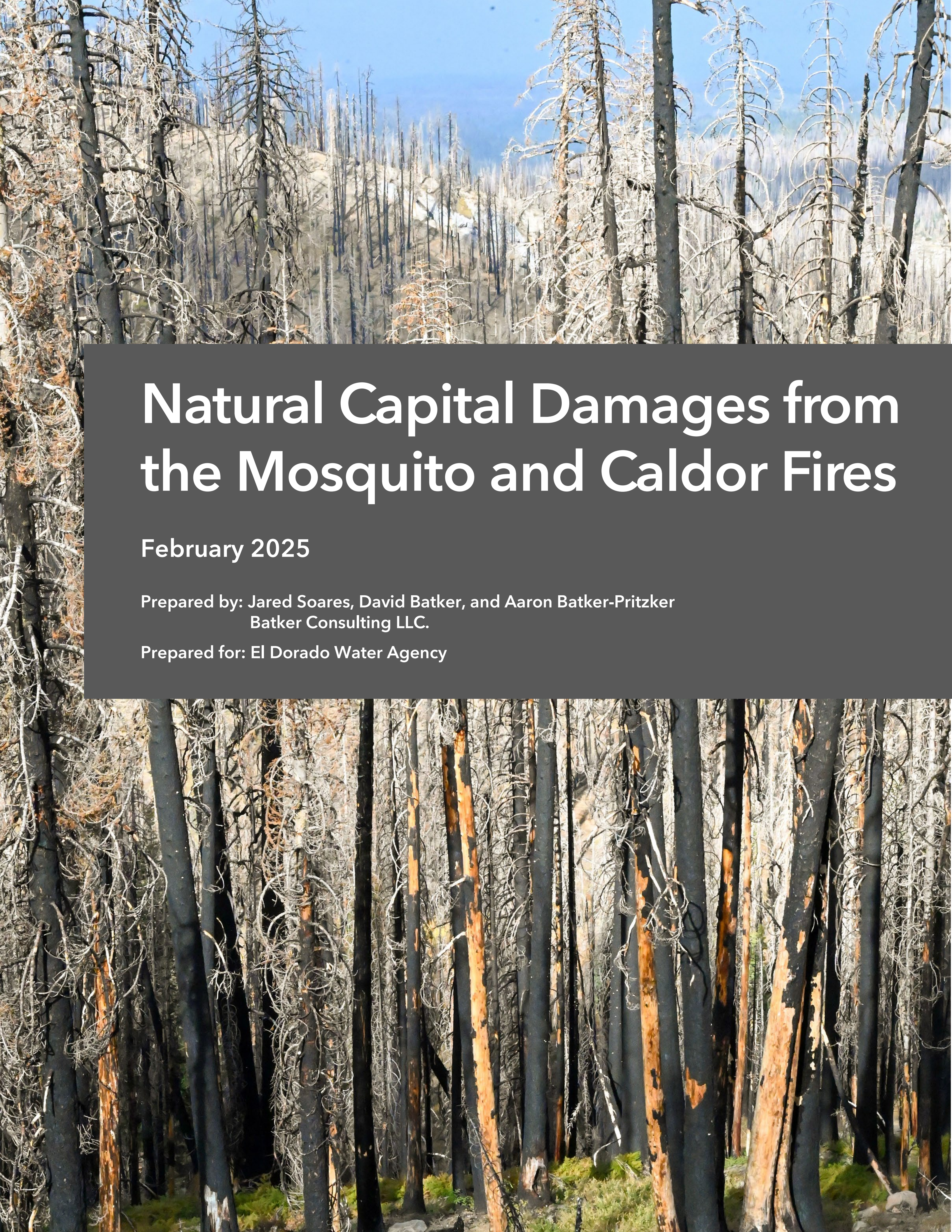

Natural Capital Damages from the Mosquito and Caldor Fires

February 2025

Prepared by: Jared Soares, David Batker, and Aaron Batker-Pritzker
Batker Consulting LLC.

Prepared for: El Dorado Water Agency

Acknowledgments

The authors would like to thank Rebecca Guo with El Dorado Water Agency and Yung-Hsin Sun at Sunzi Consulting LLC for their guidance and review of this work, and Samuel Price with Dynamic Geospatial Solutions LLC for his technical support. Any errors are the responsibility of the authors alone.

Cover photo: Caldor Fire burned area in headwaters of the North Fork Cosumnes River near the Leek Springs Hill, El Dorado County, California (courtesy of Yung-Hsin Sun, Sunzi Consulting)

NATURAL CAPITAL DAMAGES FROM THE MOSQUITO AND CALDOR FIRES

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How to cite: Soares, J., Batker, D., and Batker-Pritzker, A. 2025. Natural Capital Damages from the Mosquito and Caldor Fires. Batker Consulting, Tacoma, WA.

Executive Summary

This report provides a simplified and practical approach for the valuation of natural capital damage caused by two recent catastrophic wildfires, the 2022 Mosquito and 2021 Caldor Fires in the upper American River watershed (UARW), on the western slope of the Sierra Nevada Mountain Range in California. Fires are a natural phenomenon; smaller ground fires and traditional cultural burns help keep the ecosystems and their associated services healthy. However, catastrophic wildfires are not beneficial and cause substantial, immediate, and long-term consequences. Immediate impacts include the destruction of homes, businesses, and ecosystems, harmful air quality, and the disruption of people's lives with evacuations of homes and communities. Long-term damages of catastrophic wildfires include changes in vegetation composition, soils, and the loss of associated values of ecosystem goods and services (EGS).

The UARW is a large natural capital asset worth between $731 billion and $1.6 trillion based on 100-years of productivity (Batker et al., 2024a) and was significantly damaged due to recent wildfires. Natural capital damages account for EGS losses due to the loss and degradation of ecosystems from the wildfires and the economic impacts from the associated increase in carbon emissions. The combined damaged areas of the 2022 Mosquito and 2021 Caldor Fires is over 285,000 acres of the UARW (nearly 20 percent of the entire watershed area). **These two fires caused an estimated total of $14.7 billion in losses to EGS benefits assuming an optimistic 20-year recovery period. This includes over $12.1 billion in long-term EGS losses and nearly $2.6 billion in damages related to carbon dioxide emissions from the wildfires.**

The estimated $14.7 billion in losses to EGS benefits is conservative because this analysis does not account for public health damages from wildfire smoke including increased respiratory illnesses such as asthma, associated increased related hospital stays or deaths; as well as damage to homes and businesses, reduced property values, the potential risk of invasive species introduction, and the social, economic, and emotional cost of evacuations. The resulting demographic changes due to heightened wildfire risks and associated long-term economic and social impacts (e.g., skyrocketed fire insurance premiums) cannot be overlooked either.

