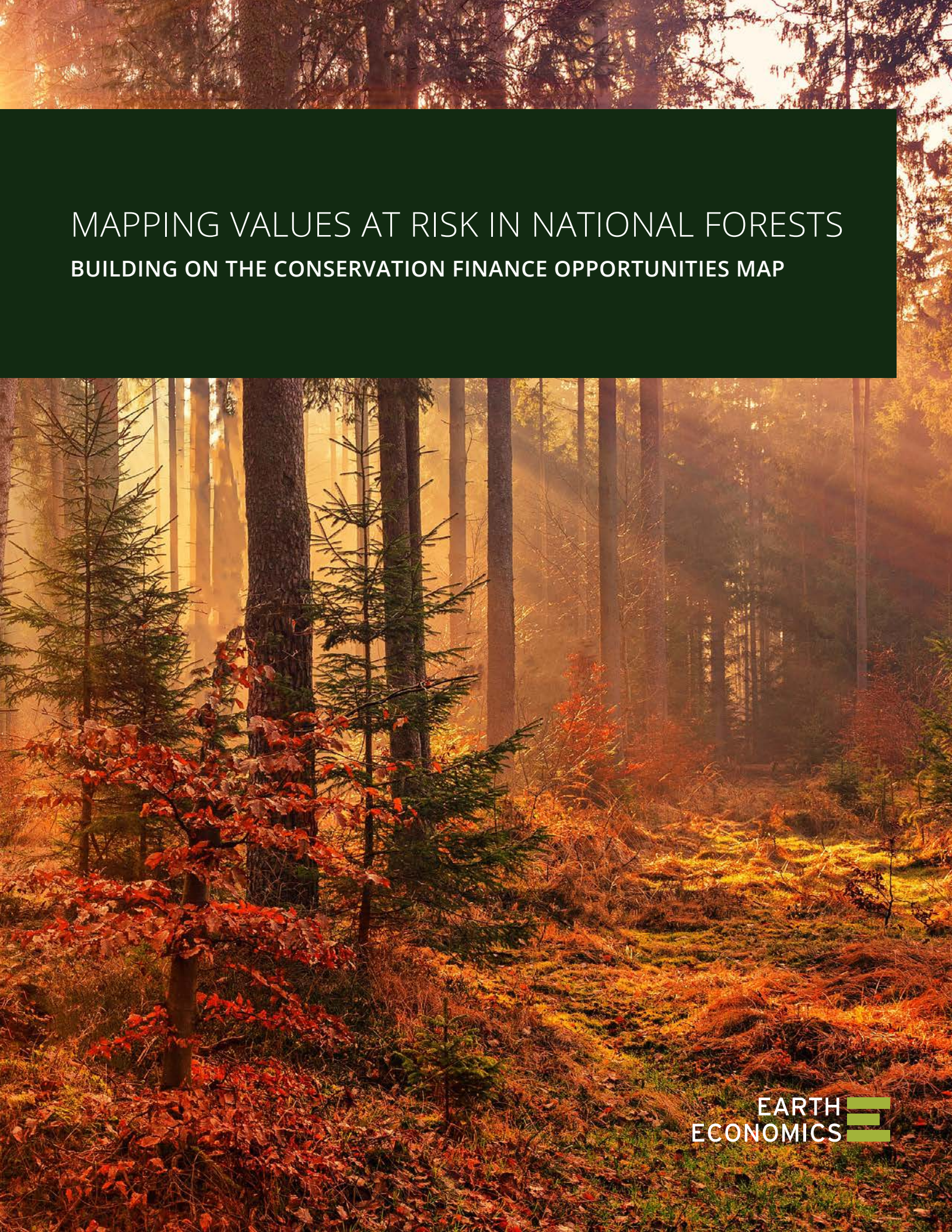
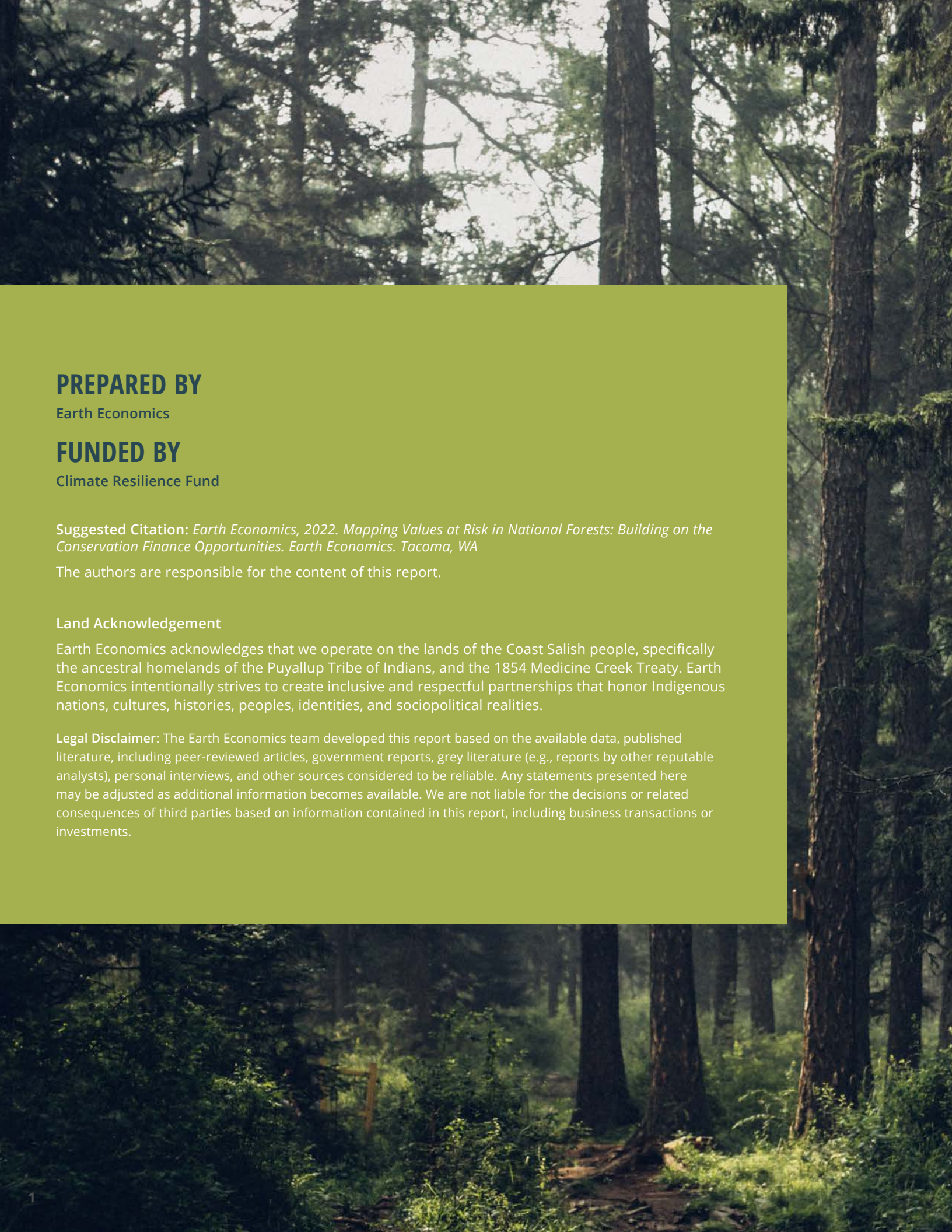


MAPPING VALUES AT RISK IN NATIONAL FORESTS

BUILDING ON THE CONSERVATION FINANCE OPPORTUNITIES MAP

EARTH ECONOMICS



PREPARED BY

Earth Economics

FUNDED BY

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The authors are responsible for the content of this report.

Land Acknowledgement

Earth Economics acknowledges that we operate on the lands of the Coast Salish people, specifically the ancestral homelands of the Puyallup Tribe of Indians, and the 1854 Medicine Creek Treaty. Earth Economics intentionally strives to create inclusive and respectful partnerships that honor Indigenous nations, cultures, histories, peoples, identities, and sociopolitical realities.

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EARTH ECONOMICS

Earth Economics is a leader in ecological economics and has provided innovative analysis and recommendations to governments, tribes, organizations, private firms, and communities around the world. **eartheconomics.org**

EXECUTIVE SUMMARY

Building ecosystem resilience on U.S. Forest Service (USFS) lands is vital to protecting natural assets from fire, pests, and disease in a changing climate. Funding this resiliency work at the speed and scale necessary to avoid catastrophic impacts requires making the economic case for investing in forest health and restoration. Earth Economics has partnered with the USFS to expand the USFS Conservation Finance Opportunities Map (CFOM) decision-support tool to include additional assets threatened by wildfire and other hazards.[1]

The CFOM is an interactive web-based mapping product intended for use by USFS and partners alike. The CFOM was initially developed by the USFS Conservation Finance Program to help the agency and partners identify locations to apply conservation finance tools and explore new partnership models that engage private capital to achieve positive ecological, social, and financial outcomes. The CFOM provides users with an aggregated Conservation Finance Opportunities Index at the watershed level (HUC12). This is a composite index based on two components:

Partnership Readiness is a combination of qualitative and quantitative estimates reflecting local capacity, partner capacity, agency capacity, and revenue potential for conservation finance in each national forest and is based on factors such as socio-political support and existing agency funding.

Landscape Needs is characterized as either Watershed (based on the presence of priority watersheds and groundwater protection areas within each national forest, as well as wildfire and flood potential, population density, and insect and disease risk) or Recreation (based on the agency's Developed Site Asset Prioritization Index).

These compound assessments of partnership readiness and landscape needs are rolled into a single index within the Conservation Finance Opportunities Map and each HUC12 is assigned a "low", "medium", or "high" designation according to its potential for conservation finance.

Earth Economics has developed additional spatial layers to integrate with the existing CFOM that highlight new potential avenues for conservation partnership. Specifically, Earth Economics expanded upon the "watershed" or "recreation" designation for landscape needs that make up the existing index by identifying economically valuable assets that intersect the HUC12 units and whose ongoing viability are directly related to forest health. These are referred to as "values at risk" or VAR. By investing in forest health and resilience, it is possible to decrease the expected value of damages to the different VAR.

