Fireshed assessment of potential wildfire exposure to developed areas surrounding Boulder, Colorado

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Summary

This report was prepared and in response to a request from Aniela Butler, Subcommittee Staff Director, House Committee on Natural Resources, on January 10th for "any data or information about the fireshed encompassing the Boulder, CO area that just burned in the Marshall fire."

The Ager team at the Rocky Mountain Research Station responded to this request by compiling data in the Fireshed Registry relevant to the Boulder area (Ager et al. 2021b). We examined the level of predicted exposure[1] by fireshed relative to other areas in Colorado, and across the western US. We also assessed the likelihood of an extreme fire event similar to the Marshall fire in and around Boulder as predicted by simulation modeling. The assessment was based on landscape conditions and wildfire simulations prior to the Marshall fire and thus represents a retrospective assessment, i.e., we estimated the predicted level of exposure prior to the fire. However, the assessment covers a broader area to predict future exposure in areas unaffected by the Marshall fire.

Key findings include:

1. The two firesheds that were burned by the 6200-acre Marshall fire were identified in the top 10 priority firesheds in the region and in the state of Colorado as part of the 20 million acres identified for treatment in FY22.
2. Boulder, Colorado is the 41st ranked fireshed in the nation out of a total of 7,688.
3. The fire burned primarily on private lands. Public lands did not contribute to loss.
4. Available data show the area has not been targeted for fuel treatments in the recent past. The area of the Marshall fire was primarily grass fuel, so the only type of fuel treatment within the footprint of this particular fire that would have likely slowed or helped stop its progression would have been a prescribed fire sometime in 2021. Once the flaming front entered communities, it became primarily a structure fire.
5. Prior fires burned in 2000 and 2011 and combined covered 2600 acres.

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[1] *The term wildfire exposure in this report refers to the intersection of wildfire perimeters and buildings. Exposure does not measure building loss but rather the juxtaposition of fires relative to building locations. This definition is consistent with the risk science literature. On average in the western US about 15 to 20% of buildings exposed to fire are damaged or lost. However, the rate is highly variable among fire events.*

6. Fire simulation modeling suggested plausible future fire events in the area with 3-4 times the building exposure and probable loss in the Boulder area. The most extreme simulated fire could potentially expose 39,418 buildings, versus 7,700 in the Marshall fire.

We noted potential biases associated with the use of landscape fire simulation models to predict exposure to developed areas. Landscape fire models were not designed to predict building loss from structural ignitions, and the landscape fuels input data consider high density developments as non burnable areas which includes some of the developed areas destroyed in the Marshall fire. While models are used to quantify exposure, where buildings are intermixed with wildland fuels, fires can and do burn into developed areas. We illustrate these important points as part of discussing the limitations of the current analysis.

Background

The 6,200-acre Marshall Fire destroyed 1,084 homes southeast of Boulder, Colorado on December 30, 2021 (Fig. 1).[2] There were a total of 7,079 buildings within the perimeter and thus the loss rate was about 15%, a value consistent with other fires (Kramer et al. 2018). The fire perimeter was contained within two 250,000-acre firesheds, the Boulder, Colorado fireshed and the Arvada, Colorado fireshed.

Was a "Marshall fire" predicted for this area?

While the Marshall Fire was the most destructive fire in Colorado, simulation modeling predicts plausible, albeit rare, worse extreme events, under contemporary weather. For instance, simulating 10,000 fire seasons using Monte Carlo sampling of contemporary weather revealed fire events within the Arvada, Colorado fireshed could potentially expose 39,418 buildings (versus 7,079 in the Marshall fire) (Fig. 2). Thus extreme simulated events in terms of building exposure were 3-4 times worse in terms of potentially exposed buildings than the Marshall fire (Fig. 3; Table 2). Note however, limitation in the simulation modeling could lead to an overestimation of building exposure in extreme fire events.

Table 2. Historical area treated and burned within the Arvada and Boulder firesheds referenced in the report, and two additional firesheds (Loveland and Morrison) around the Marshall fire. Firesheds are listed from furthest north to south.