The above estimate is conservative also because of its optimistically assumed full recovery within 20 years. Complications, such as drought, erosion, invasive species, or insect damage, can dramatically extend the period of post-fire damage. As an example, the 2014 King Fire in the UARW after a decade shows that fire-scarred landscapes are slow to recover to their pre-wildfire conditions and much clean-up and restoration efforts remain.

Understanding the immense EGS loss and associated socioeconomic effects caused by wildfires in California provides critical information to better estimate the benefits of more timely actions and targeted investment for reducing catastrophic wildfire risk and post-wildfire restoration. This study provides a first step in understanding the significant economic scale of natural capital damage from wildfires in the UARW.

Contents

1. INTRODUCTION

The 2022 Mosquito and 2021 Caldor Fires occurred in the upper American River watershed (UARW), which encompasses over 1.5 million acres of forests, grasslands, shrublands, wetlands, agricultural lands, open water, with a mixture of open space, and rural development including communities, cities, and towns. Each of these land cover types uniquely provides critical ecosystem goods and services (EGS), such as air quality, clean water supply, flood risk reduction, recreational opportunities, timber, and habitat for fish and wildlife. Like other assets, these landscapes are a form of capital: **natural capital.** Catastrophic wildfires threaten these natural capital assets. When properly managed and conserved, the natural capital of these working and natural landscapes can provide these goods and services in near perpetuity.

This report is part of a series of reports developed for El Dorado Water Agency (EDWA) to support the Upper American River Watershed Group (UARWG) and implementation of their *Programmatic Watershed Plan* (PWP; UARWG, 2023). The PWP is a collaborative, proactive plan including management strategies, prioritized projects, and implementation approaches.

The first supporting report, *Working Landscapes: Natural Capital in the Upper American River Watershed* (i.e., Working Landscapes Report), provides a watershed-scale valuation of EGS provided by working landscapes in the UARW and identifies an annual value of over $14.8 billion in EGS benefits (Batker et al., 2024a). These EGS benefits traverse the watershed, providing water, power, and other goods and services to areas in California such as Sacramento, coastal counties, the San Joaquin Valley, and Los Angeles. The results of this Working Landscapes Report are also published in the journal *Water* in a special issue on Water Resources Planning Toolkits for Climate Resiliency and Economic Sustainability (Batker et al., 2024b).

A second supporting report, *Outdoor Recreation in the Upper American River Watershed: An Analysis of Economic Impact and Value* (Radbridge, 2024), provides deep insight into the extent, location, and value of the recreation economy in the UARW. The results were incorporated in the above-mentioned Working Landscape Report. Combined, these efforts show that the UARW is an immense asset to the broader region.

This is the third supporting report and examines the natural capital damage caused by catastrophic wildfires. Another report that is under development will explore the representative value of water provided by the UARW.

These reports recognize the threat to natural capital in the UARW due to more frequent, larger, and higher-intensity wildfires in California. While wildfires are not uncommon, recent trends show that wildfires are becoming more severe with climate change (OEHHA, 2022; Turco et al., 2023). Catastrophic wildfires can damage the environment, communities, and economies. The damages of catastrophic wildfires have generally focused on lost built structures, however damages due to lost natural capital are also significant, and these landscape damages can be partially calculated. This valuation provides insights into the financial value of efforts to prevent, respond to, and recover from wildfires to help inform decision-makers concerning fire treatment actions as well as pre- and post-wildfire actions.

Purpose

This report summarizes the estimated economic cost of natural capital damage from the 2022 Mosquito and 2021 Caldor Fires, by estimating annual loss of EGS value, projected losses during recovery, and the social costs of carbon emissions for these wildfires.

Forest treatment and restoration can reduce and mitigate some catastrophic wildfire impacts and reduce threats and damage to communities. Estimates from this report provide information that can be used to estimate the benefits of forest treatment to reduce wildfire risk and restoration to alleviate impacts from wildfires. Communities throughout California may find the estimates provided in this report useful for informing wildfire restoration, adaptation, and mitigation actions and investments in their communities.

2. METHODOLOGY

EGS Value Produced in the UARW

Fires have a wide range of impacts on different land cover types and how they provide EGS. The first step in estimating catastrophic wildfire damage to EGS is to assess the value of natural capital prior to the wildfire. This process was completed in the Working Landscapes Report (Batker et al., 2024a). This report provided annual dollar-per-acre EGS benefits for seven land cover types present in the UARW. Figure 1 shows a map of the UARW and the seven land cover types categorized in the report, based on 2019 land cover, prior to the Mosquito and Caldor Fires with the fire perimeters noted. These land cover types are taken from the National Land Cover Database (NLCD), although some NLCD categories have been combined for the sake of simplicity. For example, the category Developed in this figure includes all four categories of developed land in the NLCD classification. In the valuation, only “Developed, Open Space” (one of the four Developed categories) was considered for valuation, as higher intensity developed land produces much less EGS value.

