Southern Rockies Reforestation Tool

SRRT

A Decision Support Tool to Inform Postfire Reforestation of Ponderosa Pine and Douglas-fir in the Southern Rocky Mountains

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Abstract: Recent increases in area burned, combined with poor natural regeneration in some areas, have promoted concerns about widespread forest losses throughout the western U.S. Postfire reforestation is one strategy commonly employed by land managers and land owners to facilitate forest recovery, but the area in need of planting only becomes larger each year. The Southern Rockies Reforestation Tool (SRRT) is a simple web-mapping tool that was developed to help prioritize sites for postfire reforestation. This tool can be used to develop maps of fire severity and seedling suitability for ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*), two abundant conifer species in the Southern Rocky Mountains. The seedling suitability map identifies areas that are (1) distant from live seed sources, but (2) have high topoclimatic suitability for the species of interest. In combination, these factors may help to locate sites where natural regeneration is unlikely to occur quickly, but relatively cool and wet conditions may enhance planting success. Finally, these maps can be restricted based on operational constraints such as slope angle or distance to road, and exported for use in external GIS software.

Cover photo: 2016 photo of an area near Wetmore, CO affected by the 2005 Mason Gulch Fire. Photo courtesy of Kyle Rodman, Northern Arizona University.

**Corrigendum:** Page 4: The URL to the SRRT was updated in July 2023.

Contents

High-severity wildfire activity in ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) forests of the Southern Rocky Mountains has increased since the 1980s, and future projections suggest additional increases in area burned over upcoming decades (Coop et al. 2022; Kitzberger et al. 2017; Parks and Abatzoglou 2020; Singleton et al. 2019). In the interior of large, treeless, high-severity wildfire patches, where seed sources are distant, natural tree regeneration is often insufficient to reestablish forests on management-relevant timescales (Chambers et al. 2016; Rodman et al. 2020a,b; Rother and Veblen 2016). Wildfire-driven forest loss can threaten important ecosystem services such as carbon storage, wildlife habitat, recreational and employment opportunities, and water supply, making it an important management issue (Coop et al. 2020).