The VAR framework is used internally by USFS, especially by Burned Area Emergency Response (BAER) teams to assess the cost-effectiveness of post-wildfire actions by comparing the cost of those actions against the value of resources (infrastructure, timber, non-market values etc.) and risks to them.[2] Earth Economics developed spatial layers to understand the magnitude and distribution of the following VAR across USFS-managed HUC12 units:

VALUES AT RISK	DESCRIPTION
Bridges on USFS-owned lands	Bridges that exist on USFS lands, regardless of who maintains them
Carbon storage	Above-ground carbon stored by USFS lands
Communication sites	Communication towers installed on USFS lands
Dams	Existing dams on USFS lands
Drinking water	Drinking water provided by USFS lands
Habitat	Critical habitat for threatened and endangered species
Hospitals	Hospitals within HUC12 units intersecting USFS lands
Powerlines	Above-ground power lines installed on USFS lands
Recreation assets	Trails, campgrounds, and ski infrastructure
Residential buildings	Non-USFS-owned structures that exist within a 5-kilometer buffer surrounding USFS land
Roads on USFS-owned lands	Roads—from multi-lane divided highways to roads not maintained for passenger cars—that pass through national forests
USFS-owned buildings and properties	Structures owned and managed by the USFS, including ranger stations, campgrounds, and more

While the potential applications of the CFOM are already extensive, the additional information provided by this analysis enhances and broadens the potential of the tool. By evaluating additional VAR, it is possible to identify a broader range of stakeholders who would benefit from forest restoration to reduce impacts to VAR. The development and implementation of conservation finance models involves many stakeholders: including project developers, investors, beneficiaries, researchers, and implementation partners. Expanding the list of values at risk expands the pool of interested parties, providing new opportunities for partnership and co-funding.

This project can help leverage financing in two ways. First, the expanded tool provides a more comprehensive look at the assets threatened by natural disasters, providing the motivating logic to galvanize a wide range of support necessary to restore forests to a healthy and resilient state. Second, seeing the geographic areas with the highest concentration of VAR will help the USFS to efficiently screen potential project collaborators and funders for critical resilience investments. Shared work on conservation finance lays a foundation of collaboration that extends beyond specific projects, promoting shared stewardship of USFS lands and cost-sharing between stakeholders.

The USFS estimates that 40%—or 80 million of the 193 million acres it manages—are at risk of catastrophic loss due to wildfire, disease, and pests.[3,4] The need to protect these forestlands from wildfire, drought, and other disasters—which provide people with such important services as storing atmospheric carbon, providing clean air and water, and offering recreation opportunities—is clear. Investing in forest health and resilience ensures that these ecosystems can continue to function at a high level and provide the services that people depend on.

Conservation finance—the practice of raising, managing, and deploying capital to promote positive conservation outcomes—is vital to raise sufficient funds that support forest health and resilience measures in the face of these threats that are amplified by climate change. According to a 2016 study conducted by JPMorgan Chase & Co., there are $3.1 billion of untapped private capital available for conservation.[5] The Conservation Finance team at the U.S. Forest Service (USFS) is focused on identifying landscapes and partners to accelerate the pace and scale at which USFS meets its mission to sustain the health, diversity, and productivity of the nation's forests and grasslands to meet the needs of present and future generations.

Successful forest restoration depends on dollars, which can be unlocked through innovative funding approaches and partnerships.[11] To identify and prioritize conservation finance projects and partners, the USFS has created the Conservation Finance Opportunities Map (CFOM) decision-support tool. The USFS National Partnership Office uses the tool to coordinate with local USFS regions or units to identify key ecological and social risks, and stakeholders who share those risks across watersheds. The tool is a key part of the USFS conservation finance process, which has already funded numerous forest resilience projects through congressional appropriations, philanthropic and in-kind support, and public-private partnerships.

Earth Economics has partnered with the USFS to enhance the CFOM tool by incorporating additional economically valuable assets that are at risk from wildfire and other hazards. By accounting for additional “values at risk” (VAR) from of fire, pests, and other hazards, a more comprehensive understanding of the risk profile of each national forest is developed. Measuring the relative volume and distribution of beneficial services like habitat, recreation, and carbon storage—as well as catalogue of built assets in and around USFS lands—weaves together the economic, social, and environmental values held by different stakeholders and provides the logic for identifying partnership opportunities and catalyzing investments in forest health and resilience. The values at risk identified by this project are shown in Figure 1.

While everyone benefits from healthy forest ecosystems, when disaster strikes, marginalized communities tend to be hit harder: each year, communities of color and low-income communities are disproportionately threatened by catastrophic wildfires.[6] Additionally, there are nearly 4,000 miles of shared boundaries between USFS land and tribal land, and many native tribes retain treaty-designated rights and interests in national forests.[7] Climate change has already had a marked impact on forest resources valued by tribes, including the loss of culturally important species, food, and habitat.[8] The USFS is working to protect and preserve the integrity of tribal lands, having collaborated with tribes on several forest restoration and resiliency projects.[9,10]

FIGURE 1: VALUES AT RISK

VALUES AT RISK	DESCRIPTION
Bridges on USFS-owned lands	Bridges that exist on USFS lands, regardless of who maintains them
Carbon storage	Above-ground carbon stored by USFS lands
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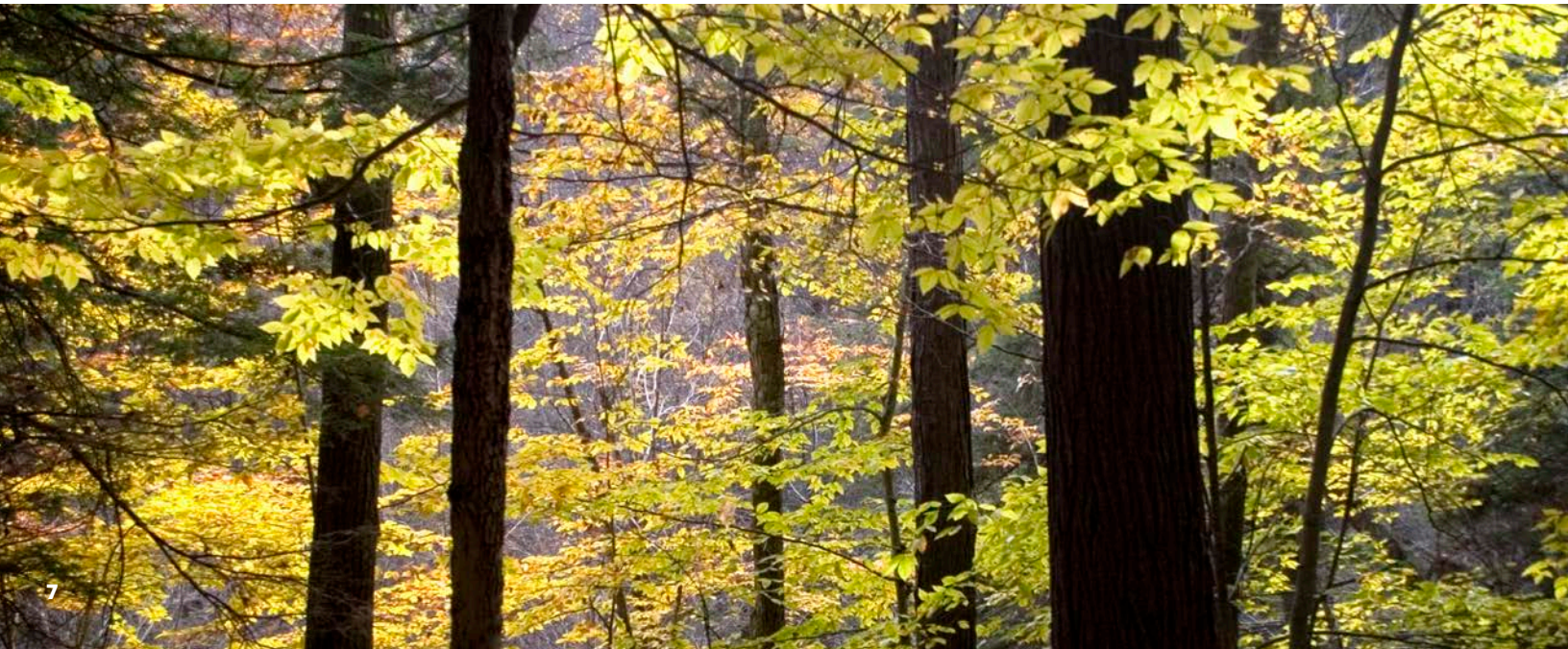
The expansion of the VAR incorporates novel data sources to identify landscape needs and grow the risk measurement capability of the tool. This approach builds on Earth Economics' partnership with the USFS on VAR in the Santa Fe National Forest. These data include value estimates of built infrastructure—houses, culverts, federal facilities, pipelines, reservoirs, roads—as well as carbon storage, habitat, and recreational use. The results of this analysis add nuance to the low-medium-high risk index used in CFOM.

Showing the location and extent of the ecosystem services and built infrastructure on USFS lands helps land managers and investors direct resources to mitigate risk in the most critically threatened areas. USFS units and their local partners will be able to use the expanded tool to quickly identify possible project sites and weigh the costs of ecosystem restoration against the benefits of protecting the values at risk of being lost to natural hazards.



Each asset class that makes up the additional VAR layers for the CFOM tool was created using the same analytical process:

1. Identify valuable assets not already accounted for in CFOM, and assess the availability of spatial data
2. Match asset data onto each HUC12 watershed, and quantify
3. Normalize results for each asset class to show where there are relatively more or less of a given asset or asset value on USFS lands across the U.S.

IDENTIFY ASSETS

Based on 2020 research conducted in the Santa Fe National Forest,[12] Earth Economics identified a wide range of community benefits and assets supported by and located in the forest that are at risk due to wildfires and other natural and man-made hazards. In order to categorize these benefits and assets, we used a modified version of the "values at risk" (VAR) framework, in line with the fireshed analysis conducted by the Nature Conservancy.[13] The VAR framework is used internally by the USFS, especially by Burned Area Emergency Response ("BAER") teams to assess the cost-effectiveness of post-wildfire actions. The USFS uses the VAR framework to compare the cost of post-wildfire actions against the value of resources, which can include infrastructure, timber, non-market values, and risks to those assets.[14]

Working with the USFS, Earth Economics identified a list of significant asset classes to include as new layers in the VAR tool. Determination of significance was based on the susceptibility of an asset class to wildfire or other natural disasters. For instance, USFS-owned buildings could be lost due to wildfire, and are therefore designated as VAR.