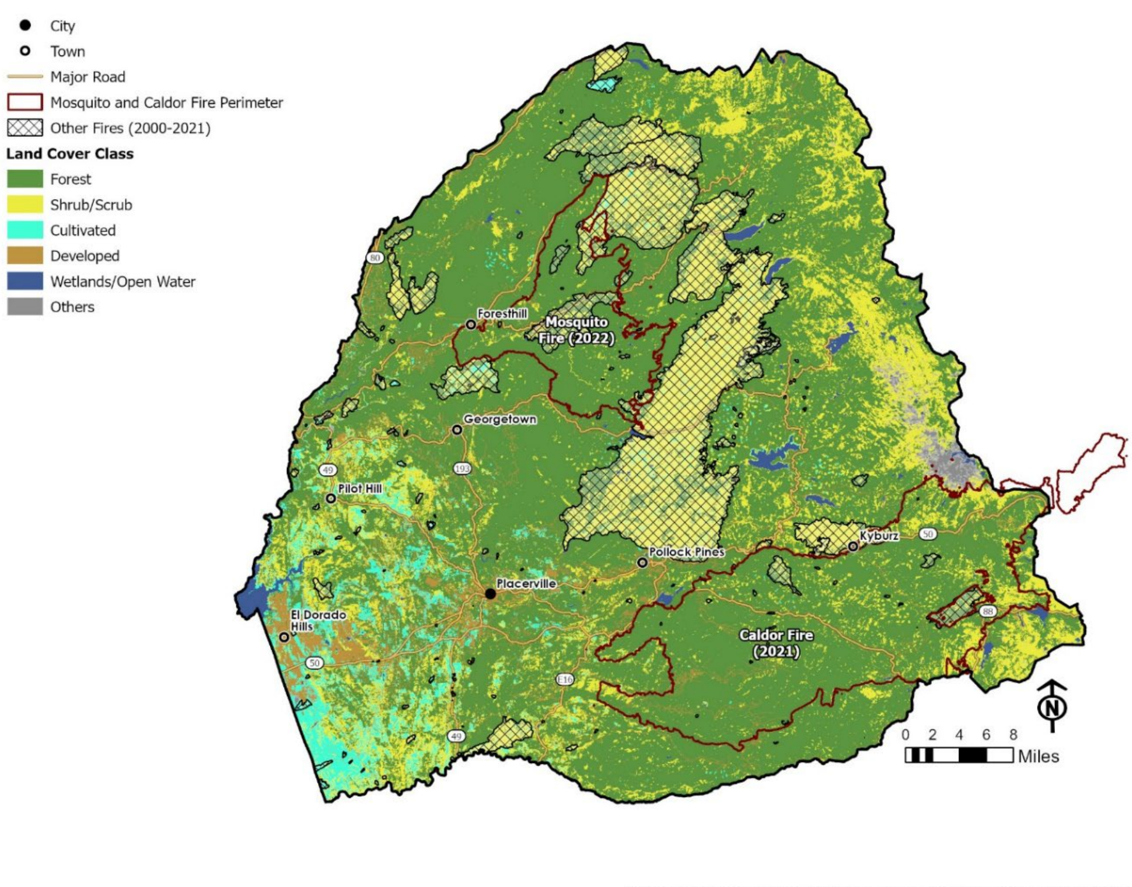

Figure 1. Land cover types in the Upper American River Watershed with the historical fire perimeters. Source: USGS NLCD

The acres present in the UARW as of 2019 for the seven land cover types are provided in Figure 2. Most of the UARW is forested. Much of the shrubland areas were formerly fully forested but were struck by previous fires, such as the King Fire (the largest yellow-hashed area in Figure 1).

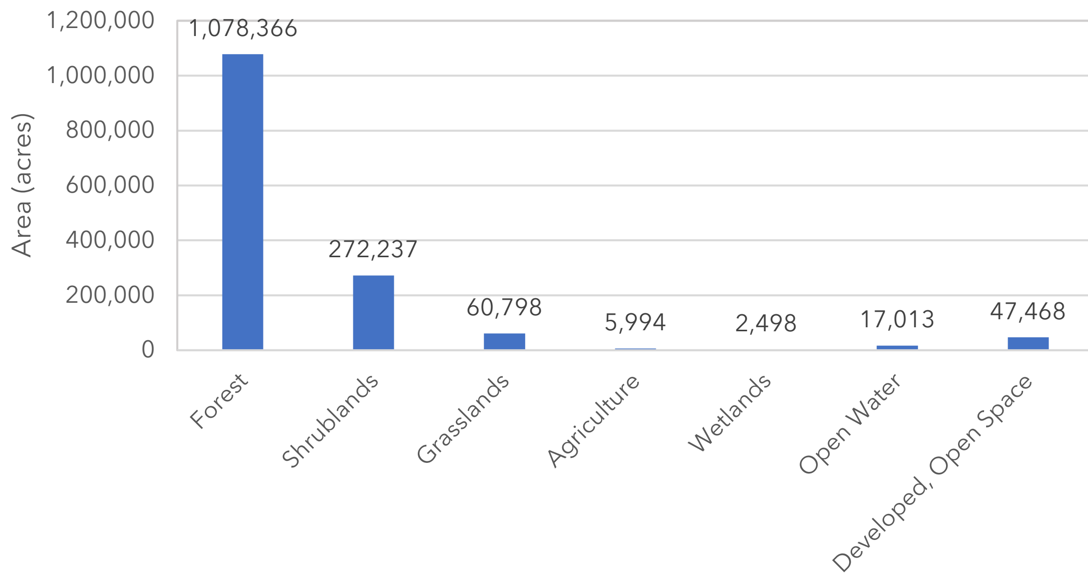

Figure 2. Areas of seven land cover types in the Upper American River Watershed.

The per-acre EGS dollar value estimates for each land cover category are summarized below in Table 1 based on values provided by the Working Landscapes Report. Additional information on the specific EGS and dollar values can be found in that report.

Table 1. EGS per-acre value by land cover.

Land Cover	Forest	Shrublands	Grasslands	Agriculture	Wetlands	Open Water	Developed Open Space
Total Annual Value ($/acre/year)	$12,958	$1,762	$1,161	$9,416	$5,772	$11,020	$2,074

Source: Batker et al. (2024a)

Burned Area

Since 2000, over half a million acres have burned in the UARW: about one third (1/3) of the total impacted areas.[1] Most of the impacted areas were burned by catastrophic wildfires, which are becoming more frequent and severe, since 2000. Over half of the total area impacted since 2000 was damaged in 2021 and 2022, and nearly all (99.6%) of these damaged areas were from the Caldor Fire (208,561 acres) in 2021 and Mosquito Fire (77,178 acres) in 2022.[2] This is highlighted in Figure 3, which shows the UARW, the Mosquito and Caldor Fire perimeters (with burn severity), and all other wildfires from 2000 through 2021.