Tree planting is a common postfire management activity that may help to offset forest loss due to high-severity wildfire (Stevens et al. 2021). However, the backlog of areas in the Southern Rocky Mountains that require planting is formidable, and only gets larger each year (Cook-Patton et al. 2020; Fargione et al. 2021; Kolb et al. 2019). Figure 1 provides a rough illustration of this point. According to the USDA Forest Service Activity Tracking System (FACTS) database, annual postfire reforestation rates in burned forests have been relatively constant over the last 37 years, with approximately 24,000 hectares (60,000 acres) planted in total on National Forest System lands in the Southern Rocky Mountains. In comparison, about 390,000 hectares (960,000 acres) burned at high severity on national forest lands during this same time period. While some of this high-severity area may naturally reforest (for example, because ponderosa pine or Douglas-fir seed sources are in close proximity), for much of it, forest reestablishment will likely require tree planting. Because tree planting requires a considerable investment of time and money—seeds must be collected and grown into 1- or 2-year-old seedlings, planting sites must be identified and prepared, and finally, seedlings must be planted—efficiently tackling the backlog will require a detailed understanding of how to best allocate resources (Fargione et al. 2021; Kolb et al. 2019).
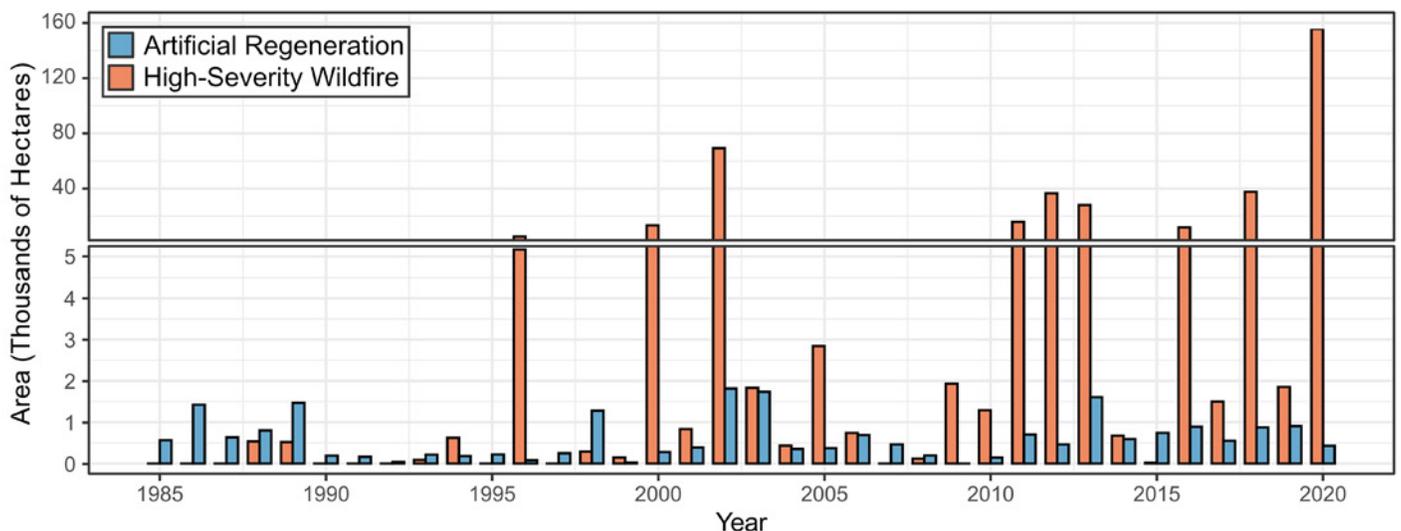
Figure 1—Trends in high-severity burned area and reforestation area on lands in the National Forest System in the southern Rocky Mountains, USA (Colorado, New Mexico, and Wyoming), 1985–2020. High-severity burned area is within fire perimeters in the region larger than 1,000 acres (405 hectares), and defined as 30-meter Landsat pixels with relative differenced Normalized Burn Ratio values >544 (Chapman et al. 2020) using the composite image methodology of Parks et al. (2018). Postfire reforestation (artificial regeneration) area was calculated from reforestation projects listed in the Forest Service's FACTS database for this region within known fire perimeters, including tree planting and seeding. Reforestation area was limited to national forest lands, so high-severity area was also restricted to these lands for a proper comparison. Figure from Stevens et al. (2021).
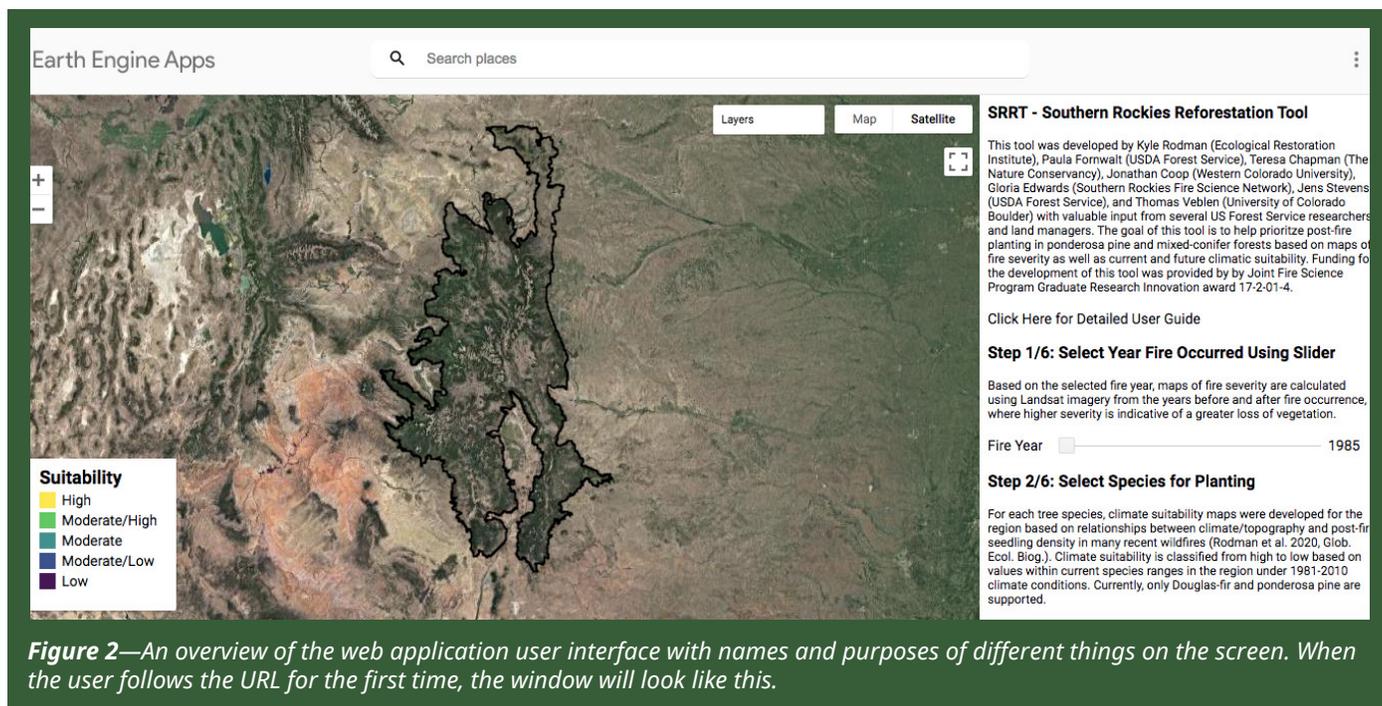
Climate and topography are two key constraints on natural postfire regeneration of ponderosa pine and Douglas-fir in the Southern Rocky Mountains, so these factors are also likely to influence the survival of planted seedlings and the success of postfire planting projects. A simple tool that uses best available science to identify topoclimatically suitable sites could help managers optimize the success of planting efforts. To that end, we have developed the Southern Rockies Reforestation Tool (SRRT), which can be accessed at https://kylerodman-eri.users.earthengine.app/view/srrt. This document describes how SRRT works and how to use it. We hope that this tool will help managers plan for large-scale, climate-suitable reforestation of ponderosa pine and Douglas-fir.