Fireshed	Historical treatments (acres/yr)	Historical area burned (2000-2018) (acres)	Most extreme simulated event (buildings exposed)	Percent of fireshed forested	Percent ownership by USFS
Loveland	699	105,387	20,322	41	26
Boulder	1,866	7,556	39,418	49	30
Arvada	107	1,640	39,418	35	2
Morrison	609	24,915	38,589	69	25

[2] *https://wildfiretoday.com/2022/01/07/marshall-fire-updated-damage-assessment-1084-residences-destroyed/*

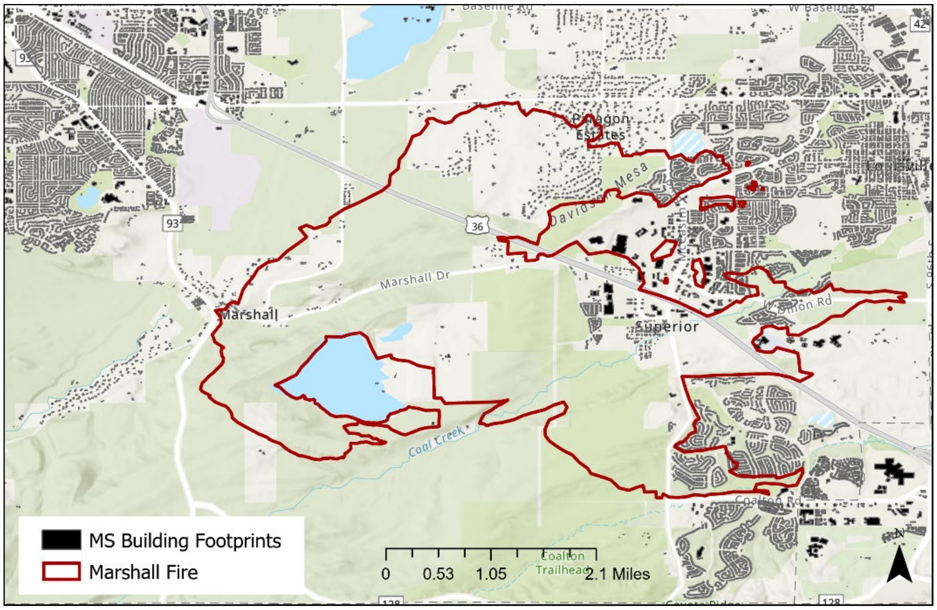

Fig. 1. The Marshall fire ignited on December 30, 2021 southeast of Boulder, Colorado burning into several housing developments. Map image shows the fire perimeter and the location of buildings as derived from the Microsoft (MS) building footprint data.

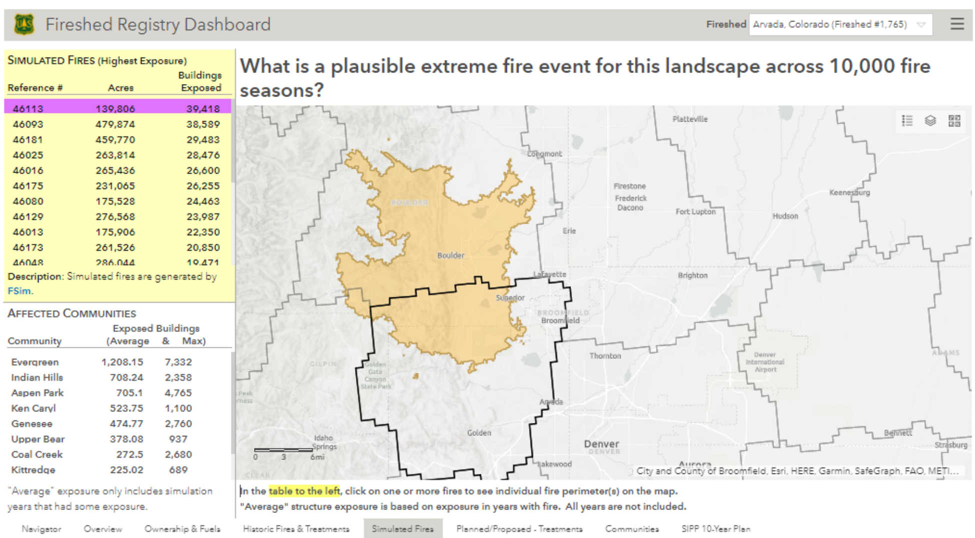

Fig. 2. The Fireshed Registry displays plausible extreme fire events for each fireshed based on wildfire simulation modeling. For the Arvada and Boulder, Colorado firesheds the most extreme simulated wildfire, shown in orange above, potentially exposed 39,418 buildings in a fire event. However, an undetermined portion of this exposure could be due to assumptions in the simulation modeling about fire growth in developed areas, hence the building exposure for this fire could be overestimated. Fireshed boundaries shown in gray, the Arvada fireshed boundary is highlighted in black.