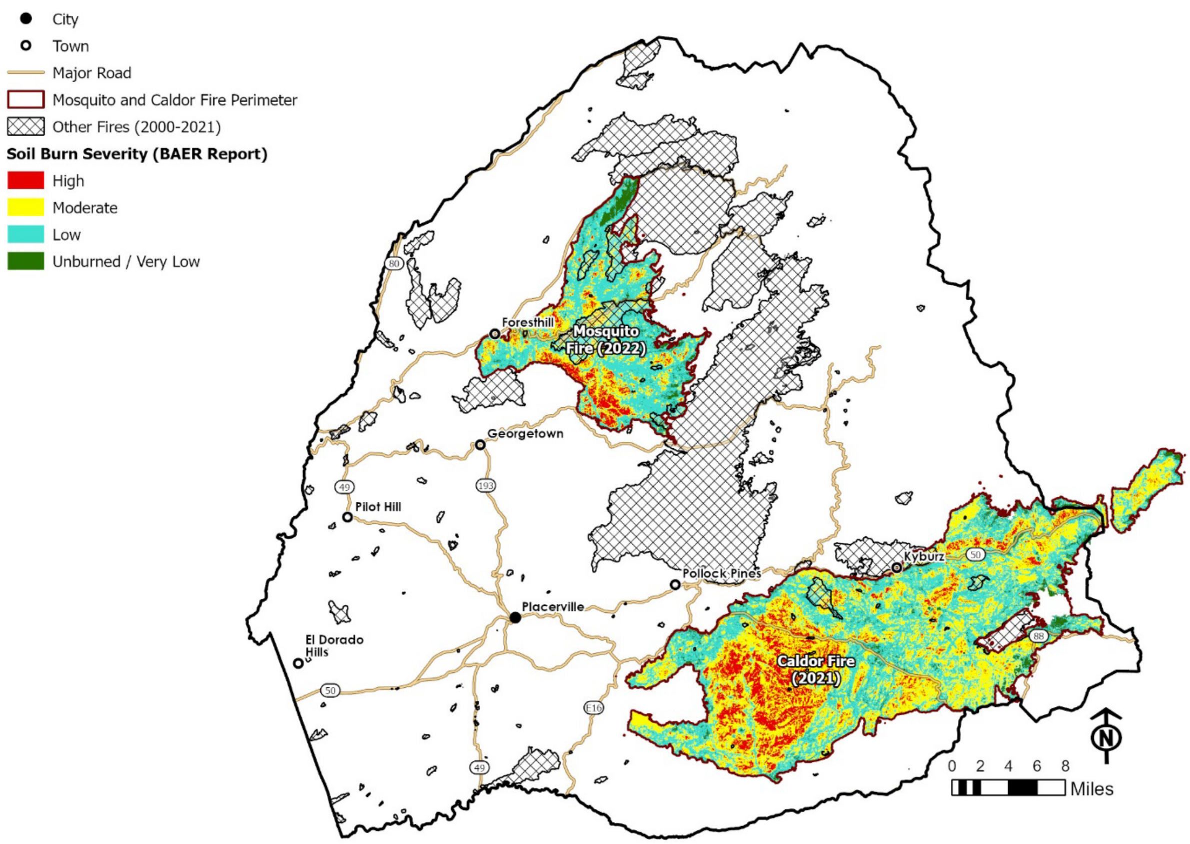

Figure 3. Wildfire soil burn severity for the Mosquito and Caldor Fires, with other UARW wildfire perimeters shown 2000-2021.

The burned land cover types included in this analysis are forests, shrublands, grasslands, wetlands, and developed open space. Open water and developed areas (other than "Developed, Open Space") are excluded from the calculations. No agricultural lands were identified within the wildfire perimeters. Thus, the areas that are analyzed in this report are

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[1] All burned area estimates were provided by Dynamic Geospatial Solutions LLC using CAL FIRE Historic Fire Perimeters which can be found at https://www.fire.ca.gov/what-we-do/fire-resource-assessment-program/gis-mapping-and-data-analytics.

[2] Areas cited in this report are only those acres within the UARW boundary. Further details on the UARW area and management priorities can be found in the UARWG's Programmatic Watershed Plan (PWP) for the upper American River watershed.

slightly lower than the total areas of both wildfires. A total of 208,561 acres were burned in the Caldor Fire. Of this total, 207,627 acres were forest, shrublands, grasslands, wetlands, and open space. Similarly, 77,178 total acres were burned in the Mosquito Fire and of this, 76,916 acres were forest, shrublands, grasslands, wetlands, and open space are included in the analysis. Most of the landscape burned by the wildfires was forestland. Forestland comprised 88% of the Mosquito Fire burn area and 85% of the Caldor Fire burn area. Figure 4 shows the breakdown of the Caldor and Mosquito Fires burned areas in the UARW by land cover type.

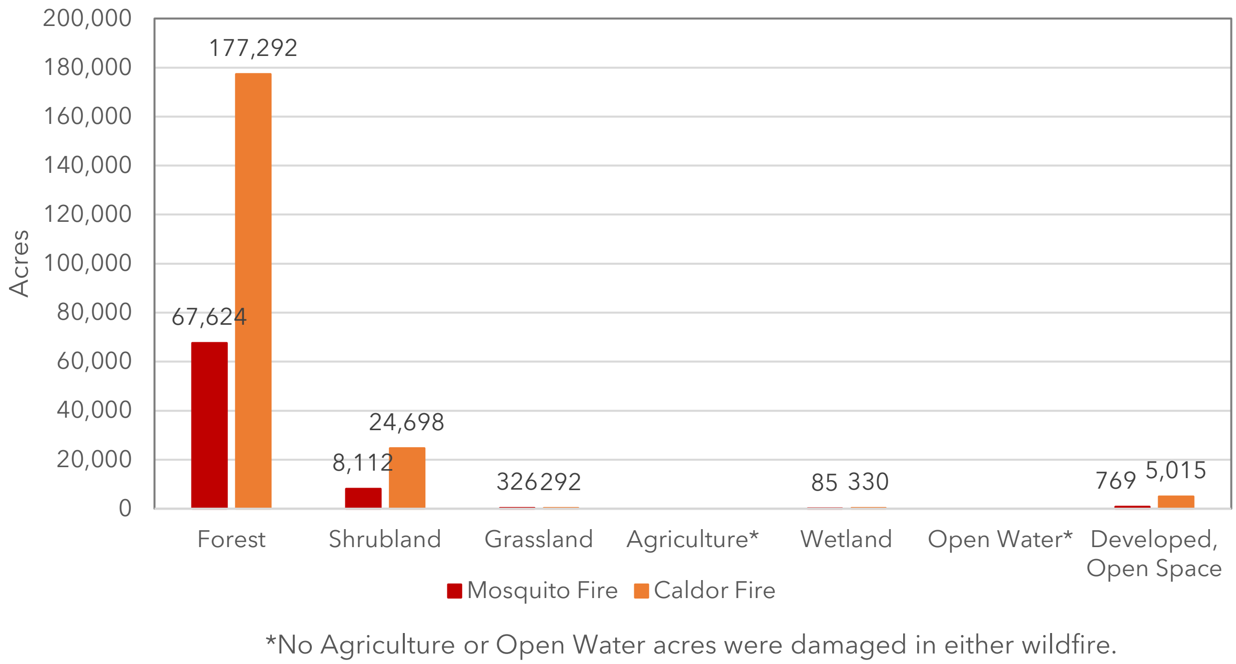

Figure 4.Caldor and Mosquito Fires burned area in the UARW by land cover type.

EGS Value Before the Wildfires

Applying the per-acre values from Table 1 to the total areas of the Mosquito and Caldor Fires (Figure 4), the total pre-wildfire value of EGS is over $3.2 billion in annual benefits. Table 2 shows the value of EGS within the wildfire perimeters if the wildfires did not occur (referred to in this report as "undamaged"). The estimated values per acre were previously provided by Batker et al. (2024a) and are shown in Table 1.

Table 2. Undamaged value of EGS within the Mosquito and Caldor Fire perimeters.

Land Cover	Forest	Shrublands	Grasslands	Wetlands	Developed, Open Space
Mosquito Fire					
Area	67,624	8,112	327	85	770
$/acre/year[1]	$12,958	$1,762	$1,161	$5,772	$2,074
Annual Value	$876,272,000	$14,293,000	$378,000	$491,000	$1,595,000
Caldor Fire					
Area	177,292	24,698	292	330	5,014
$/acre/year[1]	$12,958	$1,762	$1,161	$5,772	$2,074
Annual Value	$2,297,350,000	$43,518,000	$339,000	$1,905,000	$10,401,000
Combined Annual Value	**$3,246,542,000**				

[1] See Table 1 for the estimation of $/acre/year for each land cover.

Soil Burn Severity

To broadly estimate the economic loss from the Mosquito and Caldor Fires, soil burn severity maps (BAER, n.d.) were overlapped with data from the NLCD using the land cover categories from Tables 1 and 2 above to identify the ecosystems that were burned and to what degree. The soil burn severity is based on the Burn Composite Index (BCI), first developed by Key and Benson (2006) and later adapted by Sikkink (2015). The BCI is a widely used and reliable measure of soil burn severity (Bright et al., 2019). Table 3 summarizes the BCI and the numbers associated with each soil burn severity level.