Sources for the spatial data used to quantify VAR include the USFS, the EPA, and newly developed spatial data based on publicly available datasets, such as Building Footprint Data from Bing Maps.

MATCH ASSETS TO WATERSHEDS

One of the key purposes of this tool is to allow for comparisons of assets in and around national forests at the watershed scale. Watershed geographies are available through the Watershed Boundary Dataset, which divides and subdivides the United States into hydrologic units. Each hydrologic unit is identified by a unique hydrologic unit code, or HUC, consisting of two to eight digits based on the four levels of classification in the hydrologic unit system. This VAR analysis used the HUC12 classification. In this analysis, some data were not available at the HUC12 scale or were not suitable for distributing across HUC12 units; in these cases, data were reported at the most granular scale fit, and the methods described in further detail.

NORMALIZE

To understand where on USFS lands there are relatively more VAR, findings for each asset class—whether counts or dollar estimates—are normalized. Normalization facilitates easy comparison within each asset class, so that the HUC12 watersheds with relatively more or less value or volume of assets at risk are easy to identify.

This analysis of additional VAR is subject to certain assumptions and limitations.

LIMITATION 1: NORMALIZATION MASKS MAGNITUDE AND REMOVES CONTEXT

Normalized data, while useful for comparison within asset classes, does not allow for meaningful comparison with the normalized indices of other asset classes. Put another way, designating HUC12 watersheds within an asset class as being relatively low or high risk obscures the magnitude of the difference in the raw values at the low and high ends of the range. Figure 2 shows an example of this limitation.

There is a much wider value range in Asset Class B than A; a score of 100 and 2,000 for each asset class would be given an index value of 1, but they are evidently not the same. Values on either extreme are assigned numbers corresponding to very low or very high risk; this is a more meaningful distinction for Asset Class B than for Asset Class A, because there is a much greater range of values. Finally, it would be unhelpful to compare the normalized indices, because their value ranges can represent either biophysical counts or dollars.

FIGURE 2. EXAMPLE OF NORMALIZED INDEX VALUES

ASSET CLASS	VALUE RANGE	NORMALIZED INDEX VALUES
A	100–200	0–100
B	2,000–8,000,000	0–100

LIMITATION 2: RESTRICTED DATA EXTENT

Data for certain asset classes were only available for the contiguous United States. Without data for USFS lands in Alaska, Hawaii, and Puerto Rico, the normalized indices are incomplete. Were such data available, normalized index scores for HUC12 watersheds would change by an unknown amount.

The spatial resolution of data for certain asset classes was greater than the desired scale of analysis at the HUC12 watershed level. As previously stated, where data cannot be fit to the HUC12 scale, data were reported at the most granular scale fit, and discussed in greater detail in the following methods section.

LIMITATION 3: DATA UNAVAILABLE

Some asset classes that are threatened by wildfire and other natural and human-caused disasters were identified as highly valuable during consultation with USFS, but do not have spatial datasets for them, and were thus necessarily excluded from this analysis. With valuable asset classes not present, a complete accounting of values at risk is not possible.

LIMITATION 4: DATA REPRESENT A RANGE OF YEARS

Data collected for the analysis represents the most recent data available. Because each asset class draws on different data products, the data come from different years. As such, these results are not precise for a specific year, but represent the best current estimation based on available data.

LIMITATION 5: SCOPE OF ANALYSIS

Analysis was limited to USFS lands, for all but one asset class. For non-USFS owned buildings, which often exist in the wildland-urban interface directly adjacent to USFS lands (and much less frequently within them), the area of analysis was expanded to include a 5-kilometer buffer around USFS lands. In the same way that wildfires may start on USFS lands and threaten buildings on adjacent lands, they likely also threaten other asset classes that exist in the buffer zone. The addition of the buffer represents a special case to allow for the quantification of the threat to non-USFS owned buildings; to the extent that other assets exist in the same buffer zone, not applying this buffer will produce an undercount of VAR. This choice was made to be conservative and restrict the analysis as much as possible explicitly to USFS owned lands.

Each section below corresponds to a single asset class and follows a similar format. First, the asset is defined, and the rationale for including each in this analysis is explored. Next, the source data and any transformations are described. Finally, each layer is normalized to represent the relative presence of the asset in comparison with other HUC12 units (or other relevant scale) across USFS lands. Areas with a higher concentration of a given asset are assigned a higher index value; both the online tool and the examples in the report from the Coconino National Forest translate the index values into a heat map to show areas with greater intensity of assets at risk. In other words, areas with a higher concentration of a given asset are associated with a higher index value.

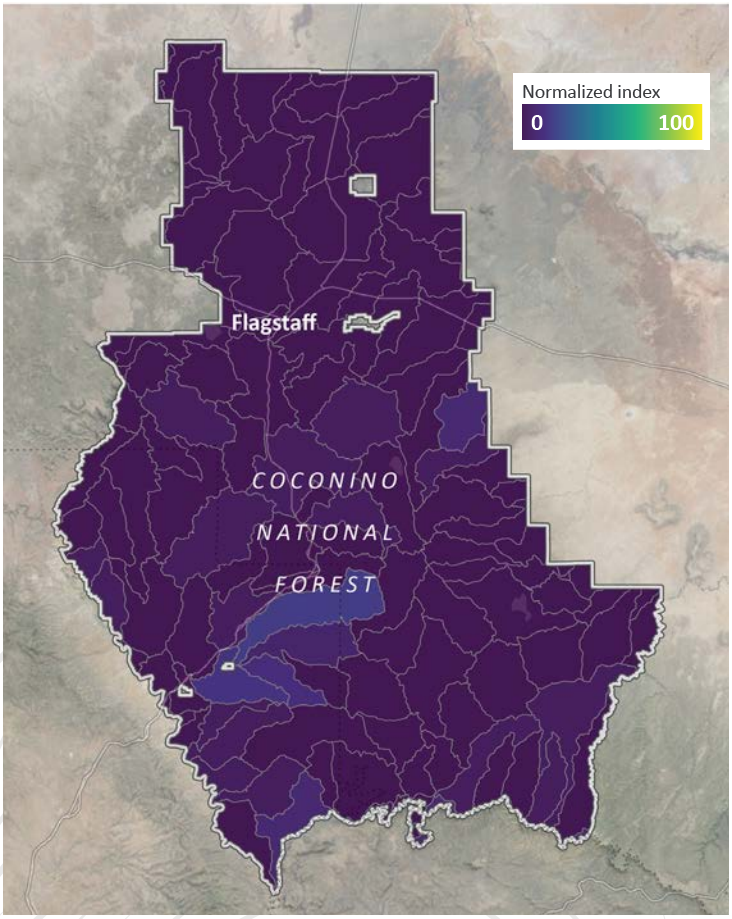
BRIDGES ON USFS-OWNED LANDS

Bridges span varied topography and water crossings across USFS-owned lands, facilitating access to natural resources, recreation, maintenance, and emergency response. Some bridges are owned by USFS while others are not. Regardless of ownership, bridges are an important asset at risk from wildfires. When fires move across the landscape, bridges – no matter the materials they are constructed of – are at risk of heat-related structural damage and resulting road closures. Post-fire, bridges may be destabilized by landslides, erosion or flash flooding due to destabilized and hydrophobic soils in burned areas.

The National Forest System Topographical Transportation Point geospatial data layer from USFS was used to quantify this asset class.[15] This layer contains multiple types of transportation-related structures, including bridges. Bridges that exist on USFS lands, regardless of who maintains them (e.g., state agencies, private owners, local government, commercial entities, other federal entity, et al.), all constitute VAR. Summing the total number of bridges for each HUC12 shows the extent of the assets at risk.

While this study does not attempt to assign an economic value to bridges threatened by wildfire, the sum of bridges across USFS lands acts as a proxy. Cleanup and repair costs will vary according to bridge design, the extent of the damage, and local labor and supply costs—these differences are not accounted for in this analysis. As with roads, extended bridge closures also impose costs on residents, recreational users, and truckers, via reduced access.

FIGURE 3. NUMBER OF BRIDGES



CARBON STORAGE

Another important function of USFS-owned lands is carbon sequestration and storage. When trees and plants grow, they convert atmospheric carbon into woody biomass, root structures, organic matter, and soil. In recent years, significant attention has been paid to the central role of carbon sequestration by forest ecosystems in climate change mitigation.[16] However, trees and other plants are not a permanent carbon sink: when they burn, years of stored carbon are released again to the atmosphere. Put another way, the total carbon storage benefit offered by USFS lands is placed at risk by wildfire.

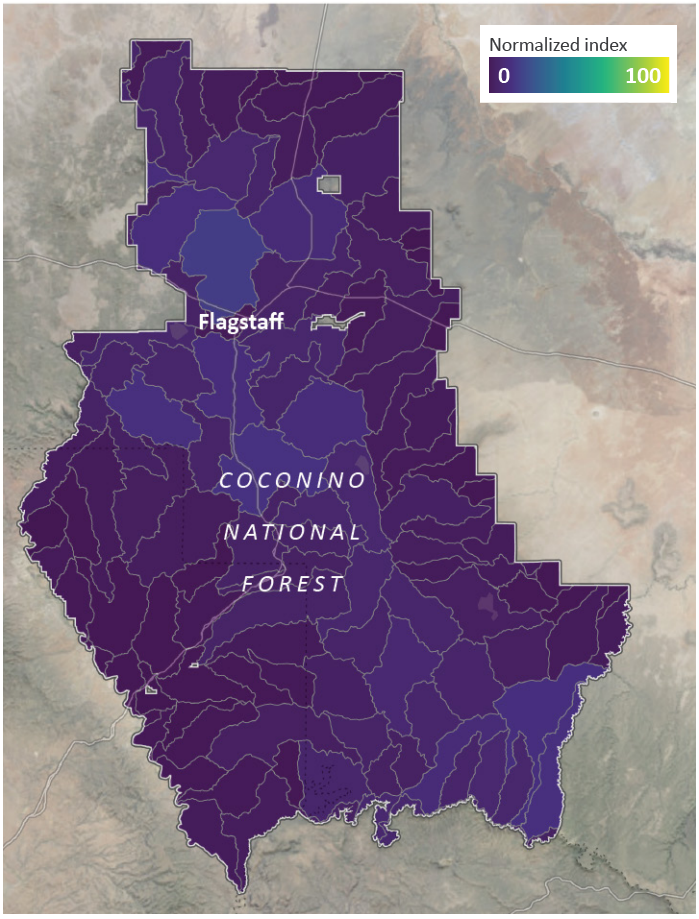
Research by the USDA estimates the volume of carbon stocks stored in above ground live forest biomass for each HUC12 across the U.S., which includes all USFS lands.[17]

While the carbon stored aboveground is clearly at risk from wildfire and is what is modeled in this analysis, the extent to which belowground and soil-based carbon are at risk is less clear. Some carbon loss is likely, but how much is unknown and likely a function of the nature of the fire and the landscape. In any case, not including the carbon stored in soils and belowground that may be re-released to the atmosphere might skew the distribution of VAR hotspots for this asset class. For example, consider a recently burned area, with its aboveground biomass eliminated, but stored carbon persisting belowground and in the soil: this carbon is not accounted for in this analysis.