How SRRT Works

The Southern Rockies Reforestation Tool uses fire severity, tree establishment, and gridded climatic and topographic data to classify locations from most to least favorable for post-fire reforestation. By using climate and terrain as proxies for soil moisture, this broad-scale planning tool may increase seedling survival post-planting by identifying locations with lower drought stress. SRRT was developed using Google Earth Engine, a cloud-based computing platform that is designed to efficiently perform calculations using spatial datasets across large areas. The tool requires only a small number of simple user-specified inputs, such as the area of interest, the species to be planted, and the year the area was burned. In the background, the tool obtains and processes prefire and postfire satellite images for the area of interest, and uses these images to identify severely burned areas more than 200 feet (60 meters) from seed trees. Based on statistical models developed in Rodman et al. (2020a), a synthesis of natural postfire regeneration in more than 1,300 plots throughout the Southern Rocky Mountains, climate and topography data are used to predict the locations that are most suitable for planted ponderosa pine or Douglas-fir seedlings following fire. As the user, you have the option to restrict the fire severity and seedling suitability layers to places adjacent to roads and flatter slopes, where postfire planting may be most cost-effective and feasible. After fire severity and seedling suitability layers have been developed, you can explore them using the Map Window by zooming and panning. There are also options to download the layers for use in geographic information systems (GIS) software such as ArcGIS and QGIS. Currently, all suitability maps are restricted to historical species ranges, but maps that include upslope areas (to help in planning assisted migration activities) will be developed in the future.