Table 3. Burn Composite Index.

Levels of Soil Burn Severity	No Effect	Low	Moderate	High
Rating Factors	0	0.5 to 1	1.5 to 2	2.5 to 3

This analysis scales the EGS values produced by each land cover type by the BCI. The rating factors from the BCI overlap well with Burned Area Emergency Response (BAER) soil burn severity map output categories: high, moderate, low, and unburned/very low. Each BCI factor and the associated percentage reduction in EGS value are shown below in Table 4. The BCI value gives a range for each category of impact selected. This analysis applies the midpoint of the range to estimate impacts on EGS. Other assumptions could be made to adjust the percentage reduction in EGS relative to the BCI. The midpoint of the BCI range for each category was divided by three (the maximum soil burn severity) to provide a relative scale of soil burn severity to represent the corresponding percentage reduction in EGS value.

Table 4. Burn Composite Index and reduction in EGS.

Soil Burn Severity[1]	BCI	Fraction of Maximum Soil Burn Severity	Reduction in EGS[3]
High	2.5 to 3	$\left(\frac{2.75}{3}\right)$	92%
Moderate	1.5 to 2	$\left(\frac{1.75}{3}\right)$	58%
Low	0.5 to 1	$\left(\frac{0.75}{3}\right)$	25%
Unburned / Very Low[2]	0.0 to 0.5	$\left(\frac{0.25}{3}\right)$	8%

Key: BAER = Burned Area Emergency Response; BCI = Burn Composite Index;
EGS = ecosystem goods and services

Notes:

[1] The soil burn severity categories here match the outputs provided in the BAER soil burn severity maps and overlap with the BCI categories.

[2] The unburned / very low category includes the low-end range of the Low BCI category (0.5).

[3] Percentage reduction in EGS is rounded to the first digit.

The percentage reductions in EGS from Table 4 are applied to the $/acre/year values from Tables 1 and 2 to estimate each land cover's post-wildfire $/acre/year value by soil burn severity. Table 5 shows the remaining EGS value after the initial loss (post-fire/pre-recovery) reductions for each land cover type relative to the dollar-per-acre values summarized in Table 1.

Table 5. First-year post-wildfire EGS value ($/acre/year) by soil burn severity and land cover type.

Soil Burn Severity	Forest	Shrublands	Grasslands	Wetlands	Developed, Open Space
Referenced Pre-Fire Value (See Table 1)	$12,958	$1,762	$1,161	$5,772	$2,074
High	$1,080	$147	$97	$481	$173
Moderate	$5,399	$734	$484	$2,405	$864
Low	$9,718	$1,321	$871	$4,329	$1,555
Unburned / Very Low	$11,878	$1,615	$1,064	$5,291	$1,901

These reduced dollar-per-acre values are multiplied by the associated areas for each land cover and soil burn severity to estimate the initial loss in annual EGS value. Table 6 shows the areas of the Mosquito and Caldor Fires by soil burn severity for each land cover. Results from this calculation are presented in the following section.

Table 6. Mosquito and Caldor Fires burn areas (acres) by soil burn severity and land cover type.

Soil Burn Severity	Forest	Shrubland	Grassland	Wetland	Developed, Open Space
Mosquito Fire					
High	6,975	130	1	16	24
Moderate	16,201	2,792	65	13	188
Low	39,288	4,800	241	15	508
Unburned / Very Low	5,160	389	20	41	50
Caldor Fire					
High	27,098	701	1	5	540
Moderate	75,290	8,051	89	81	2,045
Low	67,216	12,864	169	228	1,953
Unburned / Very Low	7,688	3,082	33	16	476

3. RESULTS

This section provides a summary of natural capital damage from the Mosquito and Caldor Fires.

Fire and EGS Provision

The interaction between wildfire and EGS provisioning is complex. There are over 20 different EGS categories, and each of them will react differently to wildfires. Roces-Diaz et al. (2022) provides a synthesis of wildfire effects on EGS for forests around the globe and finds that most impacts on EGS are negative, although some can have mixed or positive effects. Mixed and positive effects are more pronounced in prescribed burns and the smaller, less intense wildfires that are a natural part of California forest ecosystems, while negative effects are more pronounced with catastrophic wildfires such as the Mosquito and Caldor Fires. Reduced tree canopy, especially from prescribed burns and thinning, may increase water supply by improving forest health and reducing interception, among other factors. While water supply may increase, the quality of water supply may decrease due to sediment and burned chemicals released by wildfires. Water delivery timing may also change due to an increase in soil hydrophobicity and loss of forest shade for snow, resulting in earlier snowmelt. Fire-scarred landscapes have also left some downstream communities at greater risk of floods and landslides. FEMA recognizes that drought, wildfire, flood, and landslides are linked disasters (CDM Smith, 2017). These negative effects may be small enough to preserve the value of increased water supply caused by controlled burns and low-severity wildfires, but not for high-severity wildfires. Thus, while both positive and negative effects are likely present across all categories of wildfire severity, the balance is strongly negative for catastrophic wildfires such as the Mosquito and Caldor Fires.

The value of forest habitat is another example of how catastrophic wildfires produce more negative effects than controlled burns or small wildfires. Low-severity burns can clear brush, dead woody fuel, and understory vegetation. This can promote the growth of grass and other plants that serve as important food sources for wildlife. Wildfires can even promote the growth of some species (e.g., morel mushrooms). Prescribed burns and low-severity burns are often used to control invasive species, improve habitat, reduce the risk of more severe wildfires, promote nutrient cycling, and help maintain the overall integrity of the larger ecosystem (CAL FIRE, 2024; USFWS, 2024). High-severity burns, like the Mosquito and Caldor Fires, can promote colonization by invasive species during early recovery and even convert forest ecosystems to other ecosystem types, such as shrublands and grasslands.

Previous wildfires can provide insight into how EGS provision was affected by wildfires. The King Fire (2014) burned nearly 100,000 acres, and the scar can still be seen in both satellite maps and NLCD (Figure 3). Most of the previously mixed conifer forest is now classified as shrublands. Using this as a marker for the potential value of forestlands ten years after a large wildfire would reduce the previous forest value ($12,958/acre) to the shrubland value ($1,762/acre). This is an 86% reduction in value in ten years after the 2014 fire, suggesting wildfires have significant costs that have lasting impacts on the landscape.

