WILDFIRE RISK IN EASTERN REGION NATIONAL FORESTS

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Eastern Region, USDA Forest Service

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1 EXECUTIVE SUMMARY

The Eastern Region of the U.S. Forest Service contracted with Pyrologix in July 2018 to conduct a spatial wildfire risk assessment, supporting compliance with National Forest Service Policy (FSM 5140) and providing information to inform budget allocation, fuel treatment planning and prioritization, and to support the forest plan revision process.

The wildfire risk assessment for the Eastern Region (R9) consisted of three primary components: 1) Wildfire Simulation, 2) HVRA Characterization, and 3) Effects Analysis. The first component, Wildfire Simulation, requires updating and calibrating the fuelscape to produce current and realistic measures of wildfire hazard. In March 2019, Pyrologix led three in-person fuel calibration workshops hosted by the Region and attended by a wide array of local, state, and federal specialists in the fields of fuel characterization, fire ecology, and fire behavior modeling. These workshops were hosted in three locations to facilitate attendance across the large geographic area: Albany, NY; Martinsville, IN; and Milwaukee, WI. The information gathered in those workshops was used to calibrate the LANDFIRE 2014 (version 1.4.0) fuelscape initially, and those edits were brought forward to calibrate the LANDFIRE Remap data, beginning in the fall of 2020 when the Remap data became available for the Eastern Region extent. A separate report describing the methods used to produce the fuelscape is available for download.[1]

The wildfire hazard modeling was updated to reflect Remap version of the fuelscape and leverage recent improvements in fire intensity calculations. Pyrologix used spatial datasets of historical weather and fire occurrence to parameterize and calibrate the FSim fire modeling system to estimate annual burn probability across the Region. FSim also produced an “event set,” used to estimate transmission of wildfire to Highly Valued Resources and Assets (HVRA). A report describing the methods and results of the hazard modeling is available for download.[2]

The resulting simulations of wildfire hazard (likelihood and intensity) were used in conjunction with data representing high-value resources and assets to determine wildfire risk for the USFS administrative lands R9. In November 2019, a set of HVRA was identified through workshops held in Milwaukee, Wisconsin, and Albany, New York; at which a group of agency representatives identified HVRA and associated spatial data for use in the assessment. Each HVRA must also have an associated response to wildfire (positive or negative) and a relative importance assignment to integrate results across all HVRA. These assignments were determined at three additional virtual workshops throughout 2021 attended by a wide array of local, state, and federal specialists in the fields of fuel characterization, fire ecology, and fire behavior modeling.

This report documents the wildfire risk portion of the quantitative wildfire risk assessment. While this report was generated by Pyrologix LLC, the overall analysis was developed as a collaborative effort with numerous agencies and partners providing data and feedback. The results produced in this analysis provide a snapshot of wildfire risk for the year 2020.

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[1] ERRA Fuelscape report: http://pyrologix.com/reports/ERRA_FuelscapeReport.pdf
[2] ERRA Wildfire Hazard report: http://pyrologix.com/reports/ERRA_HazardReport.pdf

1.1 PURPOSE OF THE ASSESSMENT

The purpose of the Eastern Region (R9) Wildfire Risk Assessment (ERRA-R9[3]) is to provide foundational information about wildfire risk and hazard across the geographic area. Such information supports wildfire response, regional fuel management planning, and revisions to land and resource management plans. A wildfire risk assessment is a quantitative analysis of the assets and resources across a specific landscape and how they are potentially impacted by wildfire. The ERRA-R9 analysis considers:

- likelihood of a fire burning,
- the intensity of a fire if one should occur,
- the exposure of assets and resources based on their locations, and
- the susceptibility of those assets and resources to wildfire.

To manage wildfire in Eastern Region, accurate wildfire risk data must be available to inform land and fire management strategies. These risk outputs can be used to aid in the planning, prioritization, and implementation of prevention and mitigation activities. In addition, the risk data can be used to support fire operations in response to wildfire incidents by identifying those assets and resources most susceptible to fire.

1.2 QUANTITATIVE RISK MODELING FRAMEWORK

The basis for a quantitative framework for assessing wildfire risk to highly valued resources and assets (HVRAs) has been established for many years (Finney 2005; Scott 2006). The framework has been implemented across a range of scales, from an individual county (Ager et al. 2017), a portion of a national forest (Thompson et al. 2013), individual states (Buckley et al. 2014), to the entire continental United States (Calkin et al. 2010). In this framework, wildfire risk is a function of two main factors: 1) wildfire hazard and 2) HVRA vulnerability (Figure 1).

[3] ERRA-R9 is an acronym for the title of the project—Eastern Region (R9) Wildfire Risk Assessment.

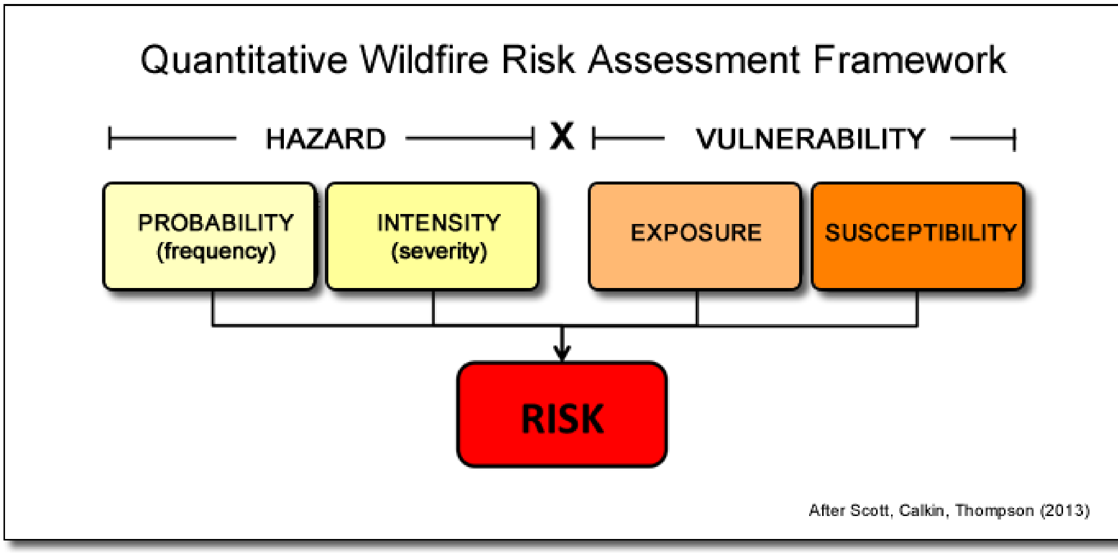

Figure 1. The components of the Quantitative Wildfire Risk Assessment Framework.

Wildfire hazard is a physical situation with the potential for causing damage to vulnerable resources or assets. Quantitatively, wildfire hazard is measured by two main factors: 1) burn probability (or likelihood of burning), and 2) fire intensity (measured as flame length, fireline intensity, or other similar measures).

HVRA vulnerability is also composed of two factors: 1) exposure and 2) susceptibility. Exposure is the placement (or coincidental location) of an HVRA in a hazardous environment—for example, building a home within a flammable landscape. Some HVRAs, like wildlife habitat or vegetation types, are not movable; they are not "placed" in hazardous locations. Still, their exposure to wildfire is the wildfire hazard where the habitat exists. Finally, the susceptibility of an HVRA to wildfire is how easily it is damaged by wildfire of different types and intensities. Some assets are fire-hardened and can withstand very intense fires without damage, whereas others are easily damaged by even low-intensity fire.

2 RISK ANALYSIS OVERVIEW

For any risk assessment, it is imperative to have spatial continuity across all aspects of project development. This ensures data alignment and logically consistent results across all ERRA-R9 data products. The project boundaries used in the Eastern Region (R9) Wildfire Risk Assessment are described below in sections 2.1.1 – 2.1.3 and are shown in Figure 2.

2.1 LANDSCAPE ZONES

2.1.1 ANALYSIS AREA

The ERRA-R9 wildfire risk assessment relies on wildfire hazard modeling produced for all lands in the Eastern Region. The Analysis Area for the Eastern Region (R9) project was defined as Administrative National Forest boundaries within Region 9, including a 10-mile buffer around Forest Service lands (Figure 2).

2.1.2 FIRE OCCURRENCE AREAS

To ensure valid Burn Probability (BP) results in the Analysis Area (AA) and prevent edge effects, it is necessary to allow FSim to start fires outside of the AA and burn into it. This larger area where simulated fires are started is called the Fire Occurrence Area (FOA). Because the fire modeling covers all lands in the Eastern Region, we established the FOA extent as a 20-km buffer on the Region 9 boundary, plus a 20-km buffer beyond the U.S. border and into Canada. The buffer provides sufficient area to ensure all fires capable of the AA are simulated. The Fire Occurrence Area covers roughly 464 million acres and is characterized by diverse topographic and vegetation conditions. We divided the overall fire occurrence extent into twenty-four FOAs to model this large area where historical fire occurrence and fire weather are highly variable. Individual FOA boundaries were developed to group geographic areas that experience similar wildfire occurrence. These boundaries were generated using a variety of inputs including larger fire occurrence boundaries developed for national-level work (Short et al. 2020), aggregated level IV EPA Ecoregions, and local fire staff input. For consistency with other FSim projects, we numbered these FOAs 901 through 924. The boundaries used for fire modeling (FOA and LCP) along with the R9 wildfire risk assessment boundary (R9 Analysis Area) are shown in Figure 2.

2.1.3 FUELSCAPE EXTENT

The available fuelscape extent was delineated by adding a 20-km buffer to the FOA extent. This buffer allows fires starting within the FOA to grow unhindered by the edge of the fuelscape, which would otherwise truncate fire growth and affect the simulated fire-size distribution, potentially introducing errors in the calibration process. A map of the ERRA-R9 AA, within the ERRA-All Lands fuelscape extent, is presented in Figure 2.

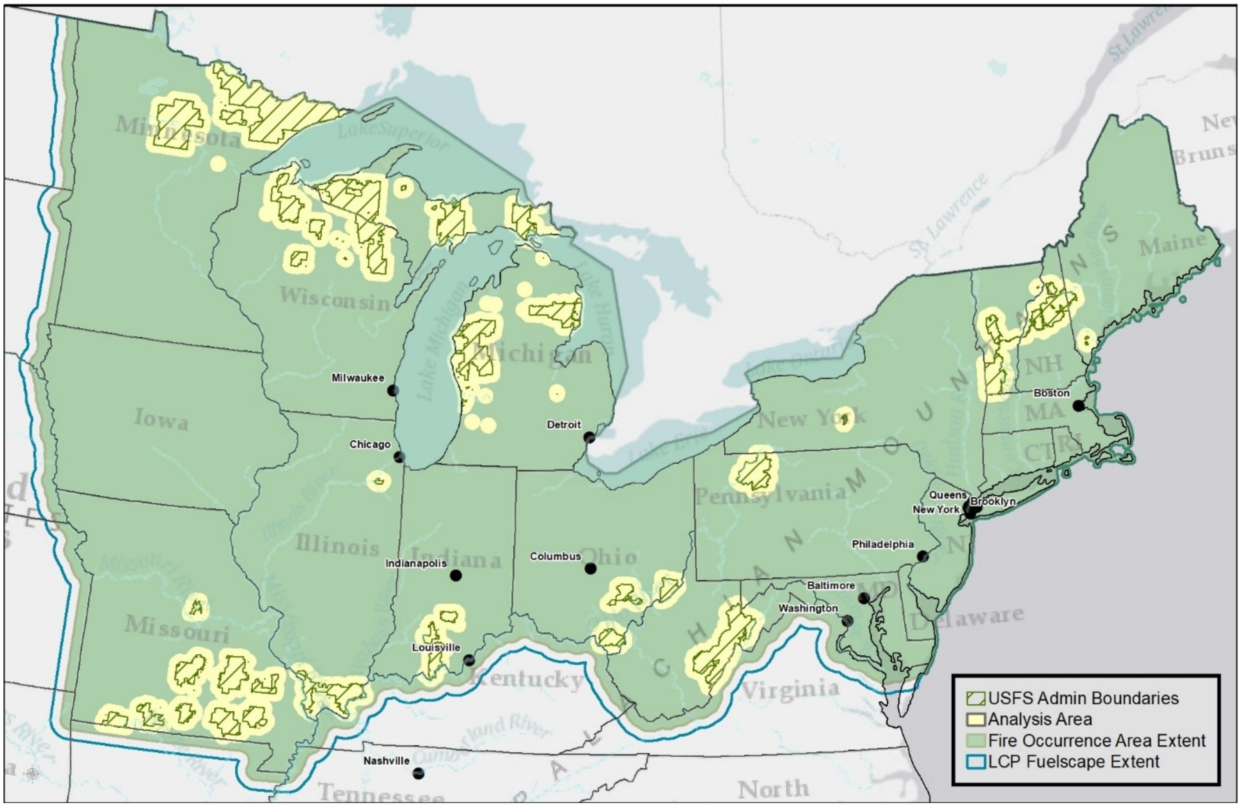

Figure 2. Overview of landscape zones for Eastern Region FSim project.

3 ANALYSIS INPUTS

Quantifying wildfire risk requires a comprehensive assessment of a focus area's high-value resources and assets, integrated with wildfire hazard (burn probability and fire intensity) to make a spatially resolved estimate of the risk. While an essential component to determining wildfire hazard is an accurate current condition fuelscape capturing the most recent disturbances and treatments. The integrated risk assessment inputs are discussed further in sections 3.1-3.2.

3.1 FUELSCAPE

The foundation of any wildfire hazard assessment is a current-condition fuelscape updated for recent disturbances and calibrated to reflect the fire behavior potential realized in recent historical wildfire events. LANDFIRE 2016 Remap 2.0.0 (LF Remap) data was leveraged to generate a calibrated fuelscape for this region-wide assessment.