The amount of carbon stored on a landscape can be valued in dollars using the social cost of carbon (SCC)—a price designed to account for the externalities created by carbon pollution. Therefore, the data contained in the map above represents a true comparison of economic value by HUC12, because the ratio between carbon storage and economic value is fixed. One commonly used SCC is that which is assigned by the Interagency Working Group for the United States government—$51 per ton of carbon dioxide.[18]

It is important to note that the social cost of carbon is expected to rise faster than inflation over time, to account for increasing negative effects placed on economic systems by climate change. Holding carbon stocks equal, the effect of this will be to increasingly underestimate the total value of carbon storage at risk due to wildfire activity.

FIGURE 4. TOTAL ABOVE-GROUND CARBON STORAGE



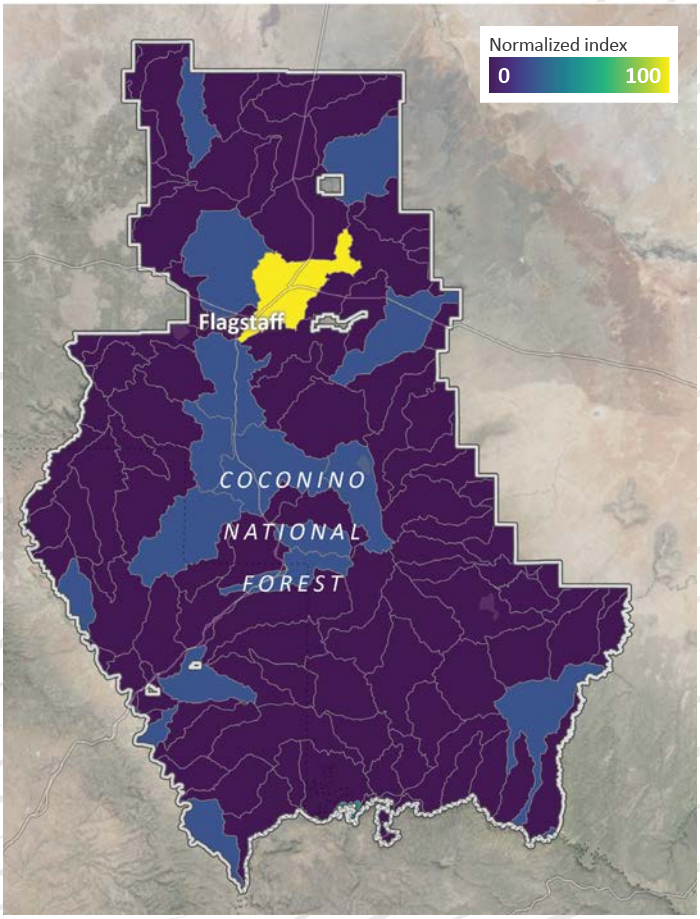
COMMUNICATION SITES

Communication towers are installed across USFS lands to provide telecommunications signal coverage for rural areas. When fire moves across the landscape, communication towers are at risk of structural and equipment damage. After a fire, communication towers may be further destabilized by landslides or erosion, and it may be difficult to access the site for repairs.

Cellular tower data maintained by Homeland Infrastructure Foundation-Level Data (HIFLD) identifies the locations of towers in the United States.[19] Summing the total number of existing communication towers for each HUC12 on USFS lands shows the extent of the asset at risk.

This analysis does not attempt to assign an economic value to the communication towers threatened by wildfire, as repair and replacement costs will vary according to the accessibility of the site and the nature of the repairs. Beyond repair and replacement, extended service disruptions to towers also imposes costs on local communities and emergency responders by restricting communication.

FIGURE 5. NUMBER OF COMMUNICATION SITES



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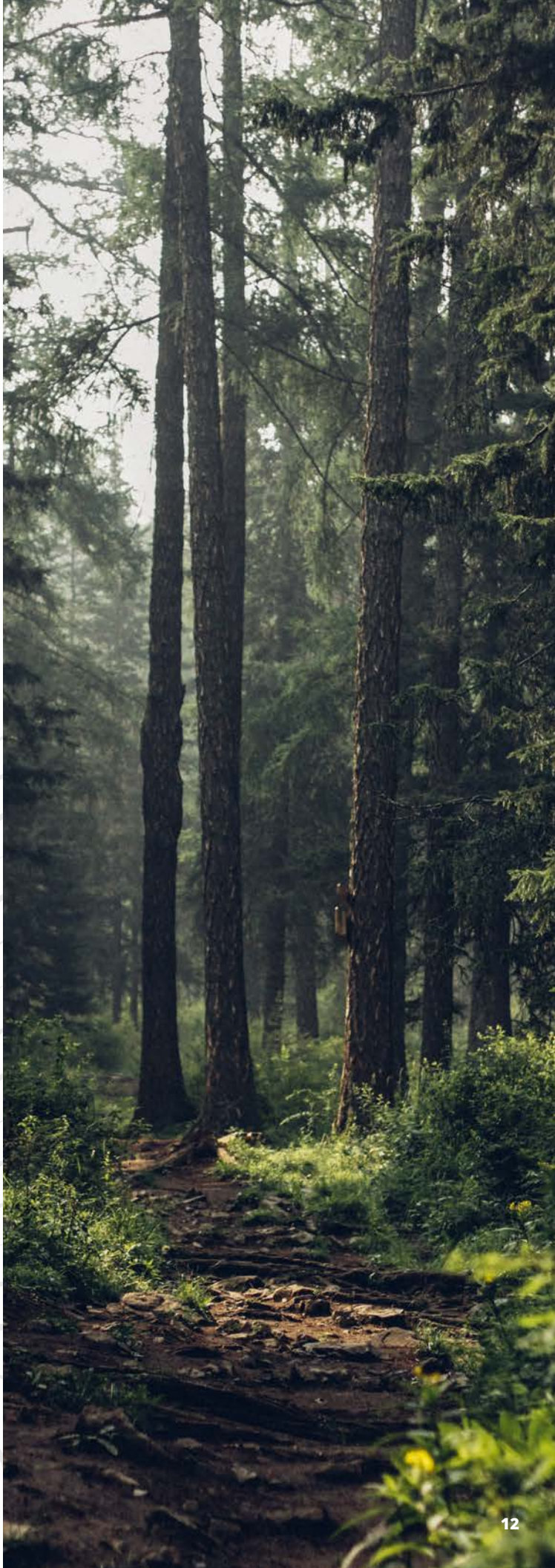


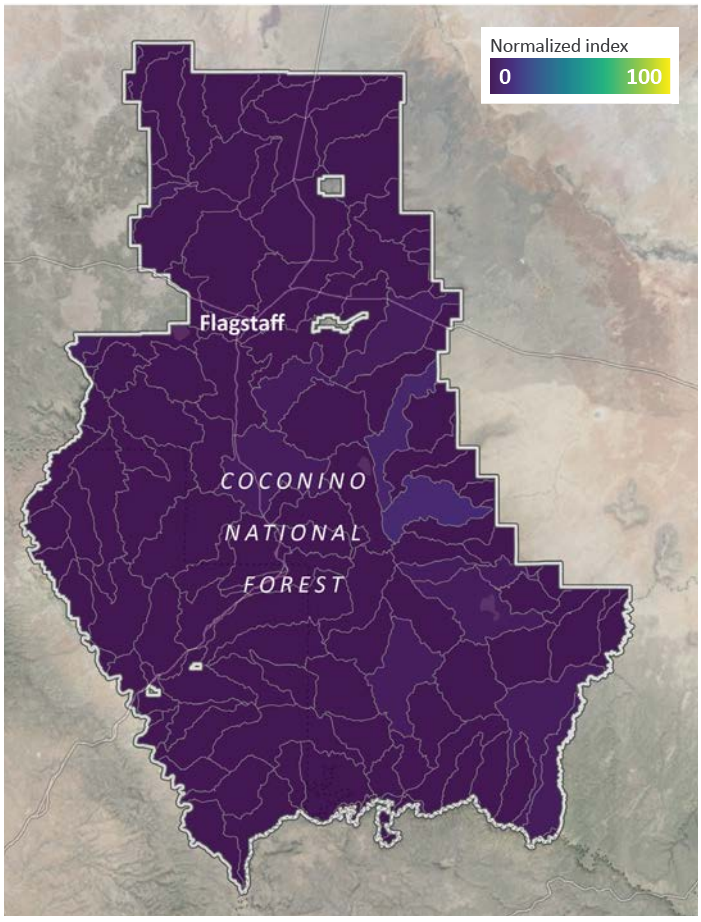
DAMS

Dams span rivers on USFS lands and provide energy production, water supply, recreation opportunities, and flood control. When fires move across the landscape, dams are at risk from heat-related structural damage; in the case of energy-generating dams, the transmission lines are also threatened. After a fire, landslides, erosion, or flash flooding on burned landscapes can flush debris into the aquatic environment and affect intake and outflow systems, and could also destabilize or otherwise damage a dam. A fire burning near a dam may incur expensive cleanup and repair costs of the structure itself, or of the surrounding environment to ensure the continued integrity of the structure.

The U.S. Army Corps of Engineers maintains a dataset that locates dams on river across the U.S.[20] These data are classified according to four categories: high hazard potential, significant hazard potential, and two additional classes based on a combination of height and storage capacity thresholds. Summing the total number of existing dams for each HUC12 across USFS lands shows the extent of the asset at risk.