Immediate Post-Wildfire EGS Loss

The loss of EGS based on soil burn severity measures allows for a rough estimate of damage after wildfires. Tables 5 and 6 provide sufficient information to calculate the post-wildfire EGS value of the burn areas, and Table 7 shows the result of that calculation. Note that Table 5 shows EGS value per acre *retained* after a wildfire, while Table 7 shows EGS value over the burned areas *lost* after the wildfires. EGS value loss is pre-wildfire value minus post-wildfire value. These values represent losses for the first year after each fire only, since ecosystems undergo complex recoveries after wildfires. This recovery is discussed in the next section. The EGS lost in the first year after the Mosquito and Caldor Fires is over $344 million and $1.14 billion, respectively.

Table 7. Estimated EGS value loss due to Mosquito and Caldor Fires, rounded to the nearest thousand dollars, during the first post-wildfire year for each wildfire by soil burn severity and land cover.

Land Cover	Forest	Shrubland	Grassland	Wetland	Developed, Open Space	All Land Covers
Mosquito Fire						
High	$82,850,000	$210,000	$1,000	$85,000	$46,000	$83,192,000
Moderate	$122,461,000	$2,870,000	$44,000	$44,000	$227,000	$125,646,000
Low	$127,273,000	$2,114,000	$70,000	$22,000	$263,000	$129,742,000
Unburned / Very Low	$5,572,000	$57,000	$2,000	$20,000	$9,000	$5,660,000
Total	**$338,156,000**	**$5,251,000**	**$117,000**	**$171,000**	**$545,000**	**$344,240,000**
Caldor Fire						
High	$321,875,000	$1,132,000	$1,000	$26,000	$1,027,000	$324,061,000
Moderate	$569,105,000	$8,275,000	$60,000	$273,000	$2,474,000	$580,187,000
Low	$217,746,000	$5,667,000	$49,000	$329,000	$1,013,000	$224,804,000
Unburned / Very Low	$8,302,000	$453,000	$3,000	$8,000	$82,000	$8,848,000
Total	**$1,117,028,000**	**$15,527,000**	**$113,000**	**$636,000**	**$4,596,000**	**$1,137,900,000**

Long-Term EGS Loss

Ecosystems take time to recover. Annual wildfire damage persists as vegetation and natural systems recover. Table 7 shows the first post-fire year loss of EGS value. With an understanding of forests and other land cover regrowth and ecological succession, the estimates from Table 7 can be used to project estimates of post-wildfire long-term EGS losses. Projecting post-wildfire recovery relies on the results from Bright et al. (2019), which analyzed post-wildfire vegetation recovery for three different coniferous forest types in western North America from 2000 to 2007. Bright et al. report vegetation recovery rates (as a percentage of "vegetation greenness") using satellite data and the Normalized Burn Ratio (NBR), which is correlated with the BCI, making it an appropriate measure for this analysis. Table 8 shows the vegetation recovery rates after 5, 10, and 13 years by forest type. The recovery rates for mixed conifers are most appropriate for the UARW. These recovery rates are assumed to apply to all land cover types present in the UARW.

Table 8. Vegetation recovery rates by forest type. Source: Table 4 from Bright et al. (2019).

Forest type	Years Since Wildfire		
	5	10	13
Ponderosa Pine	32%	47%	54%
Mixed Conifer	30%	56%	68%
Conifer-Oak-Chaparral	44%	72%	77%

The vegetation recovery rates for mixed conifer in Table 8 were applied to the initial annual losses in EGS value to project the change in EGS losses over time during the recovery process. This assumes that all land covers will recover at the same rate. This analysis also assumes that full recovery will occur 20 years after the wildfire, though recovery time may be slower and the damage greater depending on factors such as drought, invasive species, monoculture or mixed species replanting, thinning, erosion, and wildlife impacts. Figure 5 shows the annual loss in EGS value each year following both wildfires, with a total non-discounted loss of $13.3 billion from 2021 to 2042. Figure 6 shows the cumulative EGS value losses from the Mosquito and Caldor Fires discounted at 2.5%, which total over $12.1 billion in 20 years.

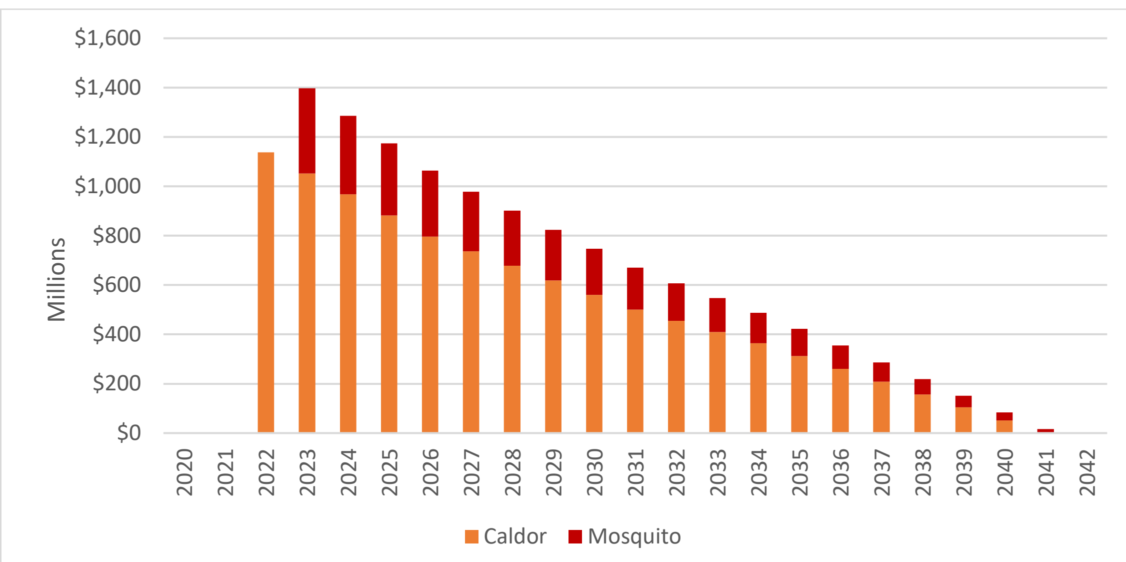

Figure 5. Annual EGS loss from the Mosquito and Caldor Fires at a 0% discount rate and assumed 20 years of recovery time.