The fuelscape consists of geospatial datasets representing surface fuel model (FM40), canopy cover (CC), canopy height (CH), canopy bulk density (CBD), canopy base height (CBH), and topography characteristics (slope, aspect, elevation). The FM40 dataset can be seen in Figure 3 in groups of similar fuel types. The fuelscape datasets can be combined into a single landscape (LCP) file and used as a fuelscape input in fire modeling programs. Further details about the methods and base data used to generate the calibrated ERRA-All Lands fuelscape are available in the fuelscape report.[1]

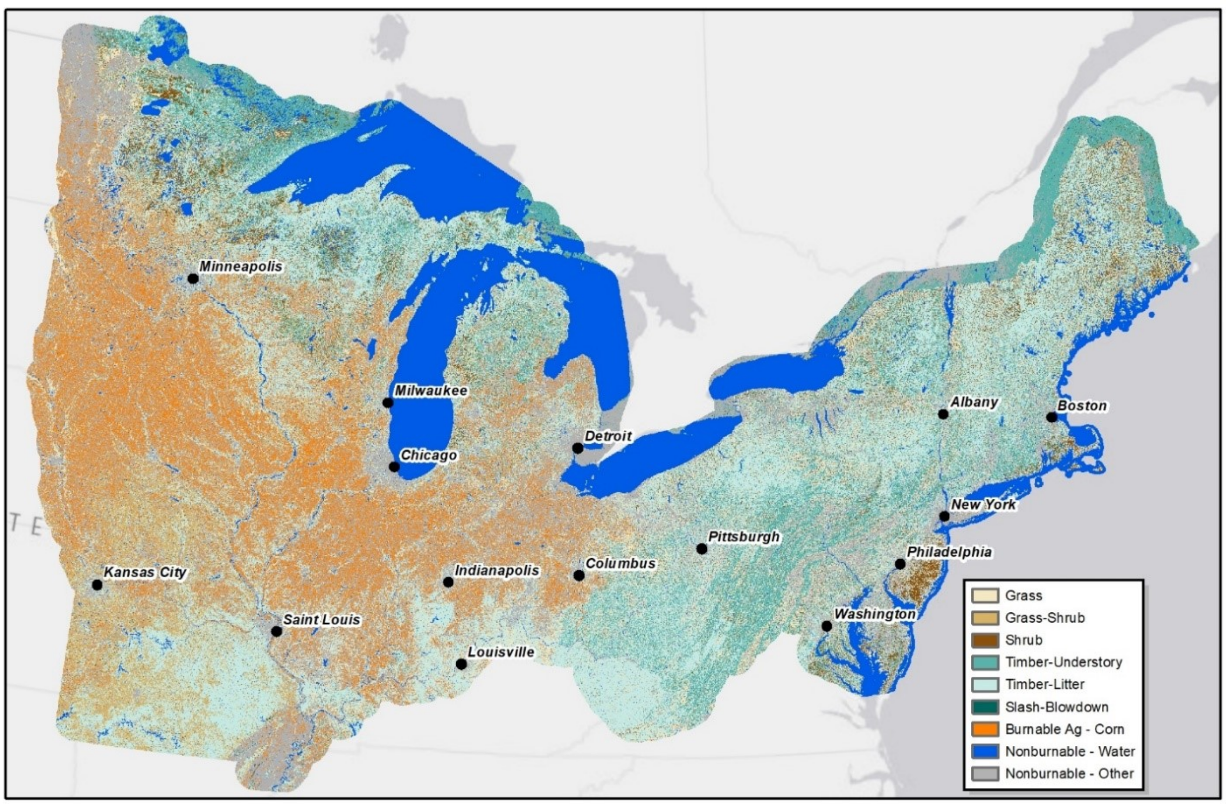

Figure 3. Map of fuel model groups across the Eastern Region LCP extent.

3.1.1 BURNABLE CORNFIELDS

The ERRA fuelscape uses a custom fuel model to represent the potential for wildfire spread into burnable cornfields. Workshop participants highlighted concerns regarding the underrepresentation of wildfire in agricultural areas in the western portion of the fuelscape due to the mapping of agriculture as non-burnable. Corn crops were identified as the agricultural fuel of greatest concern for the western portion of the Eastern Region. As a result, workshop participants requested a customization to portray the potential for wildfire in cornfields at certain times of the year. Pyrologix created a custom fuel model identical to the GR9 / 109 fuel model but labeled it separately as AG9 / 119 to allow for further customization.

3.2 WILDFIRE HAZARD

3.2.1 WILDFIRE SIMULATION (BURN PROBABILITY)

The FSim large-fire simulator was used to quantify wildfire hazard across the landscape at a pixel size of 120-m (3.5 acres per pixel). FSim is a comprehensive fire occurrence, growth, behavior, and suppression simulation system that uses locally relevant fuel, weather, topography, and historical fire occurrence information to make a spatially resolved estimate of the contemporary likelihood and intensity of wildfire across the landscape (Finney et al. 2011). Further details regarding methods and hazards results are available in the hazard report[2].

3.2.2 INTENSITY CALCULATIONS

In addition to estimates of wildfire likelihood, FSim produces measurements of predicted wildfire intensities. Due to the inherent challenges of estimating intensity with a stochastic simulator, estimates of fire intensity were instead developed using a custom Pyrologix utility called WildEST (Scott et al. 2020). WildEST is a deterministic wildfire modeling tool that integrates spatially continuous weather input variables, weighted based on how they will likely be realized on the landscape. This makes the deterministic intensity values developed with WildEST more robust for use in effects analysis than the stochastic intensity values developed with FSim. This is especially true in low wildfire occurrence areas where predicted intensity values from FSim are reliant on a very small sample size of potential weather variables. The WildEST methodology is further described in section 3 of the Hazard report[2].

3.3 HVRA CHARACTERIZATION

Highly Valued Resources and Assets (HVRA) are the resources and assets on the landscape most likely to warrant protection if found to be at risk of wildfire. The key criteria for inclusion in the ERRA-R9 assessment is an HVRA must be of greatest importance to the region, the spatial data must be readily available, and the spatial extent of the identified HVRA must be complete.

There are three primary components to HVRA characterization: HVRAs must be identified and their spatial extent mapped, their response to fire (negative, or neutral) must be characterized, and their relative importance to each other must be determined.

3.3.1 HVRA IDENTIFICATION

A set of HVRA was identified based on readily available spatial datasets for Eastern Region (R9), Administrative National Forest Service boundaries. The complete list of HVRA and their associated data sources are listed in Table 1.

Table 1. HVRA and sub-HVRA identified for the ERRA-R9 Wildfire Risk Assessment and associated data sources.

HVRA & Sub-HVRA	Data Source
People and Property	
People and Property	This data set represents housing unity density data produced by Pyrologix using the building footprints and U.S. Census - Census Block population data.
Infrastructure	
Electric transmission lines – high & low voltage	Geo-spatial data represents electric power transmission lines acquired from the Homeland Infrastructure Foundation-Level Data (HIFLD) program.
Communication Sites	Geo-spatial data communication sites and repeaters were provided by USFS, Eastern Region (R9), and supplemented with the Homeland Infrastructure Foundation-Level Data (HIFLD) program including cellular towers, land mobile towers, FM/AM transmission towers, microwave service towers, paging transmission towers, antenna structure, TV analog/digital transmitters, broadband radio transmitters, internet service providers, and internet exchange points.
Power Plants	Data representing the geo-spatial location of power plant locations was acquired from the Homeland Infrastructure Foundation-Level Data (HIFLD) program.
Substations	Substation locations were acquired from the Homeland Infrastructure Foundation-Level Data (HIFLD) program.
Oil & Gas Wells	Oil and Gas well locations were acquired from the Homeland Infrastructure Foundation-Level Data (HIFLD) program.
Natural Gas Pipelines	Data representing natural gas pipelines was acquired from the Homeland Infrastructure Foundation-Level Data (HIFLD) program.
Railroads	Railroad lines were acquired from the Homeland Infrastructure Foundation-Level Data (HIFLD) program.
Recreation	
Historical Sites	Data represents locations designated as historic sites (National Register Eligible and National Register Listed). Data was provided by USFS, Eastern Region (R9), and derived from the Forest Service Enterprise data program.
Administrative Sites	Data represent recreational administrative sites. Data was provided by USFS Eastern Region and derived from the Forest Service Enterprise data program.
Recreational Sites	Data represents high value-Recreation sites. Data was provided by USFS Eastern Region and derived from the Forest Service Enterprise data program (*RecSite_RecSitesHV_ Dev345_OpenR9)*
National Trails	Data represents high-value trails (historical and national). Data was provided by USFS Eastern Region and derived from the Forest Service Enterprise data program. (Captured *Trail of Tears* from NPS data set).
Drinking-Water	
Surface Drinking Water	Surface drinking water (24-hour) protection areas were acquired from the EPA Source Water Protection Area program.
Timber	
Timber Analysis	Data represents Forest Service timber categorized by value and fire susceptibility. Spatial data was provided and categorized by USFS Eastern Region (derived from FS Veg).
Vegetation	
Vegetation Condition	Data represents fire return interval and was derived from LANFIRE's Biophysical Setting data layer (Remap 2016).

To the degree possible, HVRA are mapped to the extent of the Analysis Area boundary (Figure 2). This is the boundary used to summarize the final risk results.

3.3.1.1 RESPONSE FUNCTIONS

Each HVRA selected for the assessment must also have an associated response to wildfire, whether positive, neutral, or negative. We relied on input from a group of both Forest Service and interagency representatives, and additional fire and resource staff at a virtual Fire Effects workshop held in February 2021. In the workshop, the group discussed each resource or asset's response to fires of different intensity levels and characterized the HVRA response using values ranging from -100 to 100. The flame-length values corresponding to the fire intensity levels used in risk calculations are shown in Table 2. The response functions (RFs) used in the risk results are shown in Table 3 thru Table 18 below.

Table 2. Flame-length values corresponding to Fire Intensity Levels used in assigning response functions.

Fire Intensity Level (FIL)	**1**	**2**	**3**	**4**	**5**	**6**
Flame Length Range (feet)	0-2	2-4	4-6	6-8	8-12	12+

3.3.1.2 RELATIVE IMPORTANCE

The relative importance (RI) assignments are needed to integrate results across all HVRA. Without this input from leadership to prioritize among HVRA, the default is to assume equal-weighting among HVRA – a result that is never a desired outcome. A virtual RI workshop was held on July 29th, 2021, for Line Officers, Forest Fire Management Officers, and agency representatives. The focus of this workshop was to establish the importance and ranking of the primary HVRAs relative to each other. The People and Property HVRA received the greatest share of RI at 48 percent, followed by the Infrastructure (26%), Timber (13%), and Water (10%) HVRA. The remaining share of RI is composed of the Vegetation (3%) and Recreation (<1%) HVRA (Figure 4). These importance percentages reflect the overall importance of the primary HVRA relative to each other.

Sub-HVRA relative importance was also determined at the RI workshop. Sub-RIs consider both the relative importance per unit area and the mapped extent of the Sub-HVRA layers within the primary HVRA category. These calculations need to account for the relative extent of each HVRA to avoid overemphasizing HVRA covering many acres. This was accomplished by normalizing the calculations by the relative extent of each HVRA in the assessment area. Here, relative extent refers to the number of 30-m pixels mapped in each HVRA. In using this method, the relative importance of each HVRA is spread out over the HVRA's extent. An HVRA with few pixels can have a high importance per pixel; an HVRA with a great many pixels can have a low importance per pixel. A weighting factor (called Relative Importance Per Pixel [RIPP]) representing both the relative importance per unit area and overall importance was calculated for each HVRA.

In Table 3 thru Table 18, we provide the share of HVRA relative importance within each primary HVRA.

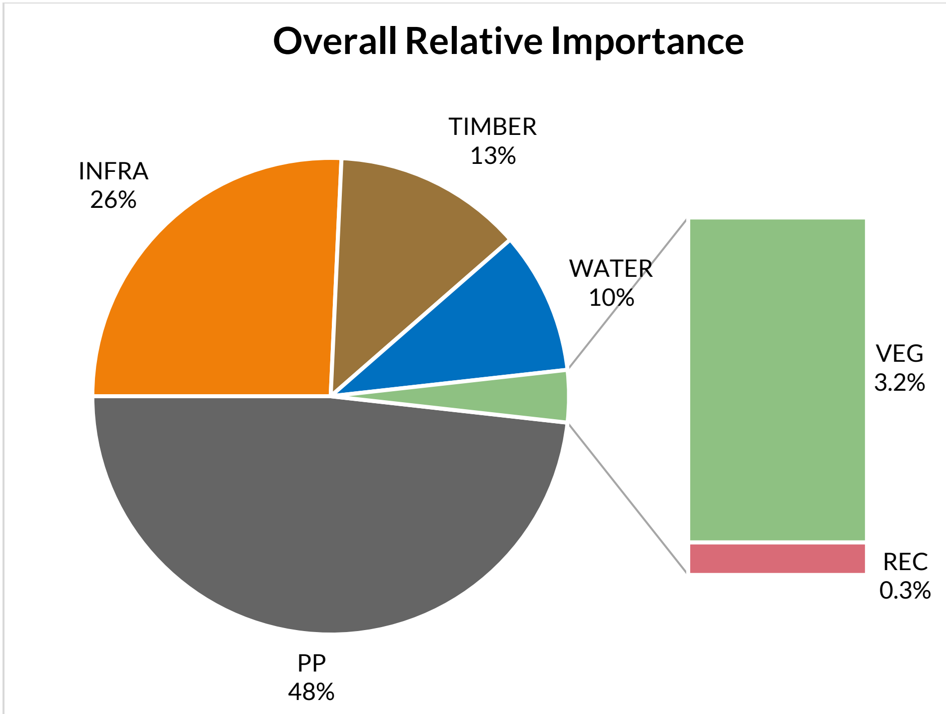

Figure 4. Overall HVRA Relative Importance for the primary HVRA.

3.3.2 HVRA CHARACTERIZATION RESULTS

Each HVRA was characterized by one or more data layers of sub-HVRA and, where necessary, further categorized by an appropriate covariate. Covariates separate HVRA by their response to wildfire, such as different response functions for transmission lines by voltage classes. The main HVRA in ERRA-R9 are mapped below along with a table containing the assigned response functions, the within-HVRA share of relative importance, and total acres for each sub-HVRA. These components are used along with fire behavior results from FSim and WildEST in the wildfire risk calculations described in section 4.1.