This analysis does not attempt to assign an economic value to dams threatened by wildfire, as repair and replacement costs will vary according to the extent of damage sustained and the purpose of each dam. Depending on the purpose of the dam, additional costs from lost energy production, water supply, and recreation opportunities may exist, to say nothing of the potential downstream costs of the low-probability, high-consequence event of a catastrophic failure.

FIGURE 6. NUMBER OF DAMS



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DRINKING WATER

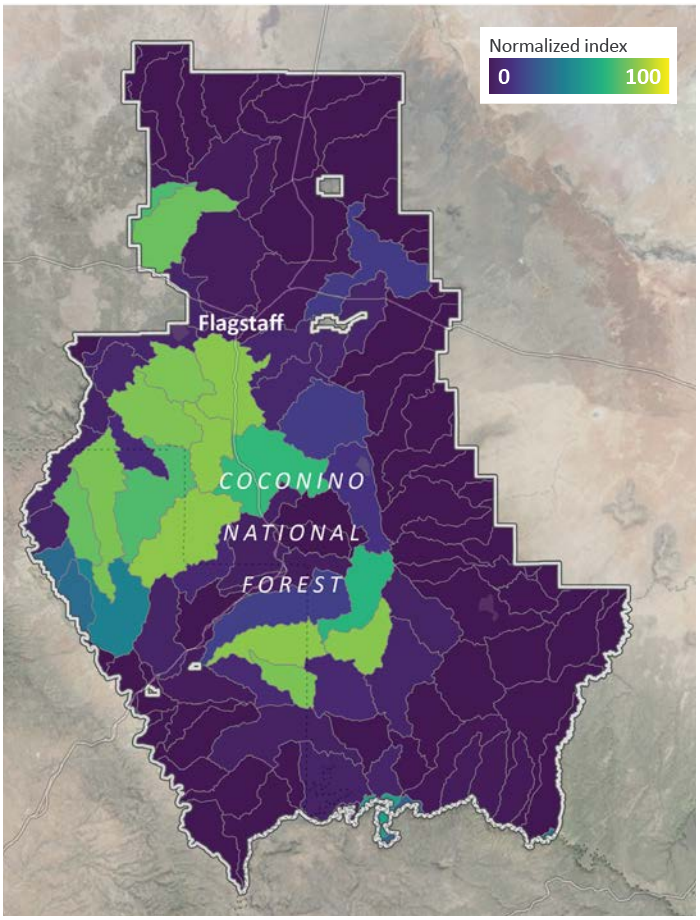
Watersheds on USFS lands provide communities with water for drinking and irrigation. Wildfire can damage water delivery infrastructure; after a fire, pipes, pumping structures, and water quality are at elevated risk due to the threat of landslides and erosion.

Two datasets were combined to produce a single layer that describes the drinking water provided by HUC12 units across the coterminous U.S.: the USDA Forest Service Forests2Faucets dataset[21] and a layer describing the percent watershed land area in a surface water Source Protection Area (SPA) for each HUC12.[22] The layers used to construct the drinking water layer were the "Important Areas for Surface Drinking Water" layer (IMP_R) which describes the sum of surface drinking water population downstream of each HUC12 (POP_DS), and the percent of each watershed in a surface water protection area (SPA_SW). The IMP_R and SPA_SW layers were already indexed on a scale of 0-100. The POP_DS layer was set on a log scale and then regularized relative to the maximum value in the country in order to create an index on a scale of 0-100. The final layer was constructed by taking the geometric mean of all three layers in each HUC12 unit.

Though this analysis does not attempt to assign an economic value to the HUC12 units that supply drinking water, the POP_DS layer that was included in the analysis is a reasonable proxy for value, as it incorporates the number of people that depend on drinking water from a particular watershed into the final index.

It is important to reiterate that the map produced for this asset class focuses specifically on drinking water, because one of the primary ways that fire and other disasters act on water supply is by affecting water quality. It is certain that some HUC12 units provide water for other uses (e.g., irrigation) for which water quality is not as important. If the analysis were to include the areas with low population but extensive agriculture that depend on irrigation water but not drinking water in the same map, the distribution of areas with the highest VAR would change, but incorporating the risks to non-potable water was not possible due to data constraints. Excluding non-potable water from this analysis undercounts the true VAR, and affects the distribution of end-users who rely on water from HUC12 units for a variety of purposes.

FIGURE 7. DRINKING WATER INDEX



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HABITAT

USFS lands provide critical habitat for a wide variety of flora and fauna; this feature of these forestlands is of particular importance to federally designated threatened and endangered species. Critical habitats, both terrestrial and aquatic, are at risk from wildfires and follow-on effects like landslides, erosion, and flash flooding. Risks for critical habitats include threats to habitat structures and disruptions to ecosystem function that are harmful to the plants and animals that depend on the forest. Fire damages can lead to expensive and time-consuming restoration and recovery efforts designed to improve damaged habitat and support threatened and endangered species.

The U.S. Fish and Wildlife Service maintains a dataset that locates critical habitat for threatened and endangered species.[23] Intersecting this layer with the HUC12 units on USFS lands reveals the relative risk posed to habitat by wildfires. This layer identifies areas that contain features essential for the conservation of threatened and endangered species that may require special management and protection. Summing the acres of critical habitat and total stream miles of critical habitat within each HUC12 shows the extent of the assets at risk.

The value of the habitat at risk is not estimated in economic terms, as restoration costs will vary depending on the location and necessary treatment. In general, larger and more remote areas will be more costly to restore, but these dynamics are not captured by the proxy of habitat acreage and stream miles. It is also important to point out that this analysis is limited to critical habitat for endangered and threatened species. This is useful for prioritization, but undercounts the habitat value provided by ecosystems not included in the U.S. Fish and Wildlife dataset.

FIGURE 8. CRITICAL HABITAT MILES

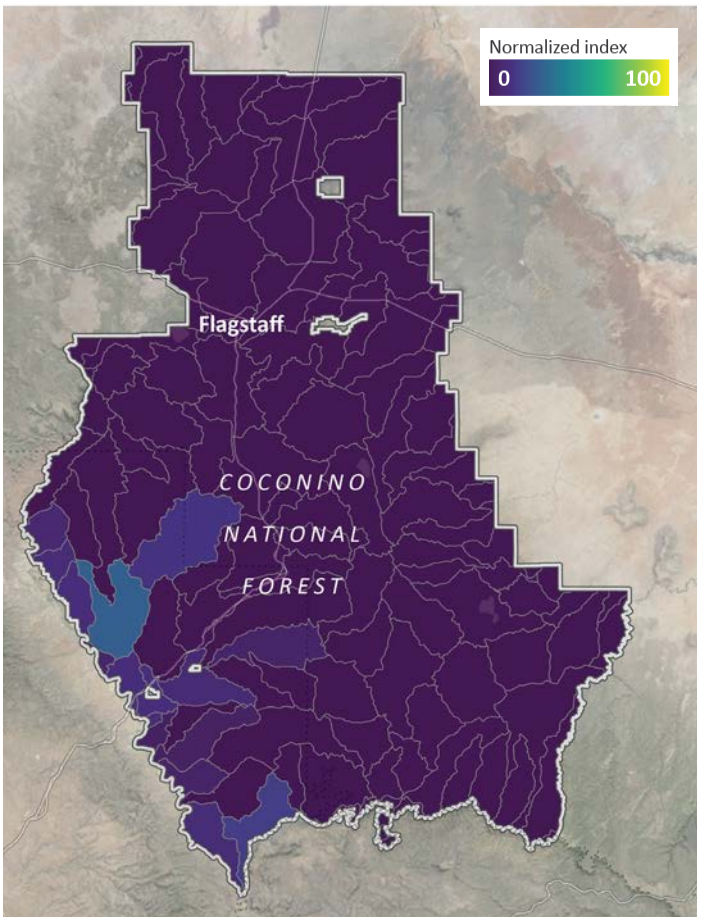

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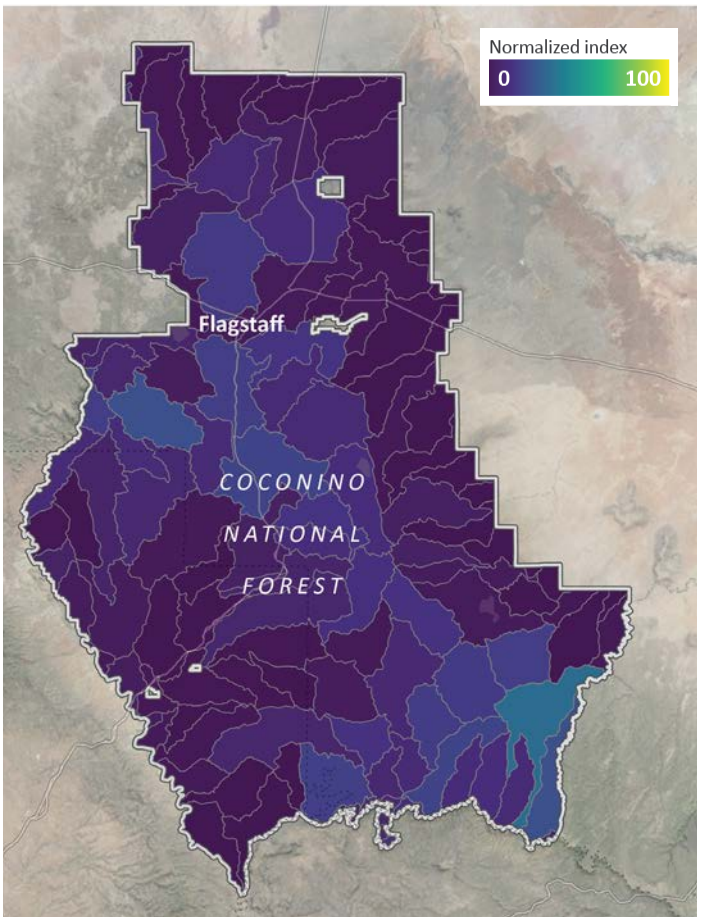
FIGURE 9. CRITICAL HABITAT ACRES



