rapid estimate of environmental benefit values and the impact of the Rim Fire. There are other tools, being developed which will help eliminate some of the limitations of the current approach.

APPENDIX F. ECOSYSTEM SERVICE VALUATION FAQ

What is Built Capital?

Built infrastructure or built capital includes the kinds of things humans create, such as roads, bridges, levees, buildings and machinery. Built capital provides humans with many services but is unable to efficiently replace a number of the essential services provided by natural capital.

What is Natural Capital?

Natural capital includes networks of natural lands, working lands, watersheds, landscape features, green spaces, and wildlife corridors. Natural capital operates at all spatial scales from urban centers to wilderness areas, and renders a range of critical environmental benefits or "ecosystem services" for humans.

What is an Ecosystem Service Valuation?

Ecosystem Service Valuation (ESV) is an economic tool that is used to determine the dollar value of our natural assets and to quantify the (positive or negative) impact of human activities on the environment.

What is Benefit Transfer Methodology?

Benefit Transfer Methodology involves estimating the value of ecosystem services through the analysis of a group of primary valuation studies, which have been previously conducted to determine the value of similar goods and services in similar geographies and contexts.

How Do You Assign a Dollar Value to Nature?

There are eight categories of primary dollar valuation methodologies to calculate ecosystem service values. Three are included here as examples (All eight are listed in Earth Economics ESV reports):

- **Market pricing**: Valuations are directly obtained from what people are willing to pay for the service or good on a private market.
  Example: Timber from US Forest Service lands is often sold on a private market.
- **Travel cost**: Cost of travel required to consume or enjoy ecosystem services. Travel costs can reflect the implied value of the service.
  Example: Recreation areas, such as Yosemite National Park, attract tourists who place value on that area based on what they were willing to pay to travel to it.
- **Replacement cost**: Cost of replacing ecosystem services with man-made systems.
  Example: the cost of replacing a watershed's natural filtration services with a man-made water filtration plant.

The full list of primary valuation techniques is described in Earth Economics' Rim Fire ESV report titled *Preliminary Assessment: The Economic Impact of the 2013 Rim Fire on Natural Lands.*

Why do ecosystem service valuations typically return a range of values?

An original and complete valuation requires more than 100 unique scientific studies for a single study area. Due to the extremely high costs associated with conducting original research for ecosystem services, Earth Economics uses benefit transfer methodology for providing a range of values for ecosystem service benefits. This type of valuation is based on peer-reviewed academic articles selected specifically for a study site.

The low and high values correspond to the range of the lowest and highest values in peer-reviewed literature. Although a great deal of research has been completed on ecosystem services in the last 30 years, this is still a new and emerging field; new values are being developed all the time. The low valuation boundaries are typically underestimates of the true economic value. However, they can demonstrate that ecological services in an area are worth at least a certain dollar amount, which can be sufficient to inform policy decisions, such as restoring or maintaining those systems.

Why not use primary valuation methods rather than Benefit Transfer Methodology?

A primary study generally looks at one or a few ecosystem services and takes up to two years, costing upwards of $100,000. Using benefit transfer methodology with a tool such as the Ecosystem Valuation Toolkit (http://esvaluation.org), a valuation study that assesses up to 23 ecosystem services can now be completed in less than six weeks and at a fraction of the cost. Benefit Transfer Methodology has been approved and used for benefit-cost analysis by federal agencies such as the U.S. Environmental Protection Agency for rule making, and the Federal Emergency Management Agency for hazard mitigation projects.

Do you value all ecosystem services in every land cover type?

Due to limitations of conducting a primary valuation, several gaps exist in the academic literature on the economic analysis of ecosystem services. Therefore, not all ecosystem services identified as valuable for each land cover class can currently be assigned a dollar value.

Why are ecosystem services worth so much?

Scarcity has shifted over the last 100 years from built capital to natural capital. For example, a century ago, to catch more fish we needed to construct more boats and nets. Today, we have an abundance of boats and nets. On the other hand, fish and fish habitat – our natural capital – is scarce.

In addition, nature does an extensive amount of work for free. For example, to replace the filtration of water that is currently accomplished by a forested watershed, Seattle would have to build a $250 million water filtration plant.

How can an ESV be used to justify investment?

Estimating the value of ecosystem services results in a better valuation than the implicit value of zero – or infinity. While human life is clearly priceless, we put a price tag on the services that people provide to the economy. What is not valued is often lost. The advantage of a valued asset is that a sufficient budget for its operations and maintenance can be justified. The valuation of a natural asset may facilitate borrowing against the asset.

Could ecosystem services values hold up in court?

Ecosystem service valuation is increasingly being used in court to support Natural Resource Damage Assessments and similar decisions across the world. In 2012 Earth Economics conducted an ecosystem service valuation to estimate the damages of a gold mine in Costa Rica. The values were later upheld by the Supreme Court of Costa Rica. Similarly, ecosystem service valuation has been used to guide compensation for the damages incurred by BP due to the Deep Horizon oil spill in 2010.

Why put a price on nature?

1. Nature does “work,” i.e. delivers ecosystem services, which provides economic value to humans. Although nature is priceless in the same way that human life is priceless, we need to put a value on the services that nature provides, in the same way that we put a price and pay humans for their unique services.
2. What is not valued is often lost. We estimate the value of ecosystem services to offer a better appraisal than the implicit value of zero.

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