3.3.2.1 PEOPLE AND PROPERTY

3.3.2.1.1 HOUSING UNIT DENSITY (HUDEN)

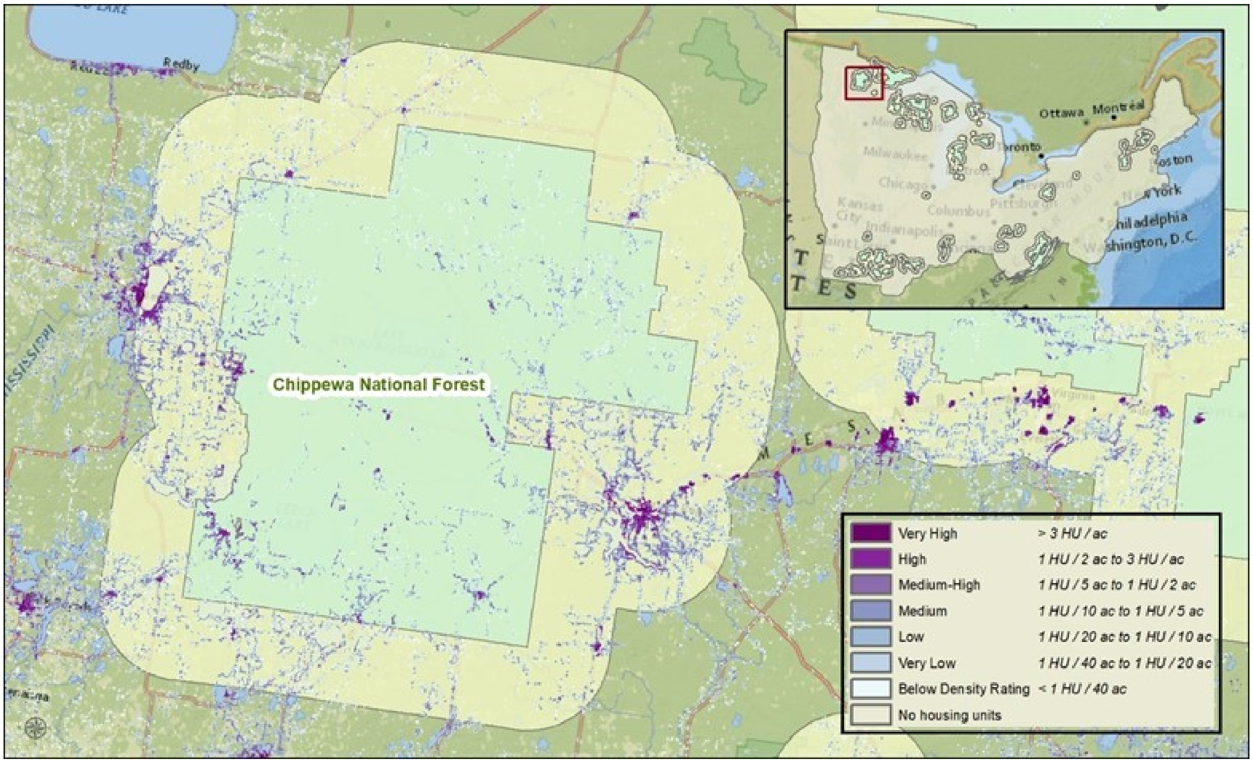

Figure 5. Map of Housing Unit Density within the Analysis Area.

The HUDen raster was produced by Pyrologix using the Microsoft Building Footprints and U.S. Census - Census Block population data. Population estimates were brought forward to 2018 county population estimates. Our approach estimates housing-unit count for a census block then allocates that count to the portions of the block likely to contain those housing units, identified as where the buildings are located within the block. This methodology was developed for the Wildfire Risk to Communities project (Scott et al. 2020). The same set of response functions was applied to all HU density classes.

The People and Property (HUDen) HVRA received negative response functions for all fire intensity levels (Table 3). The RF assignments demonstrate a pattern of increasing loss with increasing fire intensity, reaching near-total loss by FIL6.

Table 3. Response functions for the People and Property HVRA to highlight HUDen.

Sub-HVRA	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6	Share of RI[1]	Acres
P&P – HUDen, Very High	-20	-30	-50	-70	-80	-95	2%	15,353
High	-20	-30	-50	-70	-80	-95	35%	436,405
Medium-High	-20	-30	-50	-70	-80	-95	22%	1,080,228
Medium	-20	-30	-50	-70	-80	-95	18%	1,931,970
Low	-20	-30	-50	-70	-80	-95	13%	2,693,320
Very Low	-20	-30	-50	-70	-80	-95	7%	2,654,051
Below Density Rating	-20	-30	-50	-70	-80	-95	3%	3,087,016

[1] Within-HVRA relative importance.

3.3.2.2 INFRASTRUCTURE

3.3.2.2.1 COMMUNICATION SITES

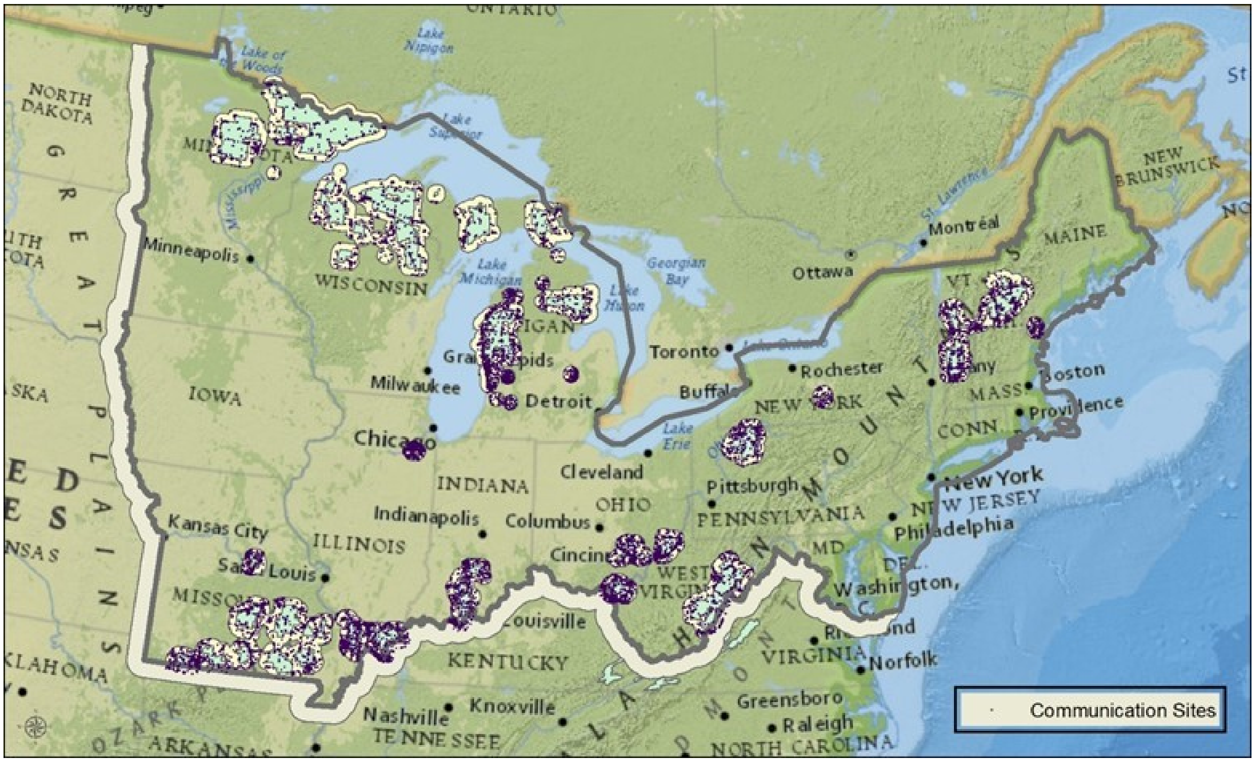

Figure 6. Map of Communication Sites within the Analysis Area.

Communication sites for the analysis area (Figure 6) were provided by USFS, Eastern Region (R9), and supplemented with data from the Homeland Infrastructure Foundation-Level Data (HIFLD)[4]. The types of communication sites compiled for the assessment include cellular towers, repeaters, land mobile towers, FM/AM transmission towers, microwave service towers, paging transmission towers, antenna structure, TV analog/digital transmitters, broadband radio transmitters, internet service providers, and internet exchange points. All communication sites were merged into a single feature class and converted to 30-m pixels using the ArcGIS Focal Statistics tool. Focal statistics were calculated using the sum of an annulus neighborhood with an inner radius of zero and an outer radius of two, resulting in a point feature being represented by thirteen, 30-m pixels.

The response functions for communication sites demonstrate a pattern indicative of their generally hardened structures and defensible space, showing a neutral response at lower flame lengths, with an increasingly negative response to fires of increasing intensity (Table 4).

Communication sites were allocated 18 percent of the share of the Infrastructure HVRA importance. The share of HVRA importance is based on relative importance per unit area and mapped extent.

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[4] HIFLD data downloaded from https://hifld-geoplatform.opendata.arcgis.com/

Table 4. Response functions for the Infrastructure HVRA to highlight Communication Sites.

Sub-HVRA	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6	Share of RI[1]	Acres
Communication Sites	0	0	-10	-20	-40	-50	18%	26,794

[1] Within-HVRA relative importance.

3.3.2.2.2 TRANSMISSION LINES

Figure 7. Map of Transmission Lines within the Analysis Area.

Transmission Lines within the analysis area (Figure 7) were acquired from the Homeland Infrastructure Foundation-Level Data (HIFLD)[4]. The lines were classified using a voltage break of 345 volts (transmission lines carrying less than 345 volts classified as '1', and those greater than 345, classified as '2'). The data were classified, converted to a 30-m raster based on voltage classification, expanded out one additional pixel (per side) using the ArcGIS Expand tool, and mosaiced back together to capture more of the area impacted by wildfire.

Low voltage lines (<345 kV) are mostly wooden poles, and therefore, demonstrate a strongly negative response to all fire intensities. Total loss was expected for fires greater than FIL4 (Table 5). High voltage transmission lines (≥345 kV) are expected to be constructed of largely non-burnable materials that can withstand exposure to lower fire intensities and experience less loss at the higher intensity classes (Table 5).

Due to the number of acres mapped on the landscape and their importance to infrastructure, electric transmission lines received 33 percent of the share of the Infrastructure HVRA importance. The share of HVRA importance is based on relative importance per unit area and mapped extent.

Table 5. Response functions for the Infrastructure HVRA to highlight Transmission Lines.

Sub-HVRA	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6	Share of RI[1]	Acres
High Volt (>=345)	0	0	0	-10	-30	-30	5%	78,294
Low Volt (wooden poles)	-30	-50	-70	-90	-100	-100	28%	410,948

[1] Within-HVRA relative importance.

3.3.2.2.3 POWER PLANTS

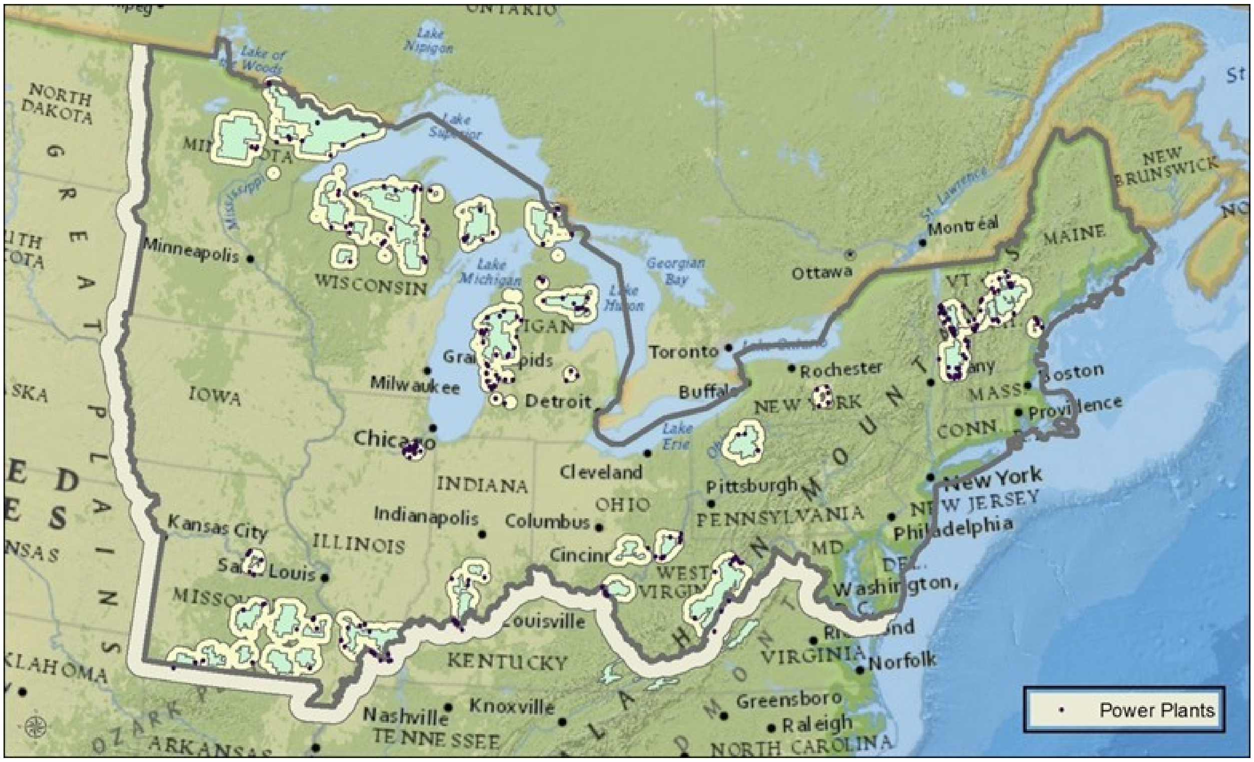

Figure 8. Map of Power Plants within the Analysis Area.

The locations of power plants within the analysis area (Figure 8) were derived from the Homeland Infrastructure Foundation-Level Data (HIFLD)[4]. The acquired data was converted to 30-m pixels using the ArcGIS Focal Statistics tool. Focal statistics were calculated using the sum of an annulus neighborhood with an inner radius of zero and an outer radius of two, resulting in a point feature being represented by thirteen, 30-m pixels.

Due to the hardened nature of the structures and defensible space, the response function assignments for power plants demonstrate a neutral response to nearly all fire intensities. They demonstrate a response only to fires of higher intensity and show minimal loss (Table 6).

Power plants were allocated less than one percent of the share of the Infrastructure HVRA importance. The share of HVRA importance is based on relative importance per unit area and mapped extent.

Table 6. Response functions for the Infrastructure HVRA to highlight Power Plants.

Sub-HVRA	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6	Share of RI[1]	Acres
Power Plants	0	0	0	0	-10	-20	0.1%	263

[1] Within-HVRA relative importance.