How to Use the Tool

When you are using SRRT, we suggest that you use Google Chrome as an internet browser. This allows for full functionality. When the tool is first opened, you will see a screen that looks similar to figure 2. The left side of the screen shows the Map Window, which has several options embedded in it that allow you to adjust the visibility of individual layers, alter basemap types, and zoom in or out. The right side of the screen shows the Tool Window, which has six simple steps that you must complete to create layers of fire severity and seedling suitability.

Figure 2—An overview of the web application user interface with names and purposes of different things on the screen. When the user follows the URL for the first time, the window will look like this.

In **Step 1**, **select the year of fire occurrence using the slider** (fig. 3). Using Landsat imagery from the growing seasons before and after the fire year, a fire severity layer is calculated based on the relative differenced Normalized Burn Ratio (RdNBR; Miller and Thode 2007). This method is an improvement upon traditional fire severity mapping efforts – by using multiple Landsat scenes from years immediately before and after the fire, clouds, shadows, and irregularities in individual scenes can be easily corrected (Parks et al. 2018).

Figure 3—An example of selecting the fire year for an area that burned in 2002, in Step 1 in the Tool Window.

The seedling suitability layers will be visible only in areas with RdNBR values exceeding 582, a value we developed by comparing Google Earth Engine-based fire severity maps with the data layers of Chapman et al. (2020) in a Classification and Regression Tree (CART) model. It is important to note that this RdNBR threshold assumes that the prefire condition was unburned. Therefore, this tool may not be appropriate to use in reburned areas, particularly if the initial fire burned with high severity. Seedling suitability maps will also be restricted to locations more than 200 feet (60 meters) from low-severity burned and unburned areas, a distance threshold beyond which early natural regeneration of these species is less likely (Chambers et al. 2016), and where planting may be more valuable.

In **Step 2**, **select a target planting species from the drop-down list** (fig. 4). Currently, ponderosa pine and Douglas-fir are the only species supported, but additional species may be added as field data become available to support map development.

In **Step 3**, **select a climate period to be used in developing maps of suitability for the target species**. Suitability under the current climate is based on climate averages from 1981–2010, while the two projected future options are based on moderate or extreme carbon dioxide (CO_2) emissions scenarios for the 2031–2060 period, corresponding to moderate or extreme increases in air temperature. These future emissions scenarios allow you to explore whether a given planting site is likely to remain suitable for the target species under changing climate conditions in upcoming decades. Topography is held constant in projections of suitability across the three different climate scenarios.

Step 2/6: Select Species for Planting

For each tree species, climate suitability maps were developed for the region based on relationships between climate/topography and post-fire seedling density in many recent wildfires (Rodman et al. 2020, Glob. Ecol. Biog.). Climate suitability is classified from high to low based on values within current species ranges in the region under 1981-2010 climate conditions. Currently, only Douglas-fir and ponderosa pine are supported.

Ponderosa Pine ⬍

Step 3/6: Determine Whether Suitability Should be Based On Current Or Future Climate

Changing the climate period modifies climate suitability maps based on observed or projected climatic conditions. If desired, this option can be used to identify areas that are more likely to remain suitable for a species in the future.

Current Climate (1981-2010) ⬍

Figure 4—An example of selecting a target species and climate period when developing maps of species habitat suitability in Steps 2 and 3 in the Tool Window. Here, ponderosa pine is selected, and the habitat map will be based on average climate conditions from 1981–2010, rather than projected future climate conditions.

In **Step 4, you may adjust sliders to limit potential planting sites based on the slope angle and distance to established roads** (fig. 5). If you want to create maps for the entire area of interest, you can leave "Mask Sites?" unchecked and ignore the sliders. If you check the "Mask Sites?" box, the slope angle is calculated for all locations within the area of interest, and areas steeper than the selected slope are excluded. Similarly, the distance to roads is calculated using all road locations in the U.S. Census Bureau's TIGER database, and areas farther than the selected distance are excluded. Note that many smaller roads on public land (e.g., USDA Forest Service secondary roads) are not in this database.