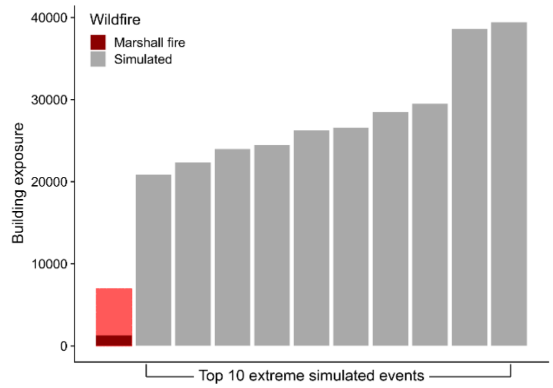

Fig. 3. Predicted building exposure for the ten most extreme simulated wildfire events in the FSim simulation library (Short et al. 2020) compared to the Marshall fire (red bar at left). Light red portion of the bar shows the number of buildings exposed to fire (i.e., within the perimeter of the fire) but not destroyed (7,079), dark red portion of the bar shows the number of buildings destroyed or damaged (1,270) in the Marshall fire.[3]

Fireshed priority ranking for the Boulder firesheds

Fireshed ranking data are being used in various hazardous fuels budget allocations in the Forest Service (USDA Forest Service 2022). Both the Boulder, Colorado fireshed and the Arvada, Colorado fireshed are identified in the top 10 priority firesheds in Region 2, and in the state of Colorado (Table 2). Boulder, Colorado is the 41st ranked fireshed in the western US out of 7,688. but ranked third in the state and region. Average annual exposure is estimated at about 39 and 27 buildings per year for the Boulder and Arvada firesheds, respectively.

Table 2. Relative ranking of the two firesheds that burned in the Marshall fire compared to national, regional, and state rankings.

Fireshed Name	Annual building exposure from all lands forest ignitions	Number of project areas	National fireshed rank	Regional fireshed rank	State fireshed rank
Boulder, Colorado	39.2	13	41	3	3
Arvada, Colorado	26.8	8	63	6	6

Schedule of fireshed treatments proposed under a 10-year accelerated plan

The study by Ager et al. (2021c) prioritized and sequenced planning areas (25,000-acre units within each fireshed) in the western US according to predicted building exposure from Forest Service land. Treatments were then simulated at the stand scale (250 acres) in each of the

[3] *Building exposure estimated with Microsoft building footprint data (Microsoft. 2018. Computer generated building footprints for the United States GitHub repository. https://github.com/Microsoft/USBuildingFootprints); building loss and damage were derived from reporting in Wildfire Today.*

planning areas to treat 80% of the predicted exposure. Since the analysis targeted specifically Forest Service lands with conifer forests, planning areas involved in the Marshall fire were not part of the plan.[4]

Forested planning areas in and around Boulder were relatively high national priorities in the plan. For instance, three planning areas were sequenced for implementation in years 2-3 in the plan, while three others were implemented in years 5-7 (Fig. 4). These planning areas were located west of Boulder where national forests occupy the majority of the land and have the potential for fires that are likely to spread to developed areas (Fig. 4).