3.3.2.2.4 SUBSTATIONS

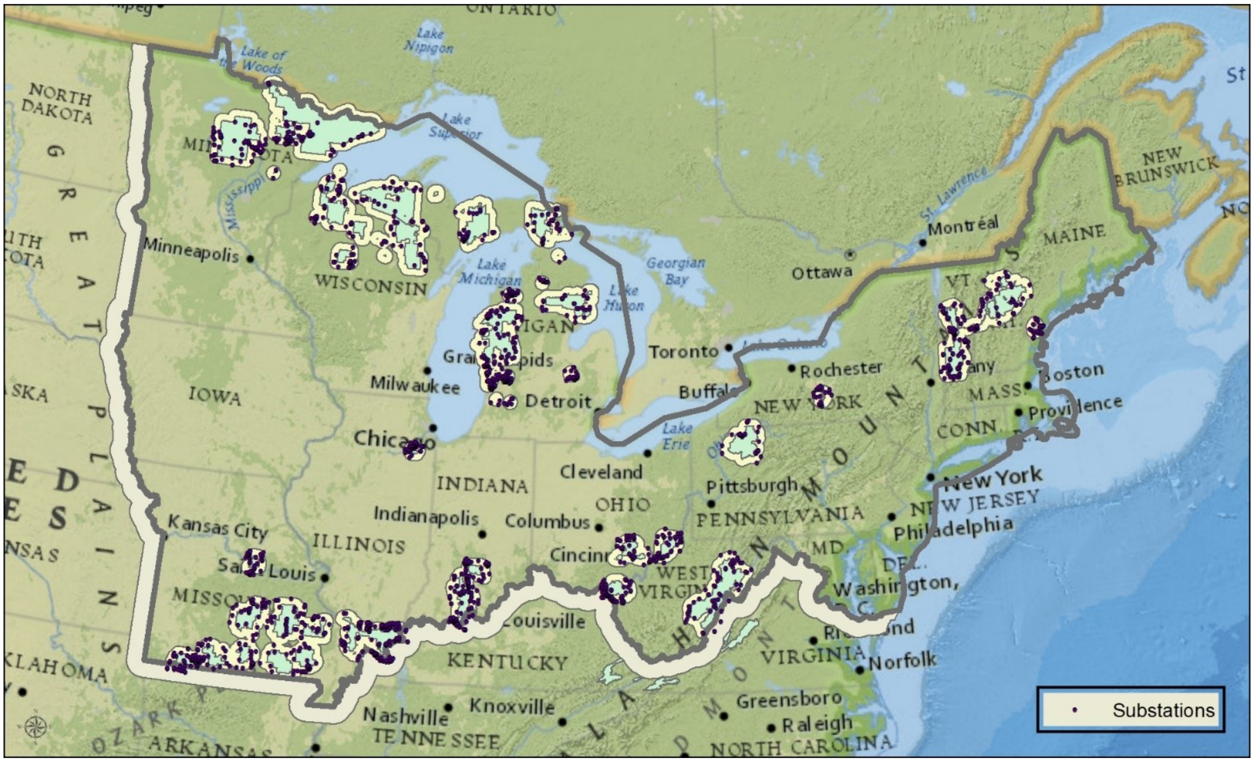

Figure 9. Map of Substations within the Analysis Area.

Substations within the analysis area (Figure 9) were derived from the Homeland infrastructure Foundation-Level Data (HIFLD)[4]. The acquired data was converted to 30-m pixels using the ArcGIS Focal Statistics tool. Focal statistics were calculated using the sum of an annulus neighborhood with an inner radius of zero and an outer radius of two, resulting in a point feature being represented by thirteen, 30-m pixels.

Due to the established, defensible space surrounding substations, the response functions are similar to that of power plants. Fires of low intensity will have little to no effect and not until FIL3 will they demonstrate a very low negative response to fire (Table 7). This negative trend continues as fire intensity increases but never surpasses mild loss.

Substations were allocated one percent of the share of the Infrastructure HVRA importance. The share of HVRA importance is based on relative importance per unit area and mapped extent.

Table 7. Response functions for the Infrastructure HVRA to highlight Substations.

Sub-HVRA	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6	Share of RI[1]	Acres
Substations	0	0	-10	-20	-30	-40	0.9%	2,569

[1] Within-HVRA relative importance.

3.3.2.2.5 RAILROADS

Figure 10. Map of Railroads within the Analysis Area.

Railroads for the analysis area (Figure 10) were acquired from the Homeland Infrastructure Foundation-Level Data (HIFLD)[4]. For use in this analysis, the data were converted to a 30-m raster and expanded out one additional pixel (per side) using the ArcGIS Expand tool to capture more of the area impacted by wildfire.

Due to the mixed construction materials (both wooden and steel railroad) represented in this layer, and our inability to identify which features use which materials at this scale, their response function assignments demonstrate a minimal, moderated response to nearly all fire intensities. It is not until fires reach high intensities that the RFs demonstrate a moderate response and show minimal loss (Table 8).

Railroads were allocated 13 percent of the share of the Infrastructure HVRA importance. The share of HVRA importance is based on relative importance per unit area and mapped extent.

Table 8. Response functions for the Infrastructure HVRA to highlight Railroads.

Sub-HVRA	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6	Share of RI[1]	Acres
Railroads	-5	-10	-15	-20	-25	-35	13%	188,765

[1] Within-HVRA relative importance.

3.3.2.2.6 OIL & GAS WELLS

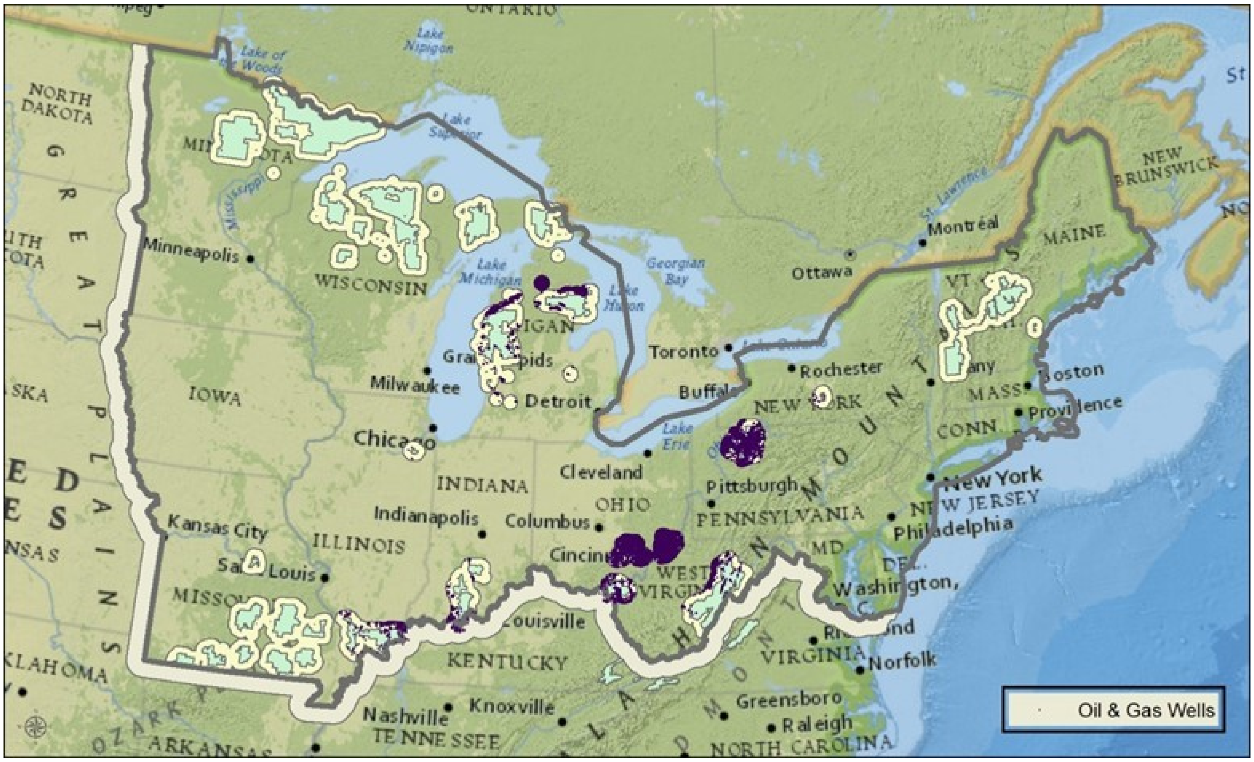

Figure 11. Map of Oil & Gas Wells within the Analysis Area.

The locations of Oil and Gas Wells for the analysis area (Figure 11) were derived from the Homeland Infrastructure Foundation-Level Data (HIFLD)[4]. The acquired data was converted to 30-m pixels using the ArcGIS Focal Statistics tool. Focal statistics were calculated using the sum of an annulus neighborhood with an inner radius of zero and an outer radius of two, resulting in a point feature being represented by thirteen, 30-m pixels.

The response function assignments for oil and gas wells show a neutral response for nearly all fire intensities. Not until 6-8-foot flame lengths (FIL4) is there a transition to a negative response. As fire intensity increases, the response functions show an increasingly negative response but remain relatively low (Table 9).

Oil and gas wells were allocated 14 percent of the share of the Infrastructure HVRA importance. The share of HVRA importance is based on relative importance per unit area and mapped extent.

Table 9. Response functions for the Infrastructure HVRA to highlight Oil & Gas Wells.

Sub-HVRA	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6	Share of RI[1]	Acres
Oil and Gas Wells	0	0	0	-10	-10	-20	14%	143,000

[1] Within-HVRA relative importance.

3.3.2.2.7 NATURAL GAS PIPELINES

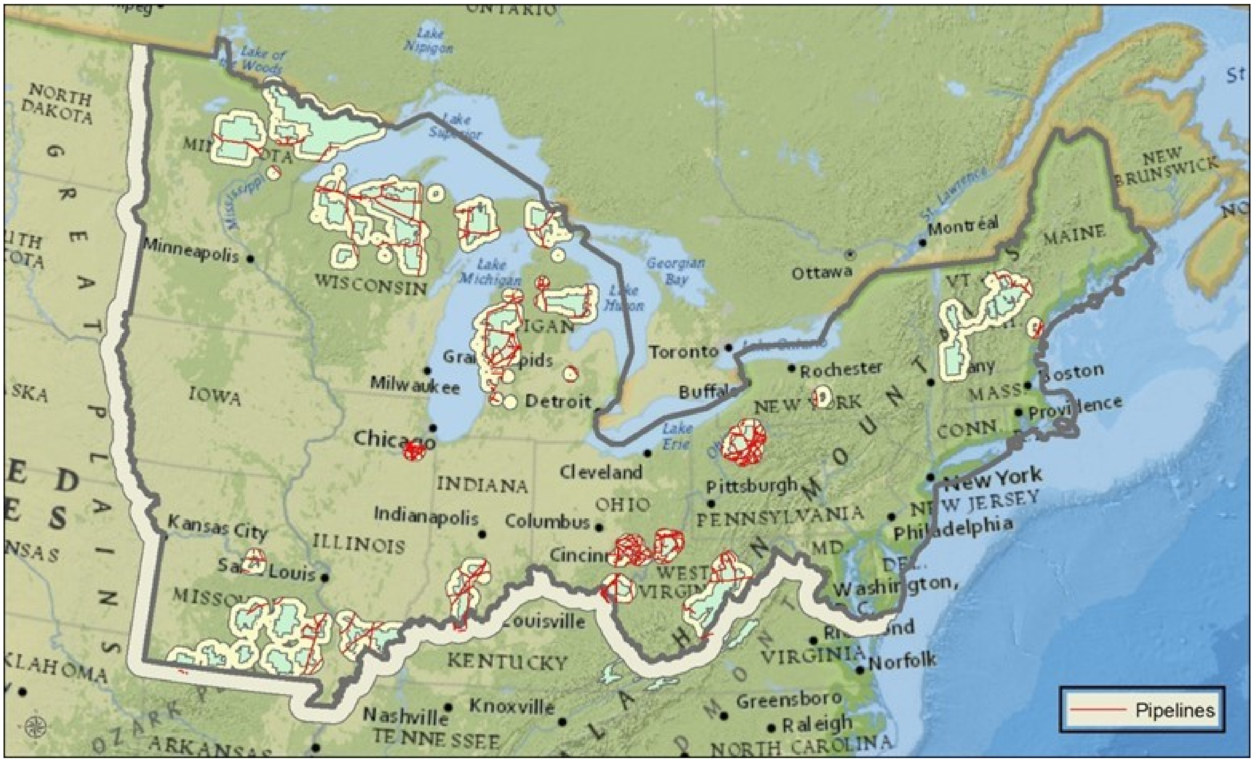

Figure 12. Map of Natural Gas Pipelines within the Analysis Area.

Natural Gas Pipelines within the analysis area (Figure 12) were acquired from the Homeland Infrastructure Foundation-Level Data (HIFLD)[4]. For use in this analysis, the data were converted to a 30-m raster and expanded out one additional pixel (per side) using the ArcGIS Expand tool to capture more of the area impacted by wildfire.

The response functions for pipelines show a neutral response at the lower flame lengths. Starting at the 6–8-foot flame lengths (FIL4) there is a transition to a negative response. As fire intensity increases, the response functions show an increasingly negative response but remain relatively low (Table 10).

Natural gas pipelines were allocated 21 percent of the share of the Infrastructure HVRA importance. The share of HVRA importance is based on relative importance per unit area and mapped extent.

Table 10. Response functions for the Infrastructure HVRA to highlight Natural Gas Pipelines.

Sub-HVRA	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6	Share of RI[1]	Acres
Natural Gas Pipelines	0	0	0	-10	-10	-20	21%	209,680

[1] Within-HVRA relative importance.

3.3.2.3 RECREATION

3.3.2.3.1 HISTORIC SITES

Figure 13. Map of Historic Sites within the Analysis Area.

Historic sites within the analysis area (Figure 13) were provided by USFS, Eastern Region (R9), and derived from the Forest Service Enterprise data program (National Register Eligible and National Register Listed). The data was converted to 30-m pixels using the ArcGIS Focal Statistics tool. Focal statistics were calculated using the sum of an annulus neighborhood with an inner radius of zero and an outer radius of two, resulting in a point feature being represented by thirteen, 30-m pixels.

Due to the intrinsic value of historic sites, their response function assignments demonstrate an initial negative response to fire. The inability to replace such structures and difficulty in suppressing fire near our around them causes this negative trend to continue as fire intensity increases (Table 11).