Step 4/6: Should Planting Sites Be Filtered to Remove Steep Areas and Those Far From Roads?

Checking the box next to "Mask Sites?" uses values of Distance to Road and Maximum Slope Angle to restrict potential planting sites based on these criteria, while leaving box unchecked ignores these criteria. If box is checked, sites further than Maximum Distance From Road and slopes greater than Maximum Slope Angle are excluded from planting consideration.

☑ Mask Sites?

Maximum Distance From Road (ft):   1500

Maximum Slope Angle (degrees):   20

Figure 5—*An example of selecting filters to limit potential planting sites to be considered when developing maps of species habitat suitability in Step 4 in the Tool Window. In this example, the user has checked the box next to "Mask Sites?", set the maximum road distance slider to 1500 feet and the maximum slope angle slider to 20 degrees, meaning that the map will remove any places farther than 1500 feet from a road and with a slope steeper than 20 degrees.*

In **Step 5**, **identify the area of interest and run the tool** (figs. 6–8). The area of interest can be identified by clicking on either the "Rectangle" or "Polygon" buttons (fig. 6) and delineating an area in the Map Window that surrounds the entire fire perimeter (fig. 7). ***The entirety of a fire perimeter must be selected for accurate fire severity estimates***. Changing the basemap in the Map Window to the "Satellite" option can be helpful for this as the burn area is likely to contrast with the surrounding area. Once the shape has been drawn, the tool will initialize and run within the selected area. This can take a couple of minutes in a large selection area. If the gray progress bars do not appear as in figure 8 (i.e., the "Layers" box is a single white rectangle without any gray progress bars), then the tool has failed to run. Make sure that all settings in Steps 1–3 have been selected in the tool window (the tool will fail to run if they have not been), and redraw the shape over the area of interest in Step 5.


Step 5/6: After Setting Options Above, Draw Boundary Around Burn Area to Run Tool

Use either the rectangle or polygon drawing options below to trace the perimeter of the fire. ENSURE THAT THE ENTIRE FIRE PERIMETER IS WITHIN THE SELECTED AREA - this ensures accurate fire severity calculations. Climate suitability can only be calculated within the regional boundary (i.e., black polygon). NOTE: The tool may take a minute or two to run - gray bars on top-right indicate that things are running. If the tool does not produce any layers on the map, make sure that all options above have been selected prior to drawing the fire boundary and that the area selected is less than ~1 million acres.
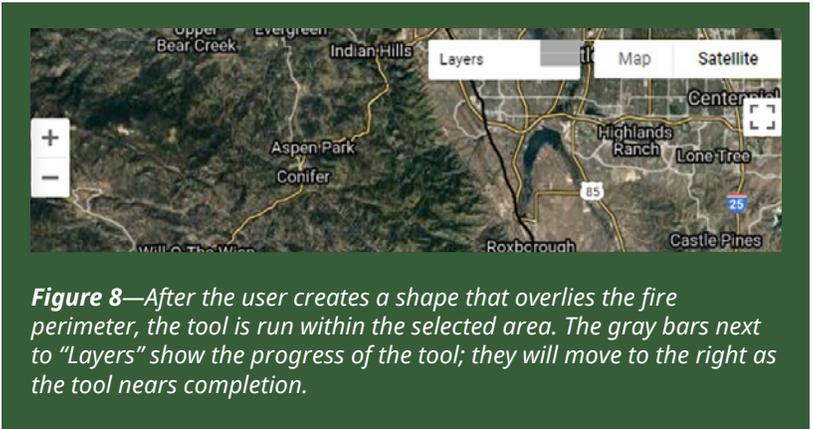
■ Rectangle   ▲ Polygon