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HOSPITALS

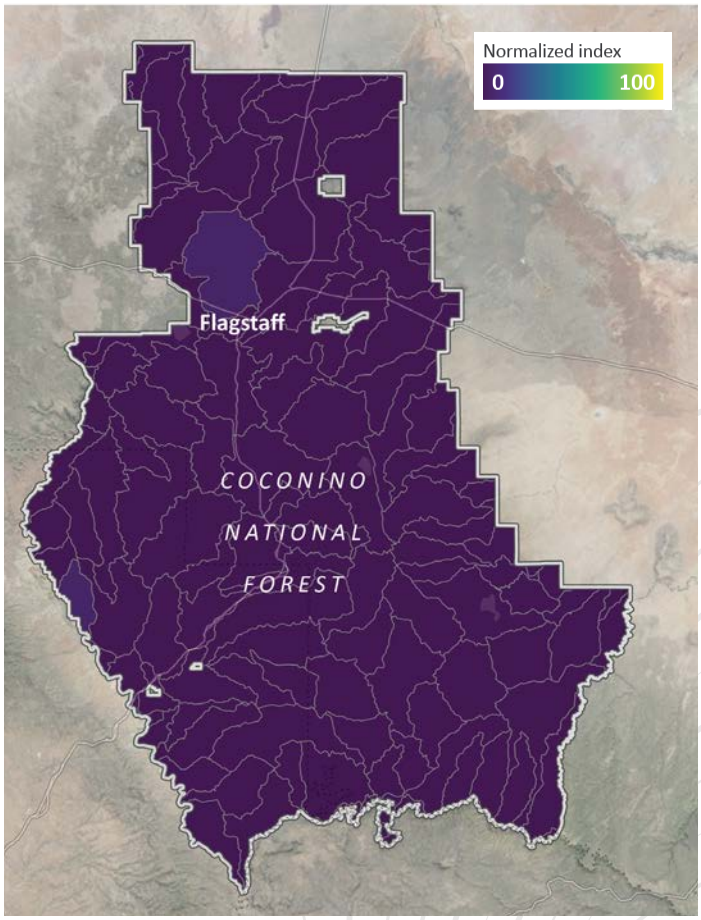
Hospitals provide essential medical service to many communities, and are strategically sited to make those services available to the most people. Consequently, there are relatively few of these critically important assets, and fewer still sited within USFS lands. This makes identifying hospital assets at risk arguably even more important, given their relative scarcity and nature of the services they provide.

Similar to other structures, the risk for hospitals is the direct threat to facilities from fire and smoke. Every day that a hospital is operating at reduced capacity due to fire damage to its infrastructure or power supply imposes costs to local communities who depend on the hospital.

The U.S.A. Hospitals dataset was used to understand the relative risk posed to hospitals by wildfire and other hazards. This layer contains an inventory of hospitals located throughout the United States. While this study does not attempt to assign a value to hospitals threatened by wildfire, the sum of hospitals within HUC12 units intersecting USFS lands acts as a proxy for understanding the extent of total risk.

Because many of the HUC12 units on USFS lands are sparsely populated, there are relatively few hospitals (raw counts) in the data. This means that the normalized index presented is skewed, with low index values dominating the map and higher values only appearing near population centers. Assessing the risk to each hospital in economic terms is not possible, as it is a function of replacement cost, which would presumably increase with facility size.

FIGURE 10. NUMBER OF HOSPITALS



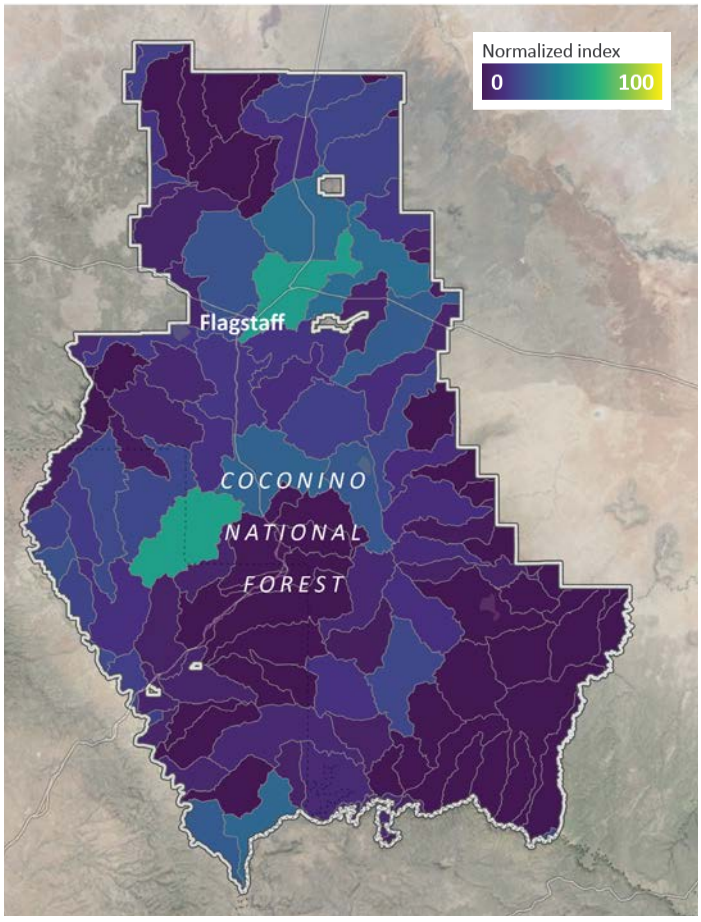
POWERLINES

Crisscrossing USFS forestlands, powerlines bring electricity to the nation. These are typically installed above-ground because, from a capital cost perspective, it is costlier to bury and maintain below-ground cables.[24] Above-ground powerlines, though easier to install and repair, are prone to damage from different hazards including winter storms, wildfire, tornadoes, and more. Damaged lines mean service disruptions to those who depend on the electricity they provide; the total cost of damaged powerlines is the sum of the cost to replace them (i.e., capital and labor costs) and the cost of disruptions (e.g., cost of running generators, losses due to lack of electricity, et al.).

Data from the HIFLD mapping the location of electric powerlines was used to assess the relative risk for each HUC12 intersected by USFS lands.[25] The following map shows the HUC12 units where there are relatively more miles of powerline at risk of damage due to fire and other natural disasters.

Though this analysis does not assign an economic value to the miles of powerline intersecting USFS-owned HUC12 units, the total mileage acts as a proxy that can be used to understand which HUC12 units are most at risk. The true cost of damaged overhead lines is difficult to estimate, as it will vary according to labor and market conditions, remoteness, and the specifications of what needs to be replaced, as well as any costs that result from power outages.

FIGURE 11. MILES OF POWER LINES



RECREATION ASSETS

People flock to USFS lands to enjoy the many recreational opportunities offered by these forest ecosystems. When wildfire strikes, these landscapes are often drastically altered, and so too the appeal of the recreational opportunities they provide. Lush, shaded trails become bare; once-bountiful flora and fauna become scarce; access to favorite views and scenery is restricted; smoke fills the air. When fires burn through these landscapes, the communities that act as the gateways to recreation—frequently located near USFS-owned lands—bear hefty economic consequences from reduced tourism and damage to structures. Additionally, when a preferred recreation spot is damaged by wildfire, a recreational user's consumer surplus—the additional value a recreational experience provides, over and above the cost of doing the activity—is removed or diminished as people opt for other locations or activities. In every case, wildfire activity renders recreation less desirable, as people seek more pristine alternatives.

To understand the consumer surplus values that are at risk of being lost or diminished due to wildfire, it is necessary to understand how many people are visiting forests and what they are doing. Summing the trail miles,[26] campgrounds,[27] and downhill and cross-country ski areas[28] present in each HUC12 provides a proxy for total visitation, and is consistent with the analytical approach to quantifying assets at risk.

Using the proxy of campgrounds, trail miles, and ski areas to estimate recreational use on each HUC12 is imperfect, because it does not take into account access points or desirability of the assets. Put another way, this analysis assumes there is a fixed relationship between HUC12 units with more assets and visitation; this is unlikely to be true to life when measuring actual visitation, as most recreational users follow the best, easiest-to-access views and trails—these are never equally distributed. Consider for example a HUC12 unit with relatively few recreation assets but which is located near a large population center. In all likelihood, this HUC12 will see high recreational use as many