Historic sites were allocated 28 percent of the share of the Recreation HVRA importance. The share of HVRA importance is based on relative importance per unit area and mapped

Table 11. Response functions for the Recreation HVRA to highlight Historic Sites.

Sub-HVRA	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6	Share of RI[1]	Acres
Historic Sites	-20	-30	-50	-70	-90	-95	28%	347

[1] Within-HVRA relative importance.

3.3.2.3.2 ADMINISTRATIVE SITES

Figure 14. Map of Administrative Sites within the Analysis Area.

Administrative sites for the analysis area (Figure 14) were provided by USFS Eastern Region (R9). The provided data represents the location of administrative buildings, offices, research/schools, housing, and service/utility structures on lands owned by USDA (Forest Service) lands. The data were extracted to the analysis area, assigned a rank based on associated importance levels (all sites are assumed to have the same wildfire susceptibility), and converted to 30-m pixels using the ArcGIS Focal Statistics tool. Focal statistics were calculated using the sum of an annulus neighborhood with an inner radius of zero and an outer radius of two, resulting in a point feature being represented by thirteen, 30-m pixels.

Due to their susceptibility to fire, the response function assignments for all administrative sites demonstrate a pattern of increasing loss as fire intensity increases (Table 12).

Administrative sites were allocated 41 percent of the share of the Recreation HVRA importance. The share of HVRA importance is based on relative importance per unit area and mapped extent.

Table 12. Response functions for the Recreation HVRA to highlight Administrative Sites.

Sub-HVRA	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6	Share of RI[1]	Acres
Administrative Sites - High	-20	-30	-50	-70	-80	-95	19%	259
Administrative Sites - Low	-20	-30	-50	-70	-80	-95	22%	693

[1] Within-HVRA relative importance.

3.3.2.3.3 TRAILS

Figure 15. Map of Trails within the Analysis Area.

Data representing trails within the analysis area (Figure 15) was provided by USFS Eastern Region and the National Park Service. The provided data represent the known locations of high-value, historical, and national trails.

The data were converted to a 30-m raster and expanded out one additional pixel (per side) using the ArcGIS Expand tool to capture more of the area impacted by wildfire.

The response functions for historic and national trails show a neutral response at the lower flame lengths. Starting at the 6-8-foot flame lengths (FIL4) there is a transition to a negative response. As fire intensity increases, the response functions show an increasingly negative response (Table 13).

Trails were allocated ten percent of the share of the Recreation HVRA importance. The share of HVRA importance is based on relative importance per unit area and mapped extent.

Table 13. Response functions for the Recreation HVRA to highlight Trails.

Sub-HVRA	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6	Share of RI[1]	Acres
Trails	0	0	0	-30	-60	-80	10%	87,832

[1] Within-HVRA relative importance.

3.3.2.3.4 RECREATIONAL SITES

Figure 16. Map of Recreation Sites within the Analysis Area.

Data representing recreation sites (campgrounds, hotels, horse camps, lodges, interpretive sites, cabins, lookouts, ski areas, picnic sites, and trailheads) within the analysis area (Figure 16) was provided by USFS Eastern Region and derived from the Forest Service Enterprise data program. The data were extracted to the analysis area, assigned a rank based on the locations associated importance level (all sites are assumed to have the same wildfire susceptibility), and converted to 30-m pixels using the ArcGIS Focal Statistics tool. Focal statistics were calculated using the sum of an annulus neighborhood with an inner radius of zero and an outer radius of two, resulting in a point feature being represented by thirteen, 30-m pixels.

Due to the susceptible nature of recreation sites, the HVRA received negative response functions for all fire intensity levels (Table 14). The response function assignments demonstrate a pattern of increasing loss with increasing fire intensity, reaching near-total loss by FIL6.

Recreation sites were allocated 22 percent of the share of the Recreation HVRA importance. The share of HVRA importance is based on relative importance per unit area and mapped extent

Table 14. Response functions for the Recreation HVRA to highlight Recreation Sites.

Sub-HVRA	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6	Share of RI[1]	Acres
Recreation Sites – High	-20	-30	-50	-70	-80	-95	4%	52
Recreation Sites - Medium	-20	-30	-50	-70	-80	-95	8%	167
Recreation Sites - Low	-20	-30	-50	-70	-80	-95	10%	323

[1] Within-HVRA relative importance.

3.3.2.4 TIMBER

3.3.2.4.1 TIMBER: VALUE & SUSCEPTIBILITY

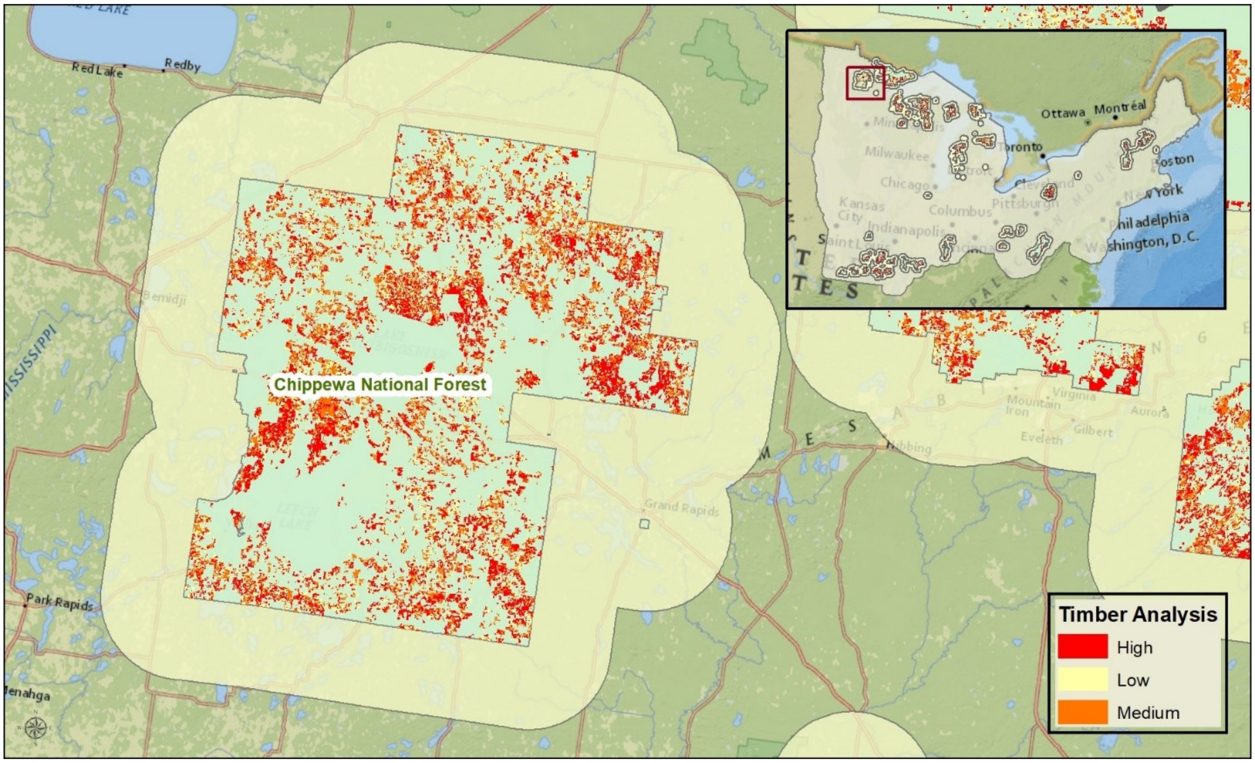

Figure 17. Map of Timber within the Analysis Area.

The Eastern region has a wide variety of high-value timber. To derive a common understanding of timber value, a team was assembled at the Regional Office comprised of the RO silviculturist, RO contracting officer, RO GIS program manager, regional trust fund manager, and other inter-agency partners to review data sources for timber representation and value assignments. This effort produced a geospatial data layer containing attributes associating the various timber species and vegetation types with an appropriate value category for use in the ERRA-R9 analysis (Figure 17).

The provided dataset was converted to 30-m pixels and assigned a wildfire susceptibility class based on a review of timber species with R9 staff. The resulting data layer allowed for a representation of timber value and susceptibility – the two components needed to assess wildfire risk. For this assessment, timber value was reflected with relative importance and susceptibility through response function assignments (Table 15).

Table 15. Response functions for the Timber HVRA to highlight Timber.

Sub-HVRA	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6	Share of RI[1]	Acres
Timber: Value - High; Susceptibility High	-10	-40	-80	-100	-100	-100	42%	2,369,531
Timber: Value - High; Susceptibility Mod	0	-20	-45	-70	-80	-100	17%	944,986
Timber: Value - High; Susceptibility Low	10	0	-10	-40	-60	-100	19%	1,079,909
Timber: Value - Mod; Susceptibility High	-10	-40	-80	-100	-100	-100	6%	482,929
Timber: Value - Mod; Susceptibility Mod	0	-20	-45	-70	-80	-100	7%	623,666
Timber: Value - Mod; Susceptibility Low	10	0	-10	-40	-60	-100	4%	356,425
Timber: Value - Low; Susceptibility High	-10	-40	-80	-100	-100	-100	2%	344,913
Timber: Value - Low; Susceptibility Mod	0	-20	-45	-70	-80	-100	2%	376,607
Timber: Value - Low; Susceptibility Low	10	0	-10	-40	-60	-100	1%	109,883

[1] Within-HVRA relative importance.

3.3.2.5 VEGETATION CONDITION

3.3.2.5.1 VEGETATION CONDITION: FIRE RETURN INTERVAL

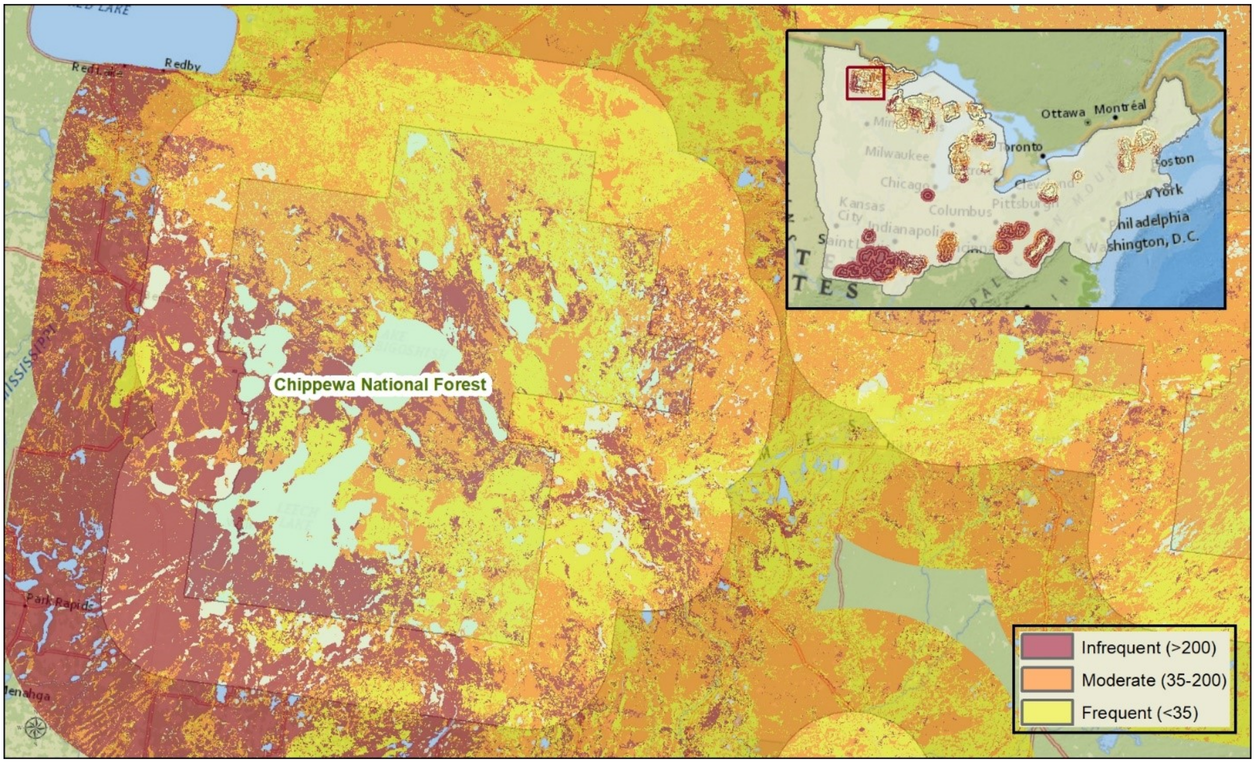

Figure 18. Map of Vegetation Condition within the Analysis Area.

Vegetation condition (Figure 18) for the analysis area was derived from Landfire's most current (Landfire 2016 Remap) Biophysical Setting[5] 30-m raster. The acquired data "represents the vegetation system that may have been dominant on the landscape before Euro-American settlement and is based on both the current biophysical environment and an approximation of the historical disturbance regime." Using the data's *Fire Regime Group (FRG_New)* attribute (Table 16), an estimate of fire return interval was derived for the analysis area (Figure 18). This HVRA is intended to capture the role of wildfire in ecosystem maintenance and health.

The response functions for the Vegetation Condition HVRA demonstrate a similar pattern across all sub-HVRA – showing a positive response at the lowest flame lengths, with increasing negativity or less benefit to fires of increasing intensity. The variation of response functions across sub-HVRA is indicative of the vegetation types associated with fire return interval. In general, the more infrequent the historical disturbance regimes are associated with less benefit and greater the loss at the higher intensity levels (Table 17).

The share of HVRA importance is based on relative importance per unit are. The Vegetation Condition sub-HVRA received equal weighting, with their share of RI varying due to differences in mapped extent.

[5] https://landfire.gov/bps.php

Table 16. Biophysical Setting, Fire Return Interval

Fire Regime Group (FRG_New)	Fire Return Interval Description	Years	Group
I-A	Percent replacement fire less than 66.7%, fire return interval 0-5 years	0-5	Frequent
I-B	Percent replacement fire less than 66.7%, fire return interval 6-15 years	6-15	Frequent
I-C	Percent replacement fire less than 66.7%, fire return interval 16-35 years	16-35	Frequent
II-A	Percent replacement fire greater than 66.7%, fire return interval 0-5 years	0-5	Frequent
II-B	Percent replacement fire greater than 66.7%, fire return interval 6-15 years	6-15	Frequent
II-C	Percent replacement fire greater than 66.7%, fire return interval 16-35 years	16-35	Frequent
III-A	Percent replacement fire less than 80%, fire return interval 36-100 years	36-100	Moderate
III-B	Percent replacement fire less than 66.7%, fire return interval 101-200 years	101-200	Moderate
IV-A	Percent replacement fire greater than 80%, fire return interval 36-100 years	36-100	Moderate
IV-B	Percent replacement fire greater than 66.7%, fire return interval 101-200 years	101-200	Moderate
V-A	Any severity, fire return interval 201-500 years	201-500	Infrequent
V-B	Any severity, fire return interval 501 or more year	501+	Infrequent

Table 17. Response functions for the Vegetation HVRA to highlight Vegetation Condition, Fire Return Interval.