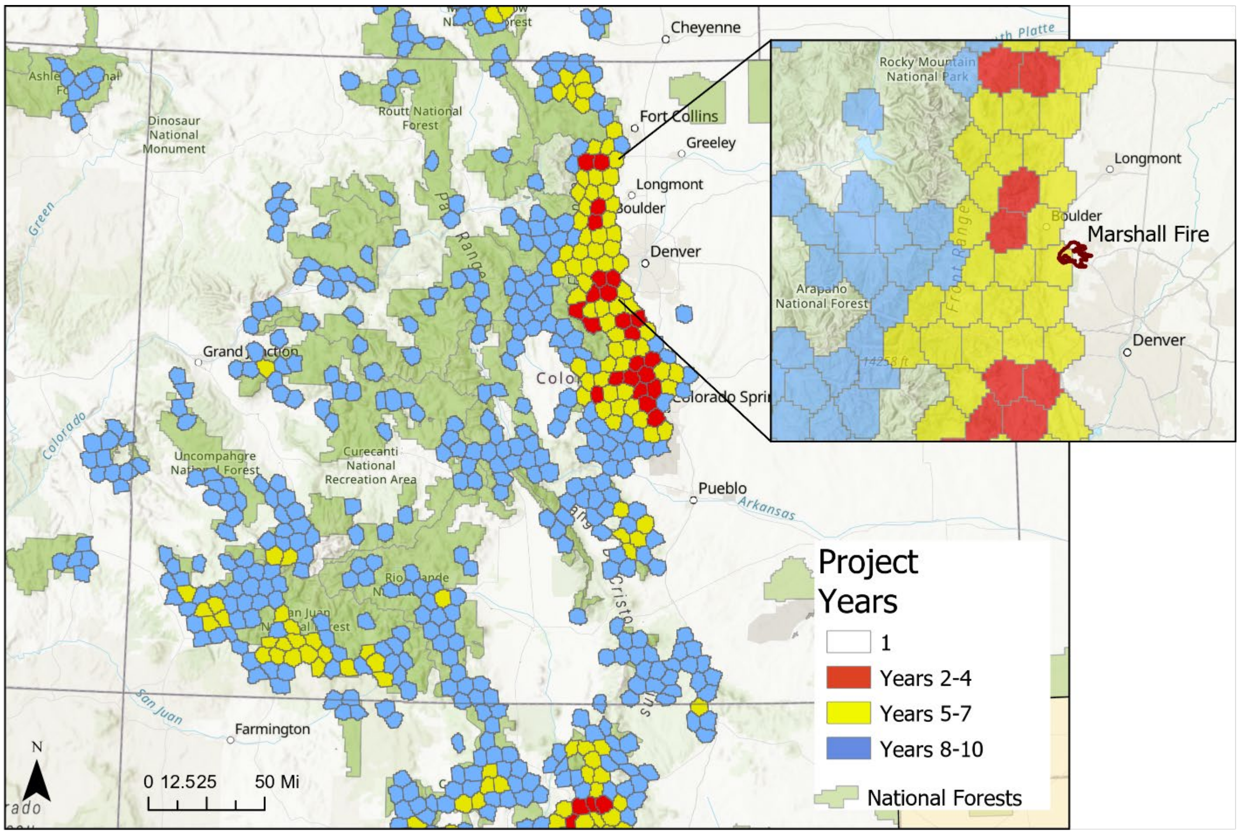

Fig. 4. Ten-year plan to reduce wildfire risk to communities in Colorado with projects symbolized by treatment year, with highest priority projects implemented in year 2 and year 1 reserved for planning (USDA Forest Service 2022). Polygons represent 25,000-acre planning units embedded within 250,000-acre firesheds. Note that entire project areas are symbolized rather than the individual stands treated. Areas in the western edge of the project area were identified for treatment in non-Forest Service, conifer stands that exposed communities in simulation modeling.

[4] *The all-lands version of the plan is not published; these data are presented at the fireshed scale in USDA Forest Service (2022).*

Limitations of the study and results

1. Landscape fire models do not have the data or underlying models to predict building ignition and loss. A major cause of house loss in the high density developed areas in the Marshall fire was structure to structure ignitions. The models and data used in landscape wildfire simulations are not designed to model building ignition and fire spread by structure to structure ignitions. Landscape fire models will spread fire into developed areas when there are wildland fuels intermixed with buildings but buildings themselves are considered non burnable. Specifically simulated fires stop at urban boundaries when more than half of the fuels are classified as non-burnable (i.e., development) (Figs. 5-6). Simulated perimeters did not penetrate dense wildland urban interface subdivisions (example in Fig. 6) in and around the Marshall fire although they did spread into developed areas where buildings were at lower densities, and the result is that wildfire simulations can underestimate total building exposure.
2. The conclusion that there are potentially more extreme wildfire events with higher potential building loss than in the Marshall fire was based on very rare events in the simulation (1 in 10,000 years events) where wildfires permeate urban boundaries, facilitated by ember showers and spotting (which is included in the model) exposing portions of communities that do not have burnable wildland fuels. Research on the Camp Fire which destroyed the town of Paradise, California showed how gradients of building and fuel density independently contribute to building exposure (Ager et al. 2021a, Knapp et al. 2021). Building exposure is maximized where thresholds of wildland fuel and building density are sufficient to spread fire into areas that have wildland fuels and substantial building density. Where wildland fuel density is low and building density is high, wildfire simulations predict lower levels of building exposure (Fig. 7). Much of the building loss in the Marshall fire occurred where wildland fuel density was low, and building density was high.
3. The weather used in the wildfire simulations represent contemporary conditions from about 1990 to 2010. Thus, if extreme weather events, like the wind gusts during the Marshall fire (100 mph), were included in the simulation, substantially more destructive fires would be observed in the simulation library.