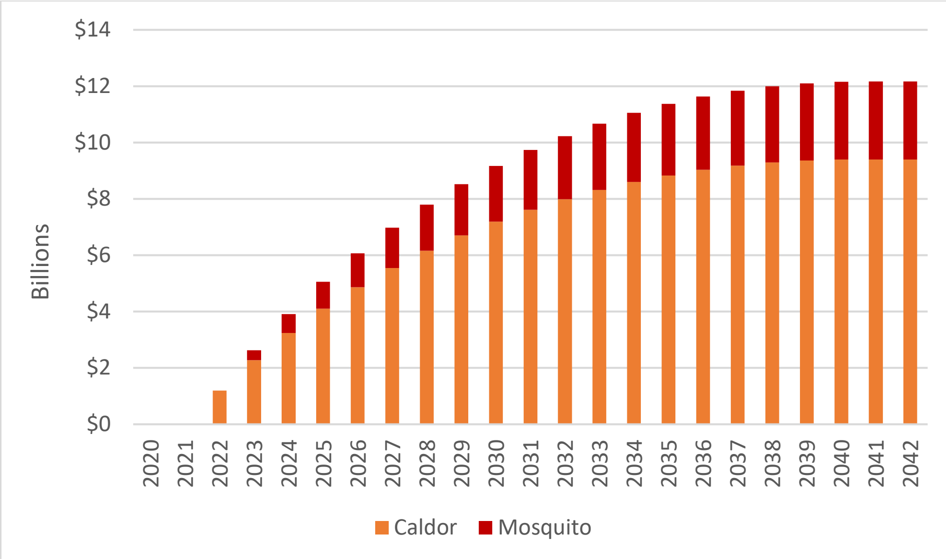

Figure 6. Cumulative EGS value loss from the Mosquito and Caldor Fires at a 2.5% discount rate and assumed 20 years of recovery time.

Wildfire CO_2 Emissions

In addition to the lost EGS noted, wildfires are significant sources of CO_2 emissions (Zheng et al., 2023), which is an additional damage that can be valued. The Mosquito and Caldor Fires produced 11.9 million metric tons of CO_2 (CARB, 2023, 2022). The damages from these CO_2 emissions can be estimated using the social cost of carbon dioxide (SC-CO_2). These estimates are developed using damage functions that forecast expected climate-related damages from CO_2 emissions. Rennert et al. (2022) provide a recent and more comprehensive analysis of the SC-CO_2 than previous studies and select a mean SC-CO_2 of $185 per metric ton of CO_2 (2020 USD). Adjusting for inflation to 2023, this is approximately $218 per metric ton of CO_2. The total CO_2 metric tons emitted from the wildfires (11.9 million) multiplied by the SC-CO_2 provides an estimate of the damages from the loss of carbon stored in the landscape. Table 9 shows the estimates reported by the California Air Resources Board (CARB) for both wildfires.

Table 9. The social cost of wildfire emissions during wildfire events.

Wildfire	CO_2 (million metric tons)	SC-CO_2 (2023 USD)	Total Social Costs from Wildfire Emissions
Mosquito (2022)	2	$218	$436,000,000
Caldor (2021)	9.9	$218	$2,158,200,000
Total	**11.9**	**$218**	**$2,594,200,000**

Key: SC-CO_2 = social cost of carbon dioxide USD = U.S. dollar

The resulting social cost of wildfire carbon emissions is added to the annual loss of EGS value to estimate the combined damage from the Mosquito and Caldor Fires.

Natural Capital Damages

Table 10 shows the damage from EGS loss and carbon dioxide emissions. This is a conservative estimate since it is not comprehensive for all EGS impacted, does not include health damages from smoke, and is limited to a conservative 20-year recovery period. Catastrophic wildfires are an increasing concern. This coarse analysis provides a rapid and clear methodology for estimating the scale of EGS and carbon emissions damages.

Table 10. Estimated damages from the Mosquito and Caldor Fires due to lost EGS and carbon dioxide emissions.

Wildfire	Ecosystem Goods and Services Loss[1]	Carbon Emissions Social Cost	Damages
Mosquito (2022)	$2,773,131,000	$436,000,000	$3,209,131,000
Caldor (2021)	$9,395,862,000	$2,158,200,000	$11,554,062,000
Total			**$14,763,193,000**

[1] Assumed 20 years of recovery period and 2.5% discount rate.

The combined damage from the Mosquito and Caldor Fires of lost EGS and carbon dioxide emissions is approximately $14.7 billion, assuming a 20-year recovery period.

The Mosquito and Caldor Fires had a devastating effect on the landscape. The estimates in this report may underestimate the true loss of EGS value. During the process of this analysis and report development, an updated NLCD map was published for 2023 which highlights how significantly the landscape changed due to the fires. Figure 7 shows the 2023 NLCD map. An initial review shows that approximately 287,000 acres of forestlands were reclassified from 2019 to 2023. This matches very closely to the 286,000 combined acres of the Mosquito and Caldor Fires (other fires also occurred during that period). As seen in Figure 7, much of the forest was reclassified as grassland and, in some instances, shrublands. This provides further evidence of the catastrophic impacts from these wildfires, and more organized and timely restoration efforts are needed.