*Figure 6*—*Choose the "Rectangle" or "Polygon" button to trace the fire perimeter.*
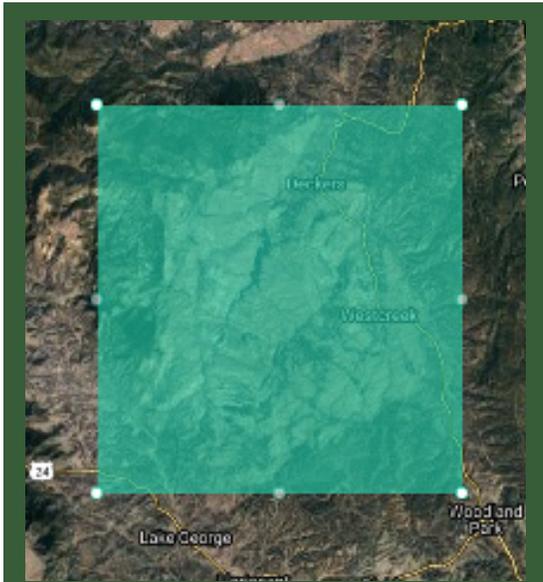
Figure 7—An example of selecting a burned area in the Map Window using the "Rectangle" option in Step 5.


Figure 8—After the user creates a shape that overlies the fire perimeter, the tool is run within the selected area. The gray bars next to "Layers" show the progress of the tool; they will move to the right as the tool nears completion.

After the tool has finished running, the created layers will appear in the Map Window. These maps should look similar to those in figure 9. After the layers have been loaded into the Map Window, you can zoom in and out using the Zoom Tool (+/- buttons) in the Map Window, alter layer visibility and transparency in the Layers Settings box (fig. 10), alter the basemap by clicking "Map" or "Satellite", and pan to different locations in the map using the cursor. Note that the layers recalculate each time the map is panned or zoomed, which can occasionally lead to lags, particularly with slower internet connections. High/low suitability is relative to all locations within a species' existing range under 1981–2010 climate conditions, assuming that these are indicative of a species' climatic tolerance. The values of habitat suitability are simplified into categories of 1–5 by splitting climate suitability values for each species into five, equal-width (i.e., 20%) bins. Thus, low suitability (i.e., 1) sites are within a species' historical range but are comparable to the warmest, driest sites that a species could tolerate, while high suitability (i.e., 5) sites are relatively cool and wet in comparison to the species' historical distribution. When re-running the tool, it can sometimes be useful to remove the past layers from the Map Window. This can be achieved by hovering the cursor over the "Layers" area (shown in figure 10), and unchecking specific layers, thereby making them invisible.