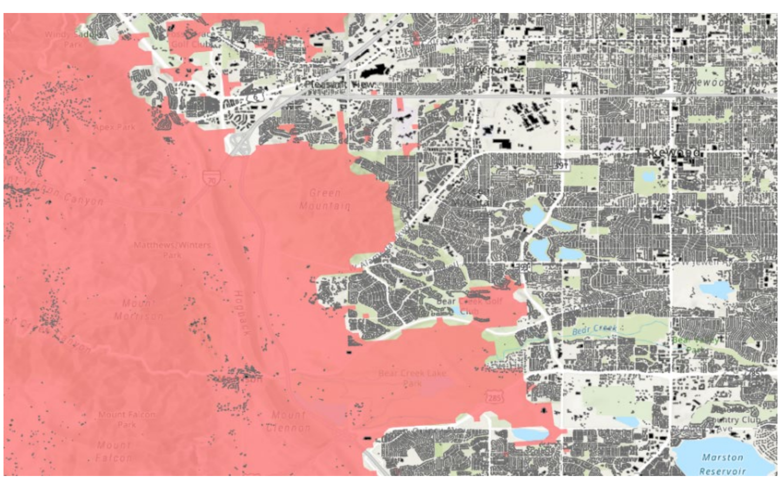

Fig. 5. In an area south of the Marshall fire and west of Lakewood, Colorado, thousands of simulated wildfire perimeters (pale pink) stop at the urban boundary.

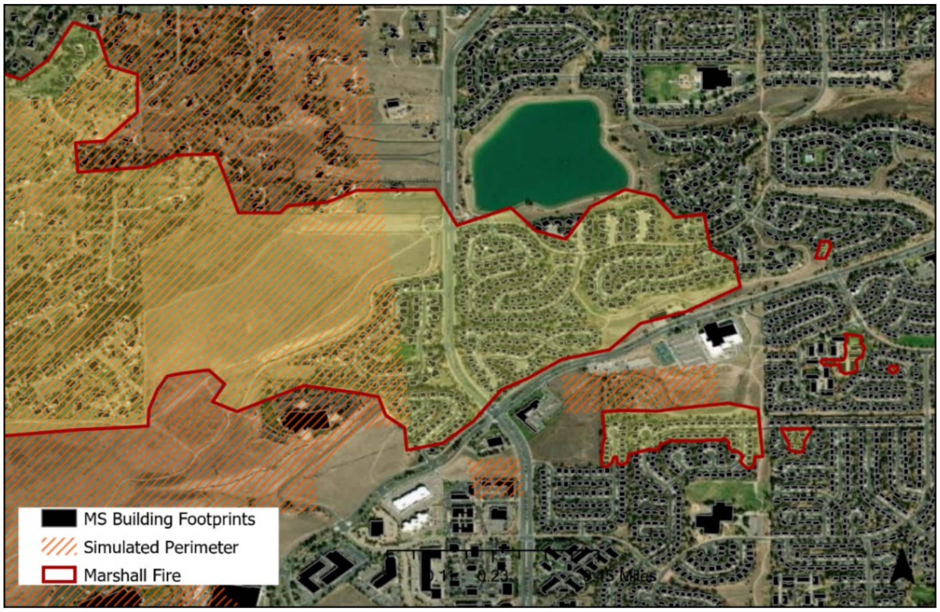

Fig. 6. An example simulated wildfire that does <u>not</u> penetrate a dense subdivision that was burned by the Marshall fire. In simulations wildfires did not burn east of McCaslin Blvd (north/south road in the map) with the exception of small spot fires. Note the Marshall fire boundary is bright red and simulated perimeters are hatched orange.