FIGURE 12. TRAIL MILES

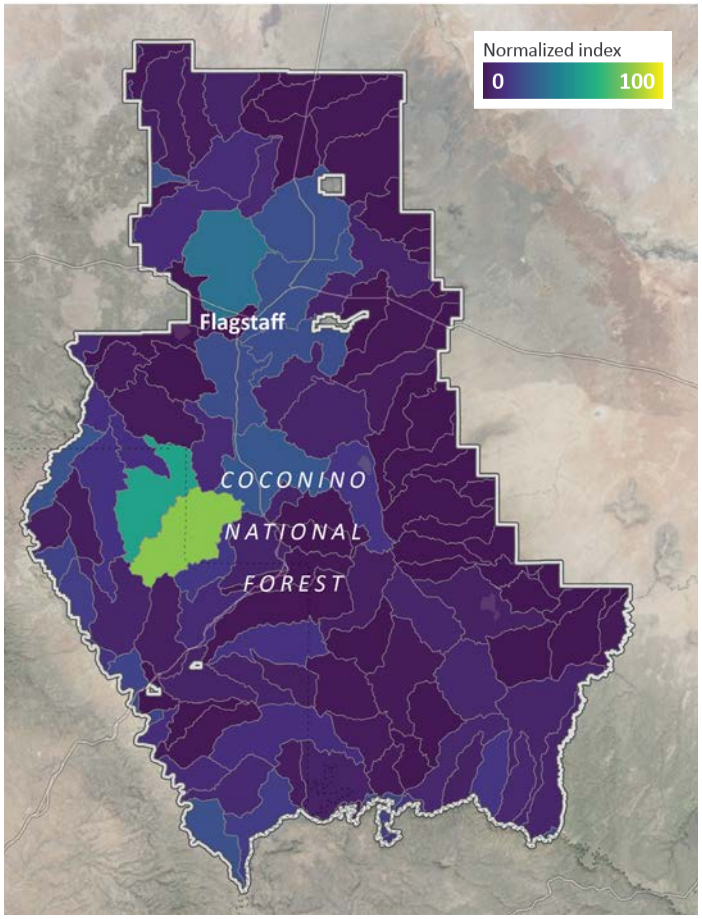


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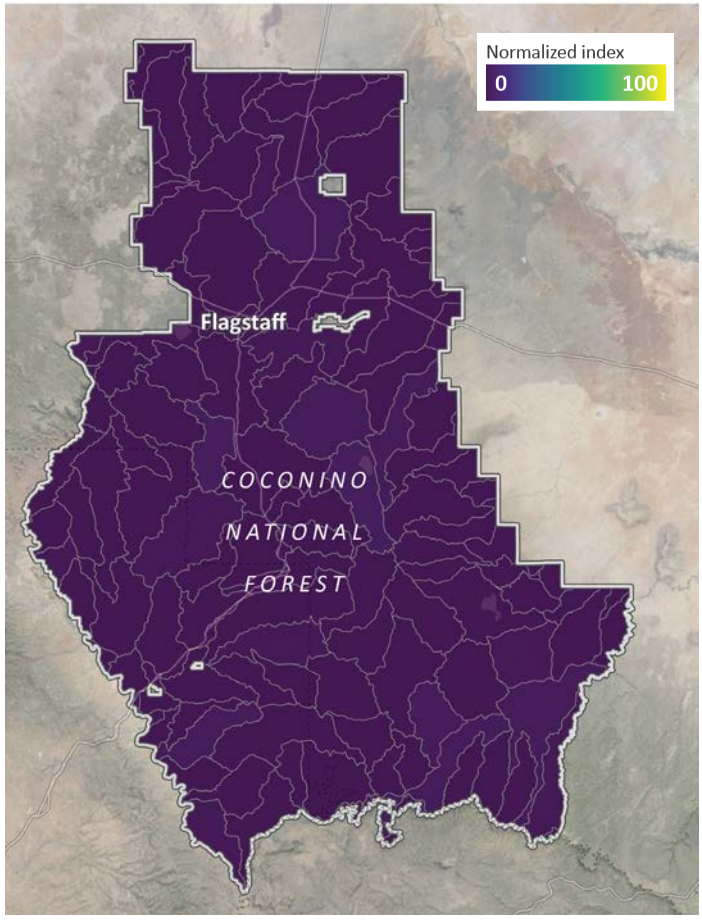
FIGURE 13. NUMBER OF CAMPGROUNDS



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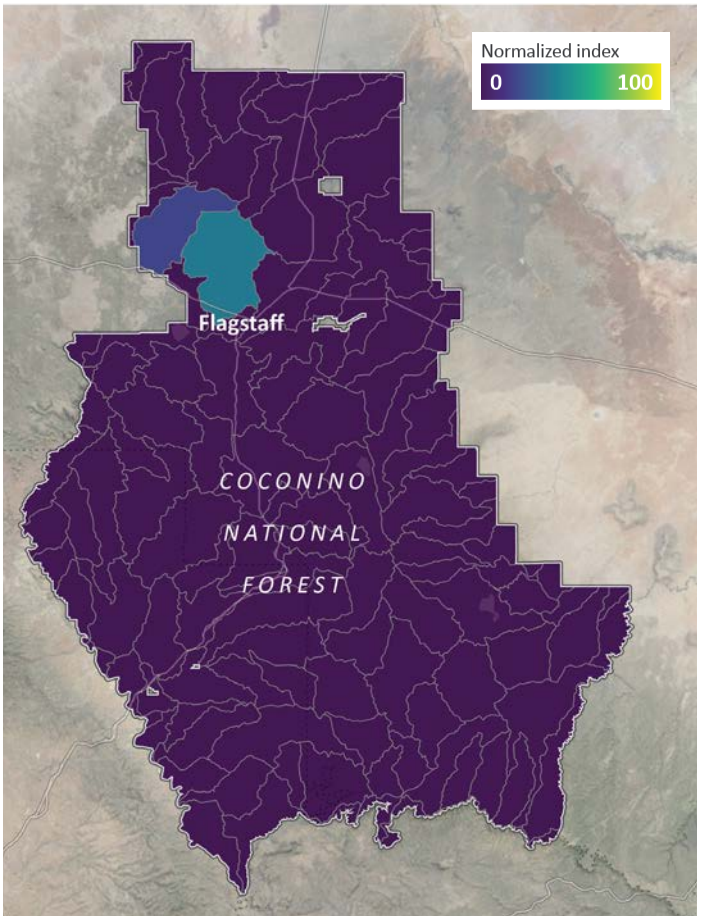
people congregate in the limited number of recreation sites. Such a site will receive a low index score, indicating relatively low VAR, which masks the fact that a solitary recreation asset may actually be incredibly valuable from the perspective of consumer surplus. Despite this disconnect with consumer surplus values, counting recreation assets as a proxy for visitation is still useful, as this analysis is focused on physical assets at risk that may be damaged during disasters and which would incur restoration and/or replacement costs.

Finally, because only some activities—hiking, camping, skiing—are represented by the visitation proxy, estimated values at risk for this asset class will be conservative. To illustrate the point, anglers will converge on water bodies for recreation; the presence of these recreationally valuable assets is not included in this assessment of VAR.

FIGURE 14. NUMBER OF SKI AREAS



RESIDENTIAL BUILDINGS

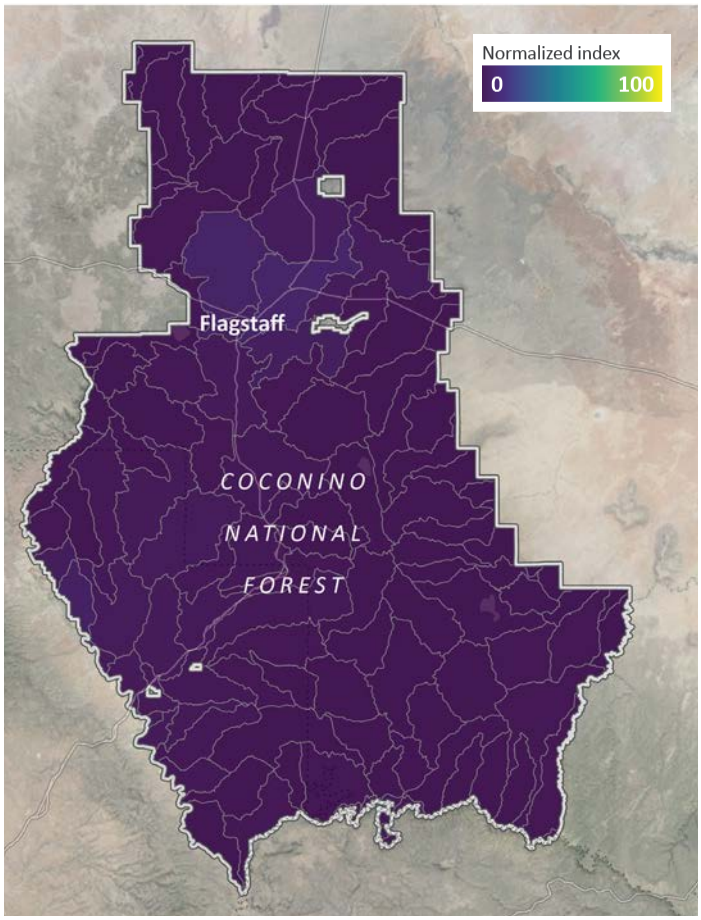
Structures built on and near USFS land in areas often called the wildland-urban interface (WUI) are threatened by wildfire activity. While USFS owns some of these structures, the vast majority do not belong to the public sector. The replacement cost of all non-USFS-owned structures that exist within a 5-kilometer buffer surrounding USFS land makes up the total VAR from wildfire for this category.

Identification of structures within the 5-kilometer buffer begins with the Microsoft U.S. Building Footprints dataset (2018), which is intersected with a 5-kilometer buffer surrounding USFS lands to determine total square footage at risk.[29] This analysis selected a 5-kilometer buffer to represent the WUI because the valuation literature exploring the connection between property value reductions and proximity to wildfire finds depressed home prices between 5 and 20 kilometers[30, 31] distant from a burned area. Choosing the 5-kilometer buffer for this analysis is a more conservative approach and is more reflective of how fire spreads from forested lands into the wildland-urban interface.

Total building footprint area from the Microsoft dataset is summed for each HUC12 and converted into dollars using the National Building Cost Manual (2020), which provides square foot replacement costs for residential homes.[32]

This valuation approach is broadly consistent with FEMA's benefit-cost framework. However, the source data required several assumptions to produce a low-bound estimate for total structure value at risk. The Microsoft Building Footprint dataset does not differentiate between commercial, multi-family, and single-family structures. As the replacement cost values from the National Building Cost Manual are unique to structure type, it is first necessary to define a single-family home using variables from the Microsoft Building Footprints dataset. For this analysis, buildings between 400 and 3,000 square feet are assumed to be single family residences, and all buildings are assumed to be single story. These assumptions narrowed the pool of structures inside the 5km buffer down from 'all structures' to 'plausibly single-family homes,' thereby creating a more conservative estimate of value at risk.

FIGURE 15. NON-USFS OWNED BUILDINGS



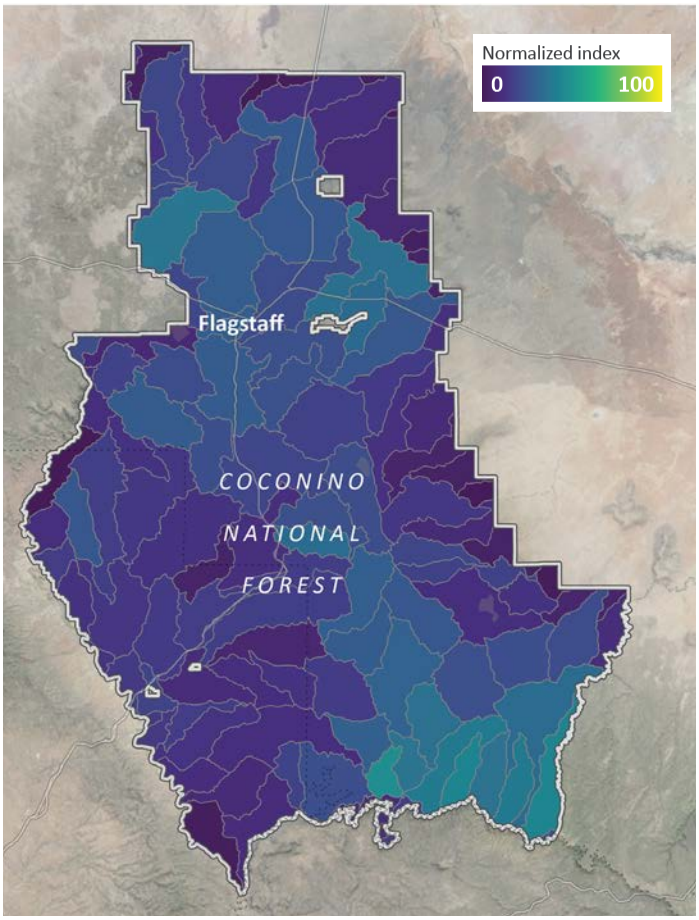
ROADS ON USFS-OWNED LANDS

Roads crisscross USFS-owned lands and facilitate maintenance, emergency response, and recreation; some are owned and/or operated by the USFS, and some are not. These roads—regardless of ownership—represent an important asset that is threatened by wildfire. When fires occur along roadways, the high temperatures and falling debris can cause damage and extended road closures. A secondary mechanism by which roads can be damaged is via elevated post-fire landslide and flood risk. In all cases, fire activity can lead to expensive cleanup and repair costs to restore connectivity, as well as imposing costs to people via longer travel times.