Suitability
- High
- Moderate/High
- Moderate
- Moderate/Low
- Low
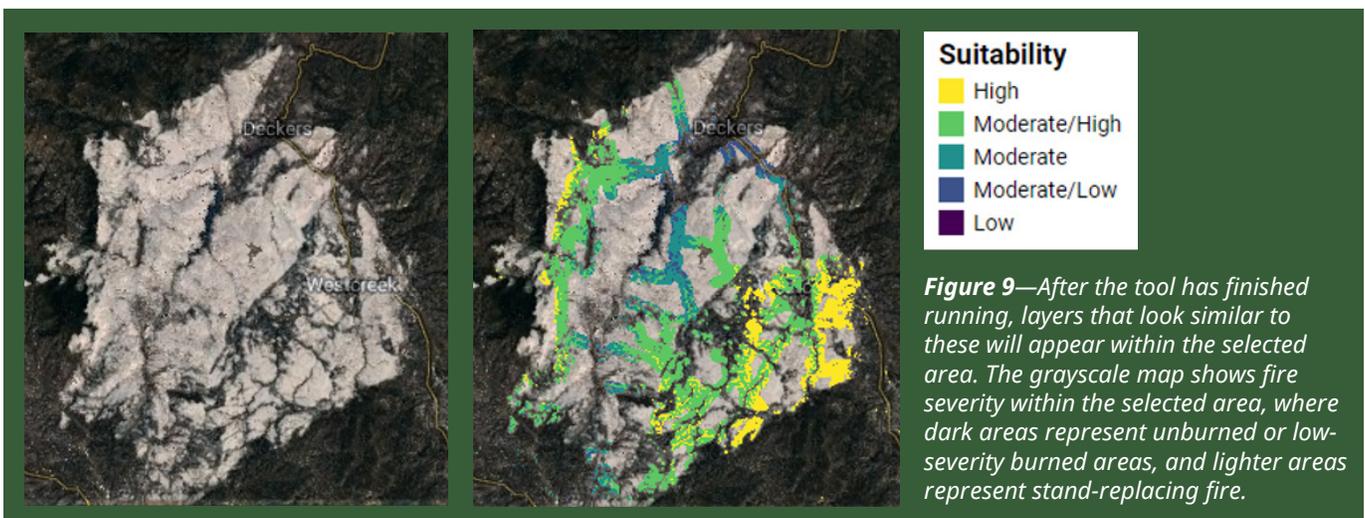
Figure 9—After the tool has finished running, layers that look similar to these will appear within the selected area. The grayscale map shows fire severity within the selected area, where dark areas represent unburned or low-severity burned areas, and lighter areas represent stand-replacing fire.
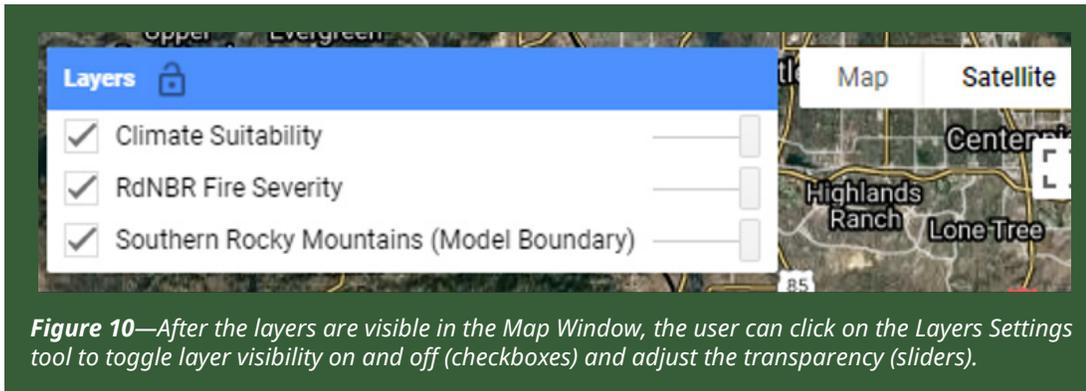
Figure 10—*After the layers are visible in the Map Window, the user can click on the Layers Settings tool to toggle layer visibility on and off (checkboxes) and adjust the transparency (sliders).*

If you would like to download the data for use outside of the web application, you can do so using the options in **Step 6** in the Tool Window (fig. 11). This can allow for quicker rendering and visualization of the maps, and close-in viewing of particular areas of interest. In addition, you may want to compare these maps with the locations of known planting areas, local road maps, or other ancillary data to identify places that have high suitability, have yet to be planted, and are easily accessible from a known road or trail.