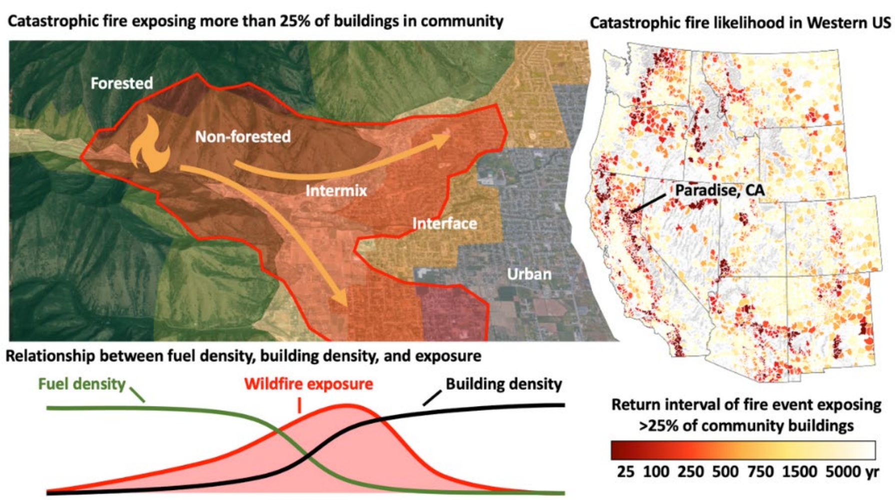

Fig. 7. Relationship between total wildfire exposure and the counter-gradients in building density and fuel density around developed areas. Combinations of the two maximize building exposure, a relationship that is obscured using discrete wildland urban interface (WUI) classes typically used to study building exposure and loss. In the case of the Marshall fire, fuel density was low and building density was high, especially on the eastern edge of the fire perimeter. Figure from Ager et al. (2021a).

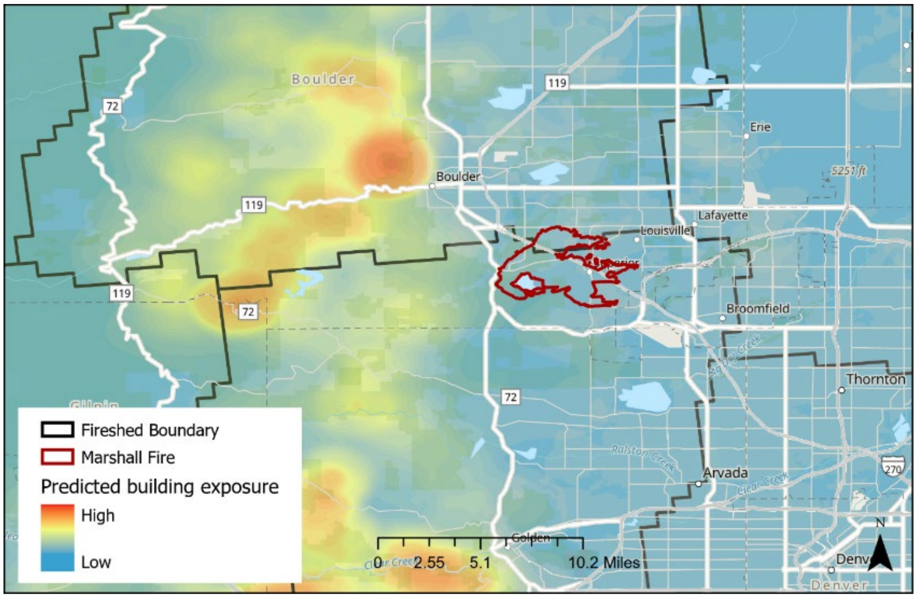

Fig. 8. Smoothed map of locations where wildfires ignite and expose buildings in adjacent wildland urban interface areas near Boulder, Colorado based on tens of thousands of wildfire season simulations (Bunzel et al. 2022). Predicted exposure within the Marshall fire is low but not zero.