Sub-HVRA	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6	Share of RI[1]	Acres
Fire Return Interval - Infrequent (> 200)	10	5	-20	-70	-80	-100	38%	21,747,318
Fire Return Interval – Moderate (35-200)	20	10	0	-55	-70	-90	25%	14,187,432
Fire Return Interval – Frequent (<35)	30	15	5	-40	-60	-80	37%	20,796,743

[1] Within-HVRA relative importance.

3.3.2.6 DRINKING WATER

3.3.2.6.1 SURFACE DRINKING-WATER

Figure 19. Map of Drinking Water Protection Areas within the Analysis Area.

Drinking water protection areas were mapped using data from the EPA's Source Water Protection Area program[6]. The dataset includes surface drinking water protection areas (24-hour critical water basins) and their associated intake facilities. Basins were limited to those with an associated intake being careful to not truncate basins at project boundaries during processing. The resulting critical watershed map is shown (Figure 19).

For the ERRA-R9 assessment, watershed resources were analyzed using a custom approach to determine the importance of each pixel within a basin, based on population served and distance to intake. We calculated the Euclidean distance to the drinking water intake for each pixel within its associated watershed. We then divided the result by the Euclidean distance to create a proportion of importance based on the distance to the intake, and to prevent values from decaying as rapidly we divided the distance by 1/3. We then multiplied by the intake's population served. The sum of the importance for each watershed was then normalized to the total population served to prevent overweighting the largest watersheds. A single pixel can belong to one or more overlapping watersheds; therefore values are cumulative across overlapping watersheds.

[6] https://www.epa.gov/sourcewaterprotection/delineate-source-water-protection-area

Table 18. Response functions for the Critical Watersheds HVRA.

Sub-HVRA	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6	Share of RI[1]	Acres
Drinking Water	0	-10	-20	-30	-40	-50	100.0%	27,605,648

[1] Within-HVRA relative importance.

4 EFFECTS ANALYSIS

An effects analysis quantifies wildfire risk as the expected value of net response (Finney 2005, Scott et al. 2013) also known as expected net value change (eNVC). Effects analysis relies on input from resource specialists to produce response functions for Highly Valued Resources and Assets (HVRA) occurring in the analysis area. A response function is a tabulation of the relative change in the value of an HVRA if it were to burn in each of six WildEST flame-length classes. A positive value in a response function indicates a benefit or increase in value; a negative value indicates a loss or decrease in value.

For the ERRA-R9 assessment, the term Highly Valued Resources and Assets (HVRA) is used to describe what has previously been labeled "values at risk". This change in terminology is important to highlight because resources and assets are not themselves "values" in a way that the term is conventionally defined—they *have* value (importance). For example, assets are human-made features, such as commercial structures, critical facilities, housing, etc., that have specific importance or value. Similarly, resources are natural features, such as wildlife habitat, vegetation type, or water, etc., also with specific importance or value. While such resources and assets may be exposed to wildfire, they are not necessarily "at-risk"—that is the purpose of the assessment.

4.1 CALCULATIONS

Integrating HVRAs with differing units of measure (for example, habitat vs. homes) requires relative importance (RI) values for each HVRA/sub-HVRA. These values were identified in the RI workshop, as discussed in section 3.3.1.2. The final importance weight used in the risk calculations is a function of overall HVRA importance, sub-HVRA importance, and relative extent (pixel count) of each sub-HVRA. This value is therefore called relative importance per pixel (RIPP).

The RF and RIPP values were combined with estimates of the flame-length probability (FLP) in each of the six flame-length classes to estimate conditional NVC (cNVC) as the sum-product of flame-length probability (FLP) and response function value (RF) over all the six flame-length classes, with a weighting factor adjustment for the relative importance per unit area of each HVRA, as follows:

$$cNVC_j = \sum_{i}^{n} FLP_i * RF_{ij} * RIPP_j$$

where *i* refers to flame length class (n = 6), *j* refers to each HVRA, and RIPP is the weighting factor based on the relative importance and relative extent (number of pixels) of each HVRA. The cNVC calculation shown above places each pixel of each resource on a common scale (relative importance), allowing them to be summed across all resources to produce the total cNVC at a given pixel:

$$cNVC = \sum_{j}^{m} cNVC_j$$

where cNVC is calculated for each pixel in the analysis area. Finally, eNVC for each pixel is calculated as the product of cNVC and annual BP:

$$eNVC = cNVC * BP$$

4.1.1 BURNABLE CORN CALCULATION ADJUSTMENTS

The ERRA fuelscape (section 3.1) included the use of a custom fuel model to represent the potential for wildfire spread into burnable cornfields. This customization is necessary because fire behavior associated with cornfields is dependent on the time of year relative to harvest. Discussions during the fuelscape calibration workshop highlighted this difference, suggesting the use of a GR2 fuel model to represent corn in its stubble form, but GR9 to represent fire behavior before harvest. Since only one fuel model can be assigned, the fuelscape customization portrays the potential for wildfire in cornfields at certain times of the year via a custom fuel model identical to the GR9 / 109 fuel model but labeled as AG9 / 119 to allow for further customization in FSim modeling. More information on the fuelscape calibration is available in the ERRA Fuelscape report.[1]

The WildEST fire intensity calculations resulting from the fuelscape adjustment express the full fire behavior potential of burnable cornfields mapped with the custom fuel model, AG9. The fire behavior shown in these products may overrepresent the potential in the months outside of the peak growing season. When determining the integrated hazard and risk it is necessary to make adjustments reflecting fire behavior associated with different stages of corn relative to harvest.

The wildfire risk results presented in this report were adjusted in pixels mapped with fuel model AG9 to reduce intensity proportional to the split between GR2 and GR9. This adjustment compensates for the difference in expected fire behavior depending on the time of year relative to corn-crop harvest. This involved a reduction factor of 50 percent from the calculated risk value. Without this adjustment, burnable cornfields appear as the most hazardous fuel type in the Eastern Region despite the moderate fire behavior expected for approximately half of the fire season.

4.2 UPSAMPLING FSIM RESULTS

FSim's stochastic simulation approach can be computationally intensive and time constraining on large landscapes. The challenge is to determine a resolution sufficiently fine to retain detail in fuel and terrain features while producing calibrated results in a reasonable timeframe. Moreover, HVRA are often mapped at the same resolution as the final BP produced by FSim. To enable greater resolution on HVRA mapping, we chose to upsample the FSim burn probability (BP) rasters to 30-m, consistent with HVRA mapping at 30-m. More information on probability upsampling is available in the ERRA Wildfire Hazard report[2].

4.3 WILDFIRE TRANSMISSION (RISK-SOURCE)

The potential for wildfires to transmit risk is a function of the spatial variation in fire occurrence and fire growth potential, in conjunction with spatial variation in HVRA location. To evaluate this potential, the total cNVC – the sum of all HVRA (People and Property, Infrastructure, Timber, Vegetation Condition, Drinking Water and Recreation)– was determined for each simulated FSim fire perimeter. The sum of total cNVC within each fire perimeter was then attributed to its associated ignition point. Summaries were limited to "large" fire perimeters, defined here as perimeters greater than the Lorenz curve large-fire threshold. Below this perimeter size, simulated fire-size distributions do not match historical distributions. More information on the Lorenz curve large-fires threshold is available in the ERRA Wildfire Hazard report[2].

The final raster dataset created from the perimeter overlay exercise (risk-source) represents the expected annual risk per km^2 (or total wildfire transmission risk) for all HVRA from ignitions across the landscape. We refer to this raster as Expected Transmitted Risk (eRiskSource_allHVRA.tif).

The Expected Transmitted Risk raster was generated using a multi-stage process. The ERRA-R9 analysis area includes eighteen Fire Occurrence Areas (FOAs) with a varying number of iterations. The number of iterations used in the simulation was added to the attribute table for each fire and a new attribute representing cNVC per iteration was generated. Including the number of iterations in the calculation provides the "expected" or likelihood component of risk-source. Using the ArcGIS Point Statistics tool, the sum of cNVC per iteration within 5-km and 10-km moving window was calculated and the results were combined giving preference to the 5-km moving window with consideration of the negative and positive values between focal windows. This approach retains the ignition impact nearer the ignition source (with the 5-km window) but uses the results of the broader focal raster (10-km) to fill missing values and to more gradually decrease wildfire risk values in areas with fewer ignitions.

The second step involved calculating the sum of the ignitable[7] land area using the same tool and parameters on a point feature class differentiating ignitable and nonignitable fuel models. Finally, the sum of cNVC per iteration was divided by the sum of ignitable land area per km^2 to get the expected risk-source per km^2 of source-area. These results can be used to look at the relative likelihood and consequence of ignitions occurring across the landscape.

[7] Ignitable fuel includes burnable fuel, but not the custom burnable-urban fuel model.

5 RESULTS

5.1 EFFECTS ANALYSIS RESULTS

The cumulative results of the wildfire risk calculations described in section 4.1 are the spatial grids of cNVC and eNVC, representing both the conditional and expected change in value from wildfire disturbance to all HVRAs included in the analysis. Results are limited to those pixels that have at least one HVRA and a non-zero burn probability. Both cNVC and eNVC reflect an HVRA's response to fire and their relative importance within the context of the assessment, while eNVC additionally captures the relative likelihood of wildfire disturbance. Cumulative effects of wildfire across the landscape vary by HVRA (Figure 20) with a net negative eNVC for all the HVRA. Results are scaled to cumulative eNVC values for the People and Property HVRA in the ERRA-R9 analysis area. People and Property show the greatest cumulative wildfire losses (eNVC) result followed by Timber, Infrastructure, Vegetation, Drinking Water, and Recreation as the HVRA with the greatest cumulative risk.

Figure 21 shows cNVC results at a 30-m resolution across the analysis area. The most adverse effects are shown in dark red and are largely concentrated around ERRA-R9 communities. Adjusting cNVC by fire likelihood (i.e., burn probability) narrows the range of values for negative outcomes and highlights areas more likely to be visited by wildfire as seen in the eNVC map in Figure 23.

Figure 22 shows the upsampled BP, as discussed in section 4.1.1. Figure 24 shows the wildfire transmission results, as discussed in section 4.3.

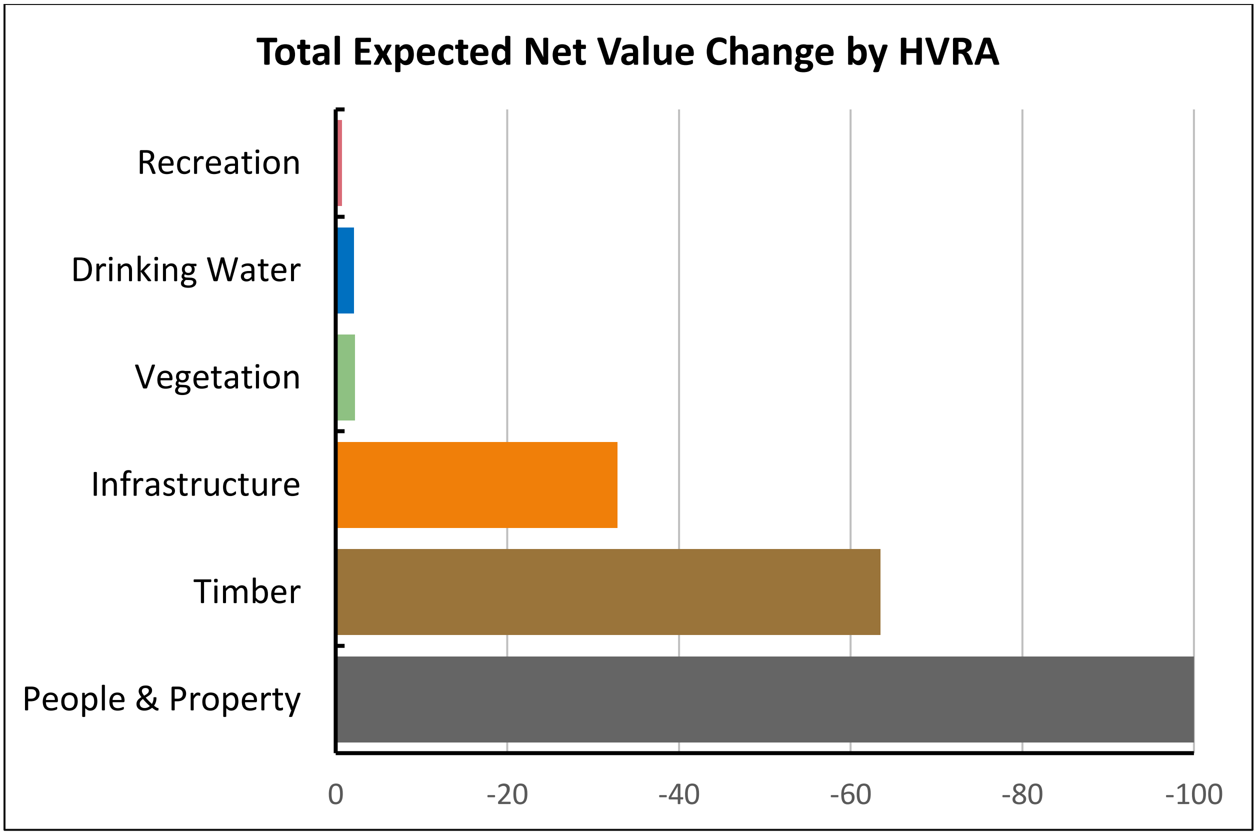

Figure 20. Weighted net response overall highly valued resources and assets (HVRAs) in the assessment. The HVRAs are listed in order of net value change and scaled to eNVC values for the People and Property HVRA.