The National Forest System Roads geospatial data layer from USFS was used to understand the relative risk posed to roads by wildfire.[33] Summing the total road miles that pass through each HUC12 shows the extent of the road assets at risk.

Cleanup and repair costs will vary according to the extent of damage, type of road, ease of access, and local labor and supply conditions; in counting road miles and treating all roads equally, this analysis does not account for these differences. In general, roads that are more developed and which carry more people will have higher per-mile infrastructure replacement/repair costs than smaller, less developed roads: sign and guardrail replacement, culvert repair, erosion stabilization, debris and hazard tree removal.[34] Beyond repair and replacement, extended road closures also impose costs on residents, recreational users, and truckers, depending on the type of road affected. One study of interstate closures related to flood and avalanche activity in Washington State estimated nearly $75 million (2008 USD) in lost economic output due to freight delay across 8 days.[35] Smaller, seasonal roads that are not as heavily freighted still impose important costs on recreational and local users, lengthening transit times to access jobs, critical services, and recreational opportunities. The nature of the traffic and who is using these roads is not accounted for in this analysis.

FIGURE 16. ROAD DENSITY

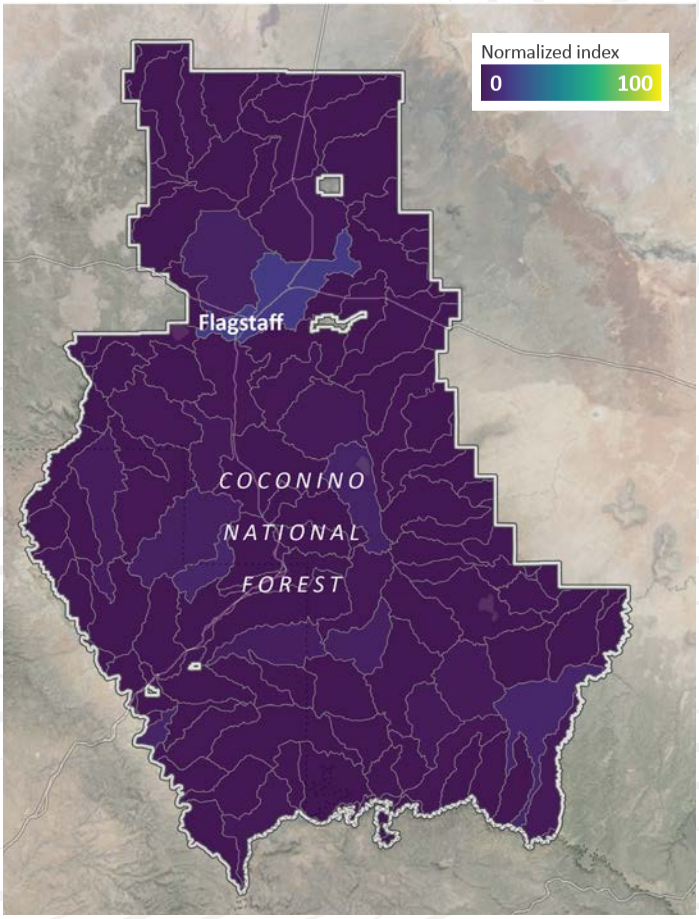


USFS-OWNED BUILDINGS AND PROPERTIES

While most buildings on and near USFS land belong to the private sector, USFS does own and manage select structures including ranger stations, campgrounds, and more. These buildings, as with those owned by the private sector, are also threatened by wildfire activity. The replacement cost of USFS-owned structures makes up the total value at risk for this category.

Because these assets are owned by USFS, the agency maintains a list of replacement costs for each of the buildings.[36] These data were summed by HUC12 and assembled into a normalized index to identify USFS lands across the nation with relatively more or less built asset value at risk from wildfire and other hazards.

FIGURE 17. USFS-OWNED BUILDINGS



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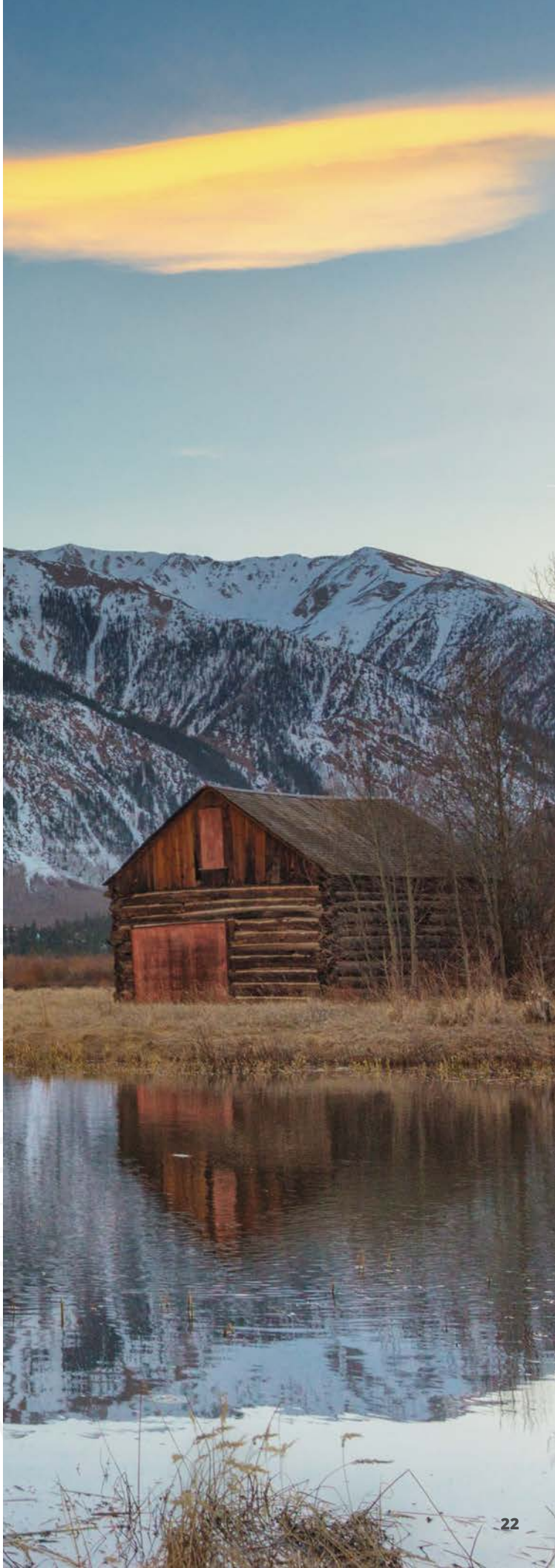

While the analysis of additional VAR reveals more "hotspots" where valuable assets are threatened by wildfire and other disasters, it does not provide a mechanism for ranking the relative importance of each asset class against one another. Put another way, it provides not one answer, but many answers to the question of where best to invest money in forest health and resilience projects that protect valuable assets. This may actually be a strength: as USFS seeks partners to co-fund these projects, assets that are most "valuable" will be different for stakeholders with different priorities, providing multiple pathways to catalyzing resilience-building investments. And while the VAR "hotspots" for each asset class are clustered in different places around the U.S., investments in forest health motivated by a desire to protect a specific asset class will also protect any other VAR that are present in a given watershed.

This is also true of additional VAR not quantified in this analysis. From conversations with USFS, other assets whose risk from natural and human-made hazards could be mitigated from forest health and resilience investments include:

Forest products—the goods provided by forestlands that are sold in markets (e.g., timber, wood products, foraged goods, and more). Due to the complex nature of harvesting forest products—forest regeneration schedules, changing market prices, and lease and confidentiality agreements—these values were not included.

Other public infrastructure—much like powerlines, other infrastructure like wastewater systems and power generating sites may exist on or near USFS lands, and provide valuable services to surrounding communities.

Though the values at risk highlighted in this analysis often indirectly acknowledge the human impact of fire and other disasters in the forest, the potential human impacts of disasters striking these HUC12 units should be examined explicitly when using the identified VAR "hotspots" to make decisions. Certain populations—by virtue of their economic circumstance, demographics, and more—bear a disproportionate burden when assets on USFS lands are affected by disasters. FEMA maintains a dataset that estimates social vulnerability at the census tract level.[xxxvii] The index is a composite of 29 socioeconomic variables, combined into a single score designed to help local officials identify communities that may need support before, during, or after disasters. Because these data exist at the census tract level—which are typically much larger than the rural, low-population areas that constitute the bulk of USFS lands—using areal weighting to incorporate them into USFS HUC12 units provided results that were too general to be meaningful. Nevertheless, an analysis of VAR hotspots would benefit from a parallel investigation into social vulnerability using the FEMA tool to identify where marginalized and otherwise socially vulnerable populations live, so as to locate restoration projects in sites which not only protect forest health and the asset classes included here, but also encourage resilience in nearby populations.

Ultimately, this expanded decision-support tool will provide regional and local USFS teams with the information necessary to identify the communities adjacent to national forests with significant assets threatened by wildfire and other disasters, and help steer resources towards protecting these communities and the forestlands that sustain them.

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