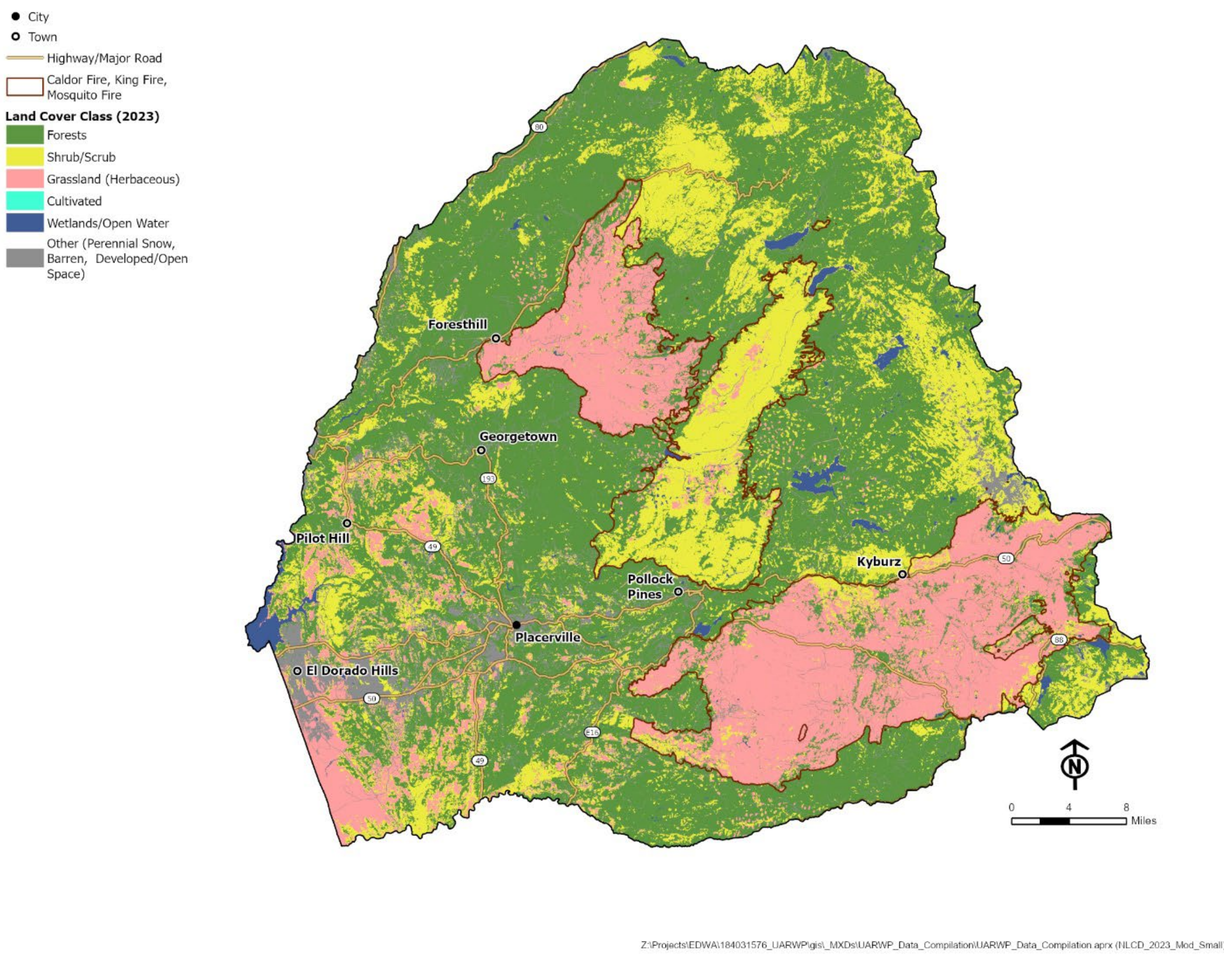

Figure 7. Land cover types in the Upper American River Watershed in 2023, highlighting the change in land cover designations within the Mosquito and Caldor Fire perimeters since 2019. Source: USGS NLCD

Wildfires are remarkably complex, and this study provides a simplified and practical valuation approach to the valuation of catastrophic wildfire damages. The effects of stand age, rainfall variation, elevation, seed availability, burn severity, slope steepness and stability, invasive species, restoration, thinning, and forest health actions all influence post-fire recovery and the value of EGS. As evidenced by Figure 7, more analysis of EGS and post-fire values is needed. A better understanding of these influences would improve valuation results. What is clear is that catastrophic wildfires are significantly damaging to working landscapes and downstream communities. Understanding the economics of catastrophic wildfires, including the value of damage, can help inform effective investment in these important landscapes.

REFERENCES

BAER, n.d. BAER Imagery Support Data Download URL https://burnseverity.cr.usgs.gov/baer/baer-imagery-support-data-download.

Batker, D., Soares, J., Sun, Y.-H., Batker-Pritzker, A., 2024a. Working Landscapes: The Natural Capital of the Upper American River Watershed. El Dorado Water Agency, El Dorado Hills, CA.

Batker, D., Soares, J., Sun, Y.-H., Batker-Pritzker, A., Guo, R., 2024b. Headwater Valuation as a Tool for Economic Development, Healthy Forest Management, and Water Resilience. Water 16, 2121. https://doi.org/10.3390/w16152121

Bright, B.C., Hudak, A.T., Kennedy, R.E., Braaten, J.D., Henareh Khalyani, A., 2019. Examining post-fire vegetation recovery with Landsat time series analysis in three western North American forest types. Fire Ecology 15, 8. https://doi.org/10.1186/s42408-018-0021-9

CAL FIRE, 2024. Prescribed Fires In California | Benefits & FAQs [WWW Document]. Ready for Wildfire. URL https://readyforwildfire.org/forest-health/prescribed-fires/ (accessed 9.25.24).

CARB, 2023. Wildfire Emission Estimates for 2022 [WWW Document]. California Air Resources Board. URL https://ww2.arb.ca.gov/sites/default/files/classic/cc/inventory/Wildfire%20Emission%20Estimates%20for%202022%20ERRATA%20FINAL.pdf (accessed 11.4.24).

CARB, 2022. Wildfire Emission Estimates for 2021 [WWW Document]. California Air Resources Board. URL https://ww2.arb.ca.gov/sites/default/files/classic/cc/inventory/Wildfire%20Emission%20Estimates%20for%202021%20%28v2022-09-01%29_%28ADA%20by%20JR%29.pdf (accessed 11.4.24).

CDM Smith, 2017. Innovative Drought and Flood Mitigation Projects. FEMA.

Key, C.H., Benson, N.C., 2006. Landscape Assessment (LA): Sampling and Analysis Methods, in: FIREMON: Fire Effects Monitoring and Inventory System., General Technical Report. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

OEHHA, 2022. Wildfires [WWW Document]. California Office of Environmental Health Hazard Assessment. URL https://oehha.ca.gov/climate-change/epic-2022/impacts-vegetation-and-wildlife/wildfires (accessed 9.26.24).

Rennert, K., Errickson, F., Prest, B.C., Rennels, L., Newell, R.G., Pizer, W., Kingdon, C., Wingenroth, J., Cooke, R., Parthum, B., Smith, D., Cromar, K., Diaz, D., Moore, F.C., Müller, U.K., Plevin, R.J., Raftery, A.E., Ševčíková, H., Sheets, H., Stock, J.H., Tan, T., Watson, M., Wong, T.E., Anthoff, D., 2022. Comprehensive evidence implies a higher social cost of CO2. Nature 610, 687–692. https://doi.org/10.1038/s41586-022-05224-9

Roces-Díaz, J.V., Santín, C., Martínez-Vilalta, J., Doerr, S.H., 2022. A global synthesis of fire effects on ecosystem services of forests and woodlands. Frontiers in Ecology and the Environment 20, 170–178. https://doi.org/10.1002/fee.2349

Sikkink, P.G., 2015. Comparison of six fire severity classification methods using Montana and Washington wildland fires, in: Proceedings of the Large Wildland Fires Conference; May 19-23, 2014, Proceedings. USDA Forest Service, Missoula, MT, pp. 213–226.

Turco, M., Abatzoglou, J.T., Herrera, S., Zhuang, Y., Jerez, S., Lucas, D.D., AghaKouchak, A., Cvijanovic, I., 2023. Anthropogenic climate change impacts exacerbate summer forest

fires in California. Proceedings of the National Academy of Sciences 120, e2213815120. https://doi.org/10.1073/pnas.2213815120
Upper American River Watershed Group, 2023. Programmatic Watershed Plan for the upper American River watershed. https://www.eldoradocounty.ca.gov/files/assets/county/v/1/documents/water-agency/upperamrwatershedplan_nov2023.pdf
USFWS, 2024. Prescribed Fire to Improve Wildlife Habitat | U.S. Fish & Wildlife Service [WWW Document]. URL https://www.fws.gov/story/2024-03/prescribed-fire-improve-wildlife-habitat (accessed 9.25.24).
Zheng, B., Ciais, P., Chevallier, F., Yang, H., Canadell, J.G., Chen, Y., Velde, I.R. van der, Aben, I., Chuvieco, E., Davis, S.J., Deeter, M., Hong, C., Kong, Y., Li, Haiyan, Li, Hui, Lin, X., He, K., Zhang, Q., 2023. Record-high CO2 emissions from boreal fires in 2021. Science. https://doi.org/10.1126/science.ade0805