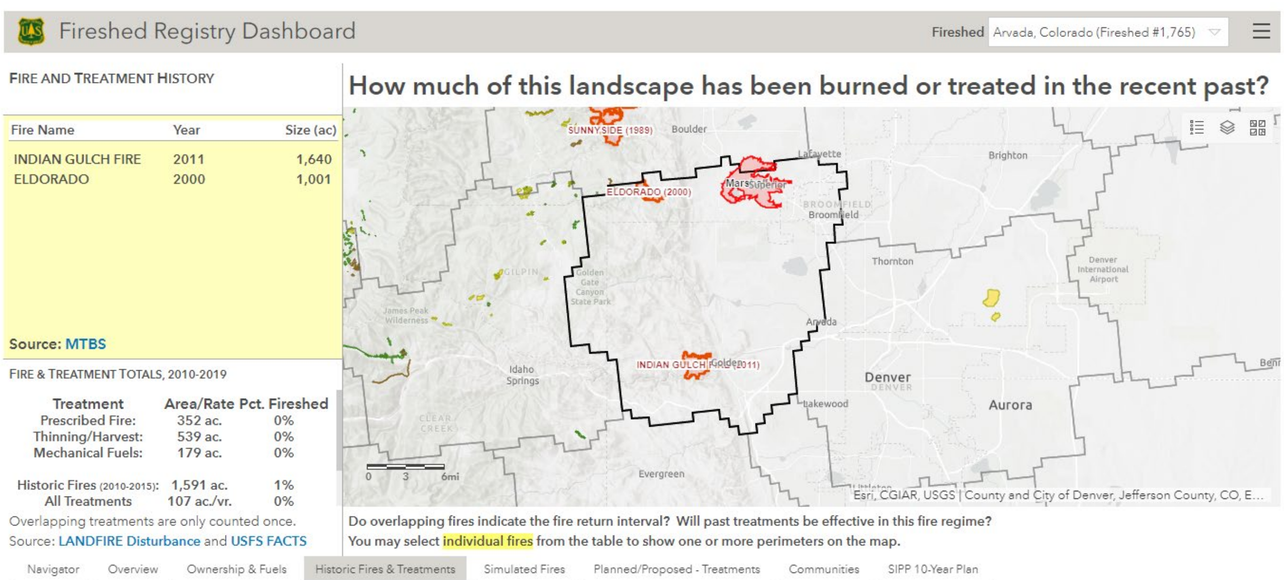

Fig. 9. Fireshed Registry data showing historic fire and location of treatments. Note the Marshall fire does not show up in the table data.

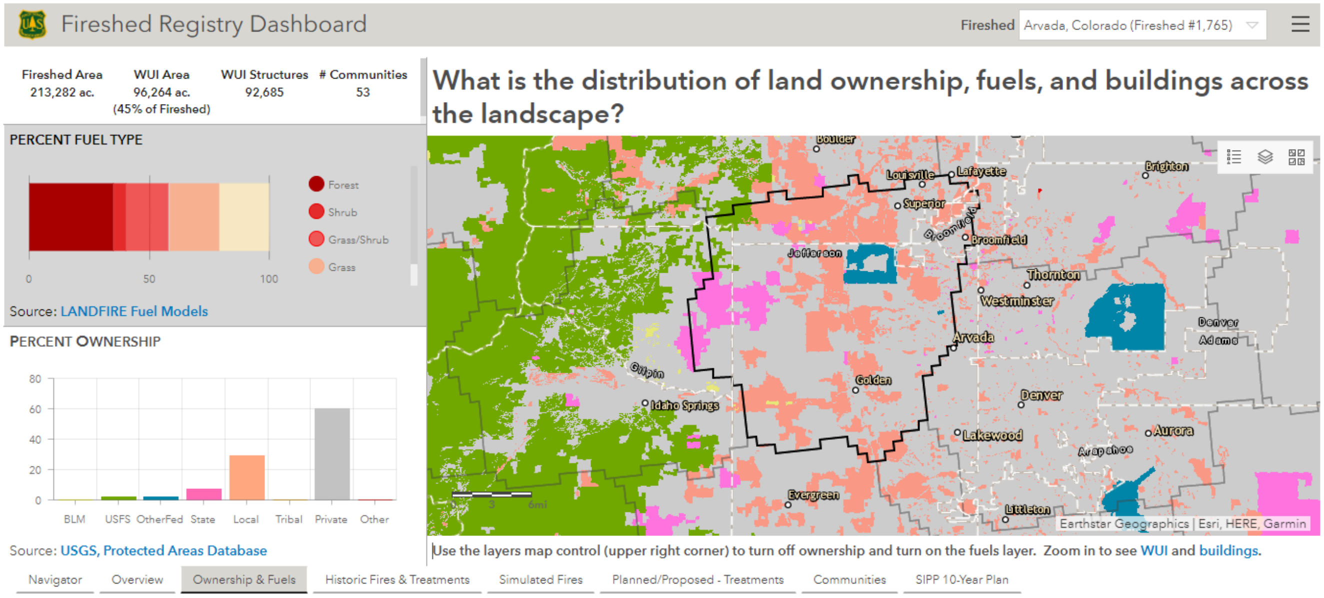

Fig. 10. Image from the Fireshed Registry showing land ownership in the Arvada, Colorado fireshed.

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