5.1.1 CONSEQUENCE – CONDITIONAL NET VALUE CHANGE (CNVC)

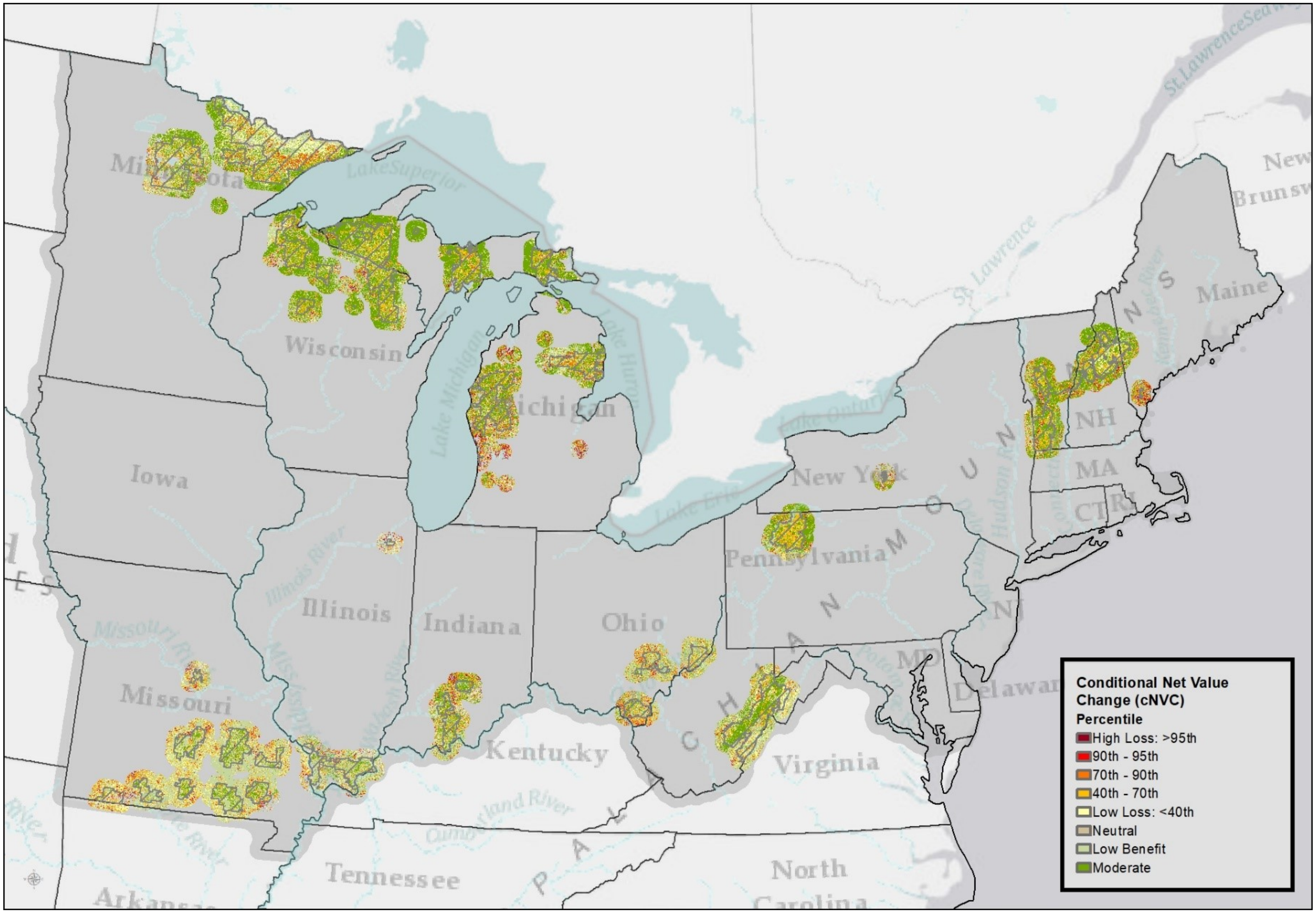

Figure 21. Map of Conditional Net Value Change (cNVC) at 30-m for the analysis area.

5.1.2 LIKELIHOOD – ANNUAL BURN PROBABILITY (BP)

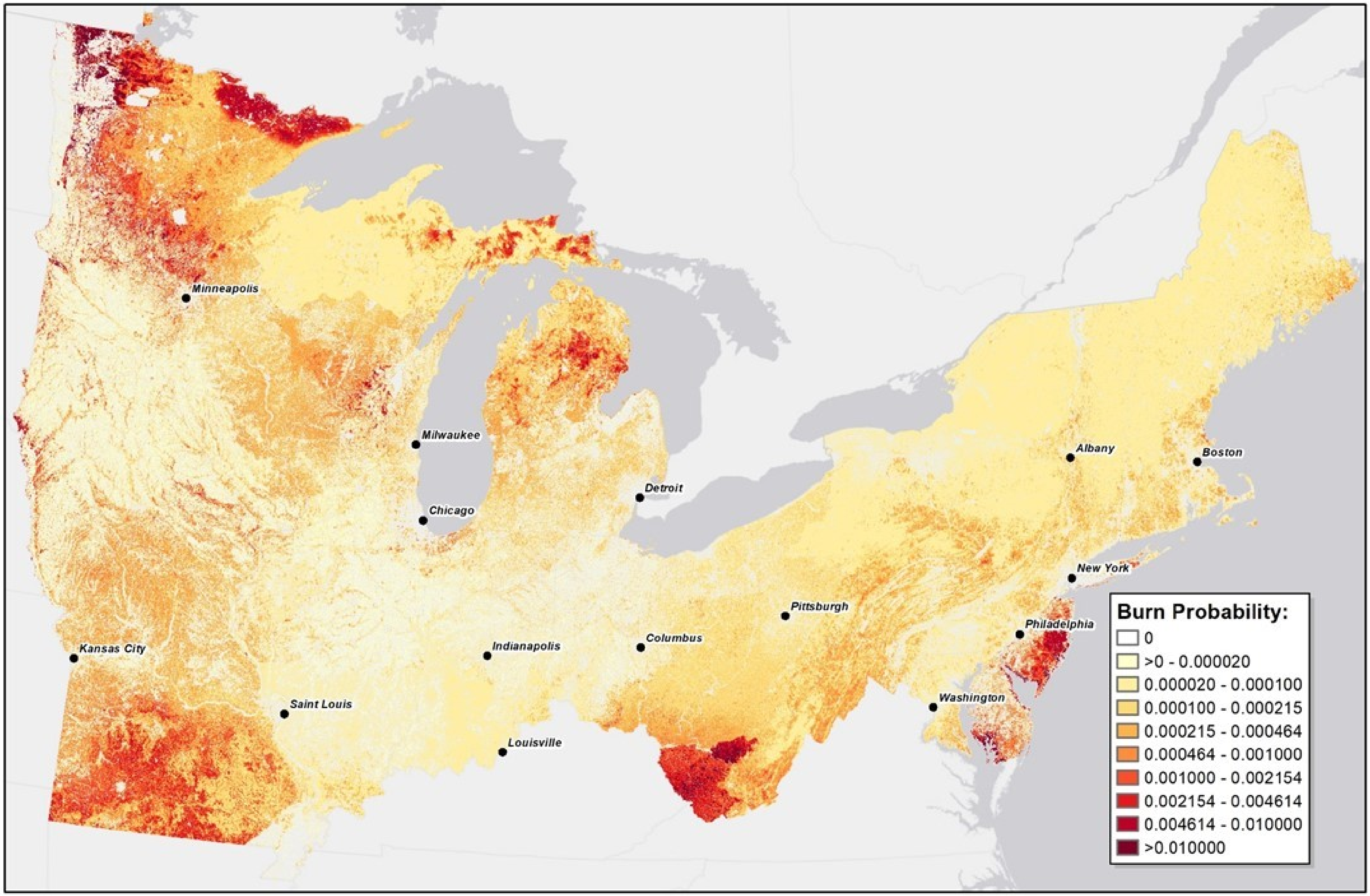

Figure 22. Map of integrated FSim burn probability results for the Eastern Region study area at 30-m resolution.

5.1.3 RISK – EXPECTED NET VALUE CHANGE (ENVC) - TOTAL

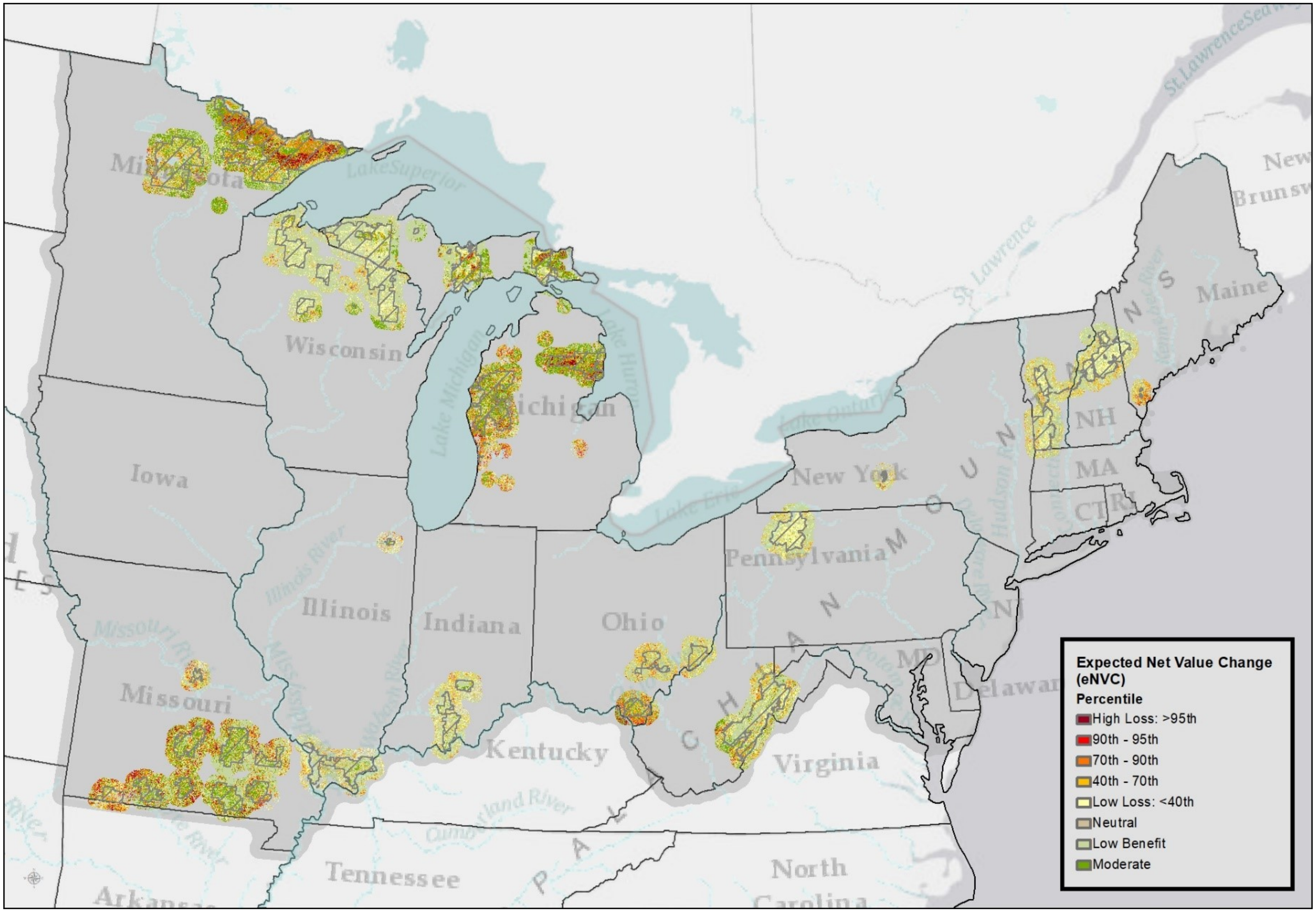

Figure 23. Map of Expected Net Value Change (eNVC) at 30-m for the analysis area.

5.1.4 WILDFIRE TRANSMISSION (RISK-SOURCE ANALYSIS)

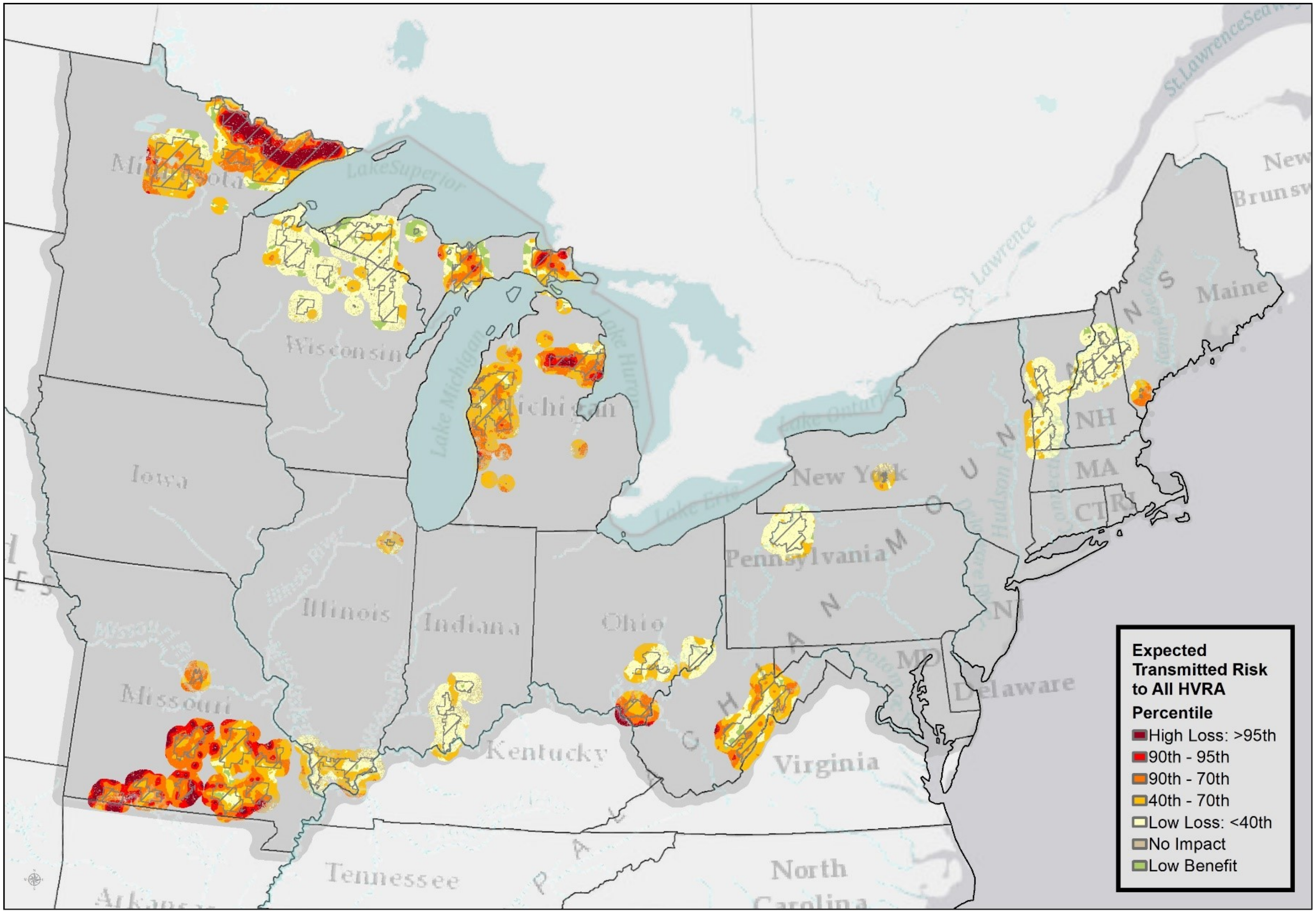

Figure 24. Map of the annual wildfire transmission risk (Expected Transmitted Risk) to all HVRA from ignitions across the landscape.

5.1.5 FOREST-LEVEL SUMMARIES

5.1.5.1 EXCEEDANCE PROBABILITY

Frequency analysis of natural hazard events involves tallying events (simulated or historical) and accumulating their magnitude or consequence to determine their likelihood of future occurrence. This approach can be used to estimate the probability of the event occurring over the time period of the analysis in a concept similar to a 100-year flood event. The recurrence interval (how often the event is likely to happen over the time interval) is based on the probability that the given event will equal or exceed a given magnitude in a single year.

For ERRA-R9 we calculated the area burned using FSim fire perimeters. For each Administrative National Forest, fire perimeters were limited to forest service boundaries, and the total acres by fire year was calculated to determine the season-level area burned. For each simulated fire season, we calculated the inverse number of iterations in the simulation. This is to account for differences in the number of simulation years across FOA boundaries. The probability is calculated by first ranking the simulated fire seasons (largest first) of the magnitude of area burned among all N events or simulations and accumulating the inverse number of iterations in each season and across all simulation years.

For the ERRA-R9, season-level area burned results were used to generate exceedance probability (EP) charts indicating the probability of exceeding a given level of area burned within an administrative unit during a single season (Table 19). These charts allow for a probabilistic exploration of potential fire outcomes. For example, 10 percent of the simulated fire seasons burned more than 25,855 acres in the Superior National Forest, but only one percent burned more than 145, 023 acres (Table 19 and Figure 25). These area burned estimates represent the 10- and 100-year fire events for the National Forest (Scott and Thompson 2015, Thompson et al. 2015). The full set of ERRA-R9 data deliverables includes a spreadsheet with an exceedance probability chart for each of the ERRA-R9, administrative units.

Table 19. Administrative National Forest Exceedance Probability, Fire Size (acres) for 10 and 100-year Events

Forest name	Abbreviation*	10-yr event (acres)	100-yr event (acres)
Allegheny National Forest	ALF	17	202
Chequamegon-Nicolet National Forest	CNF	41	651
Chippewa National Forest	CPF	1,299	4,068
Green Mountain and Finger Lakes National Forests	GMF	41	189
Hiawatha National Forest	HIF	285	10,367
Hoosier National Forest	HOF	0	12
Huron-Manistee National Forest	HMF	1,459	9,256
Midewin National Tallgrass Prarie	MPF	0	175
Mark Twain National Forest	MTF	2,587	7,115
Monongahela National Forest	MOF	554	3,635
Ottawa National Forest	OTF	41	3,255
Shawnee National Forest	SHF	150	723
Superior National Forest	SUF	25,855	145,023
Wayne National Forest	WAF	234	811
White Mountain National Forest	WMF	33	309

* USDA Forest Service National Fire Code Override

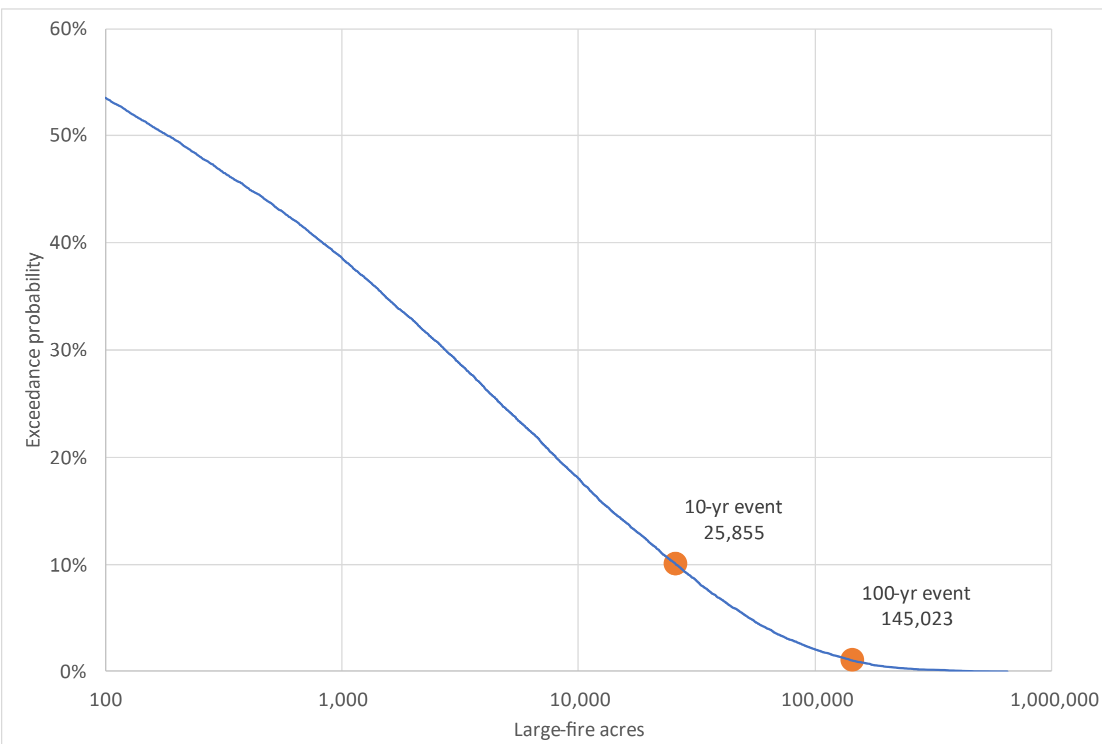

Figure 25. Exceedance Probability Curve, Superior National Forest.

5.1.5.2 TABULAR SUMMARIES FOR REGION 9 ADMINISTRATIVE BOUNDARIES

An effects analysis quantifies wildfire risk in terms of the expected value of net response (eNVC) by quantifying an HVRA's response to fire, its relative importance within the context of the assessment, and the relative likelihood of wildfire disturbance. These cumulative effects of wildfire can vary drastically across the landscape. To put these results into context, we summarized a set of Effects Analysis results using Administrative National Forest boundaries and National Forest buffered by 10 miles. A series of summary charts were developed from these results enabling comparisons across ERRA-R9, Administrative National Forests. The summary of mean wildfire risk (mean eNVC) for all HVRA by National Forest is provided in Figure 26. The figure highlights a sample of the risk attributes summarized and graphed for Eastern Region (R9), Administrative National Forest boundaries.

The total eNVC metric highlights which National Forests have the greatest cumulative risk, but because administrative unit sizes are variable, it is useful to examine risk concentration, or mean eNVC. Ranking or graphing by mean eNVC is most useful to examine which National Forests, on average, have the greatest concentration of wildfire risk. The mean eNVC by HVRA shows which HVRA are most at-risk in each administrative unit and which contribute the greatest proportion to the overall mean eNVC. Mean eNVC can help identify which units might be prioritized for potential wildfire risk mitigation efforts, but the level of funding and mitigation efforts must be informed by the total eNVC.

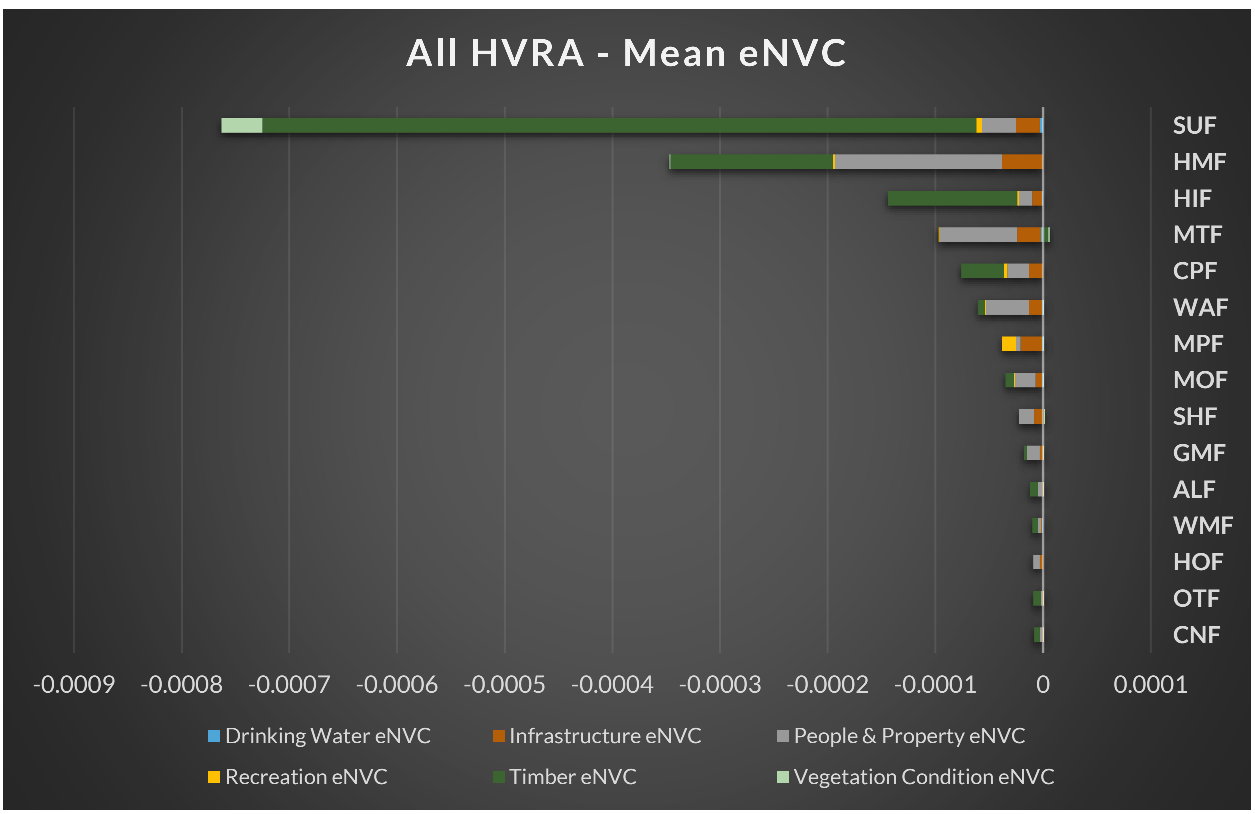

Figure 26. Mean eNVC by Administrative National Forest

The full set of ERRA-R9 data deliverables includes two spreadsheets (National Forest boundaries and National Forest boundaries including 10-mi buffer), each containing zonal summaries for cNVC and eNVC, as well as charts representing mean eNVC for all HVRA, mean eNVC for resource-only HVRA, and mean eNVC for asset-only HVRA.

6 ANALYSIS SUMMARY

The ERRA-R9 Wildfire Risk Assessment provides foundational information about wildfire hazard and risk for Eastern Region (R9). The results represent the best available science across a range of disciplines. While this report was generated by Pyrologix LLC, the overall analysis was developed as a collaborative effort with numerous agencies, across a range of disciplines. This analysis can provide great utility in a range of applications including resource planning, prioritization and implementation of prevention and mitigation activities, and wildfire incident response planning. Lastly, this analysis should be viewed as a living document. While the effort to parameterize and calibrate model inputs should remain static, the landscape file should be periodically revisited and updated to account for future forest disturbances.

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8 DATA PRODUCTS

The Eastern Region (R9) Risk Assessment required the development of a wide range of data products. The section below outlines those datasets, with a brief description, based on provided data deliverables. More detailed descriptions of data product background and development procedures can be found in the metadata of each data product.

Deliverable Folder	Data Product	Description
	HVRA Characterization	
2.1.5.1	List of HVRA	This subfolder contains an Excel file containing a list of the HVRA and their associated data source.
2.1.5.2	Table of final RFs/RIs	The subfolder contains an Excel file containing a table of response functions and relative importance values for each assessed HVRA.

Deliverable Folder	Data Product	Description
	Effects Analysis	
2.1.6.1	HVRA rasters and tabular effects	The subfolder contains five ESRI 10.7 geodatabase containing • The 30-m *HVRA rasters* used as inputs for the risk calculations: Drinking water, communication sites, natural gas pipelines, oil & gas wells, power plants, substations, railroads, transmission lines, people & property, recreation administrative sites, cultural/historic sites, trails, recreation sites, timber and vegetation condition. • *Conditional (cNVC)* & *expected (eNVC)* NVC results for all assessed HVRA, individually and in total. • ***Unweighted*** *conditional (cNVC)* & *expected (eNVC)* NVC results for all assessed HVRA, individually and in total.

2.1.6.2	Graph of NVC by HVRA	This subfolder contains an Excel file containing a graph of eNVC by HVRA (Figure 20).
2.1.6.3	Map of expected large fire NVC	This subfolder contains a PDF map (Figure 23) of expected large-fire NVC
2.1.6.4	Map of conditional large fire NVC	This subfolder contains a PDF map (Figure 21) of conditional large-fire NVC
2.1.6.5	Risk Source Analysis	This subfolder contains a 30-m risk source raster in TIFF format representing the *Expected Transmitted Risk to all HVRA*. The subfolder also contains an ESRI ArcMap 10.3 layer file for recommended symbology.

9 CHANGE LOG

The change log documents changes made to this document after the initial submission.

Date	Location of Change	Author	Description of Change
12/29/2021	-	-	Initial submission