To download the layers, you must first run the tool and have the data layers visible in the Map Window. After doing this, click either the "Get Climate Suitability Map" or "Get Fire Severity Map" button, depending on the layer of interest (fig. 11). After you click the button, blue text with a download link ("Click This Link to Download"; fig. 12) should appear below the download buttons. Once you click this link, a new tab will appear in the browser, indicating the download has initialized (fig. 13). It can take a couple of minutes for Google Earth Engine to perform the calculations and organize the data for export.
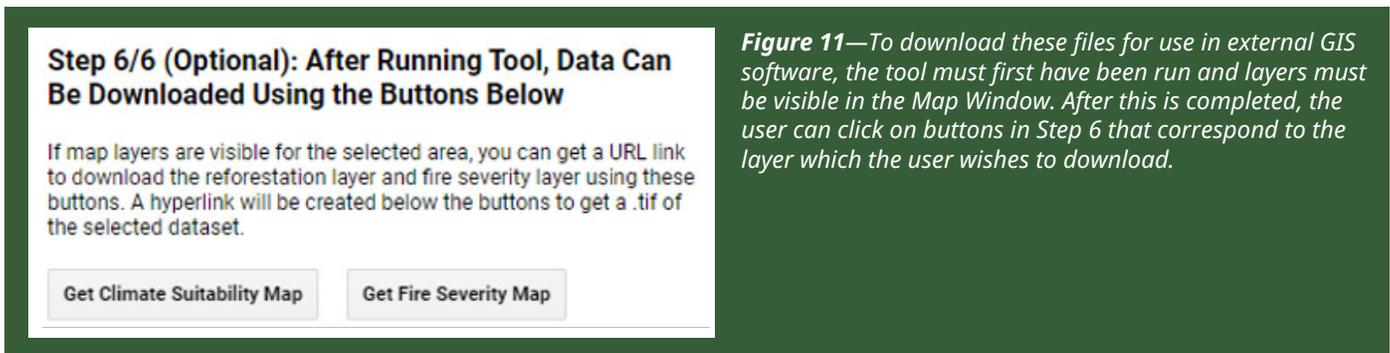
Figure 11—*To download these files for use in external GIS software, the tool must first have been run and layers must be visible in the Map Window. After this is completed, the user can click on buttons in Step 6 that correspond to the layer which the user wishes to download.*
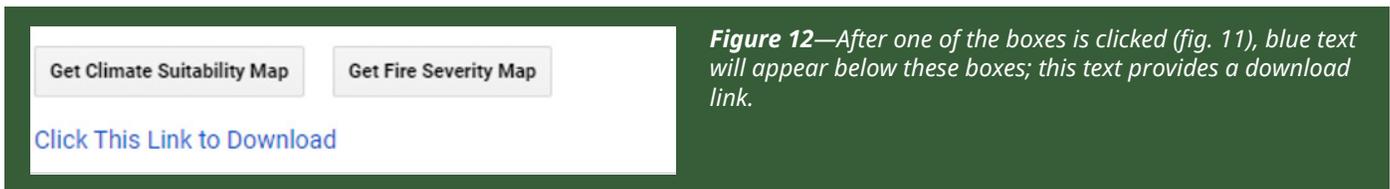

Figure 12—*After one of the boxes is clicked (fig. 11), blue text will appear below these boxes; this text provides a download link.*
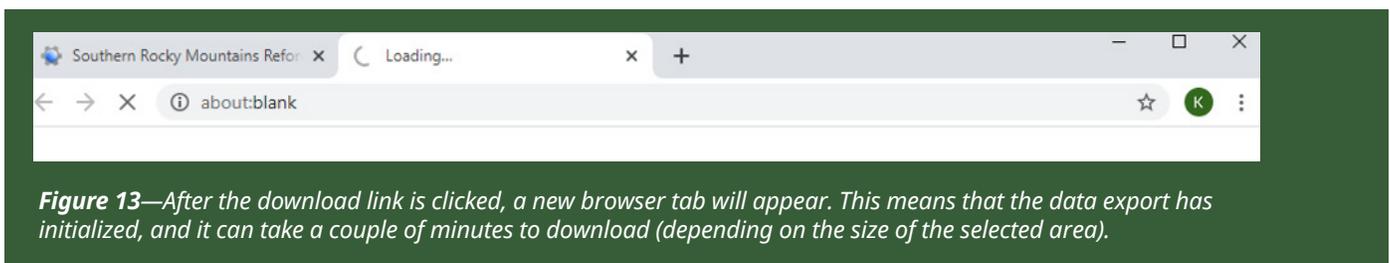
Figure 13—*After the download link is clicked, a new browser tab will appear. This means that the data export has initialized, and it can take a couple of minutes to download (depending on the size of the selected area).*

Once the download has completed, an output ".zip" file will appear in your default download folder. This can be extracted to any location on the computer (it will be a GeoTiff file in EPSG:4326, also called WGS84/Lat-Long). The extracted raster layer can then be opened in any standard GIS software (fig. 14).
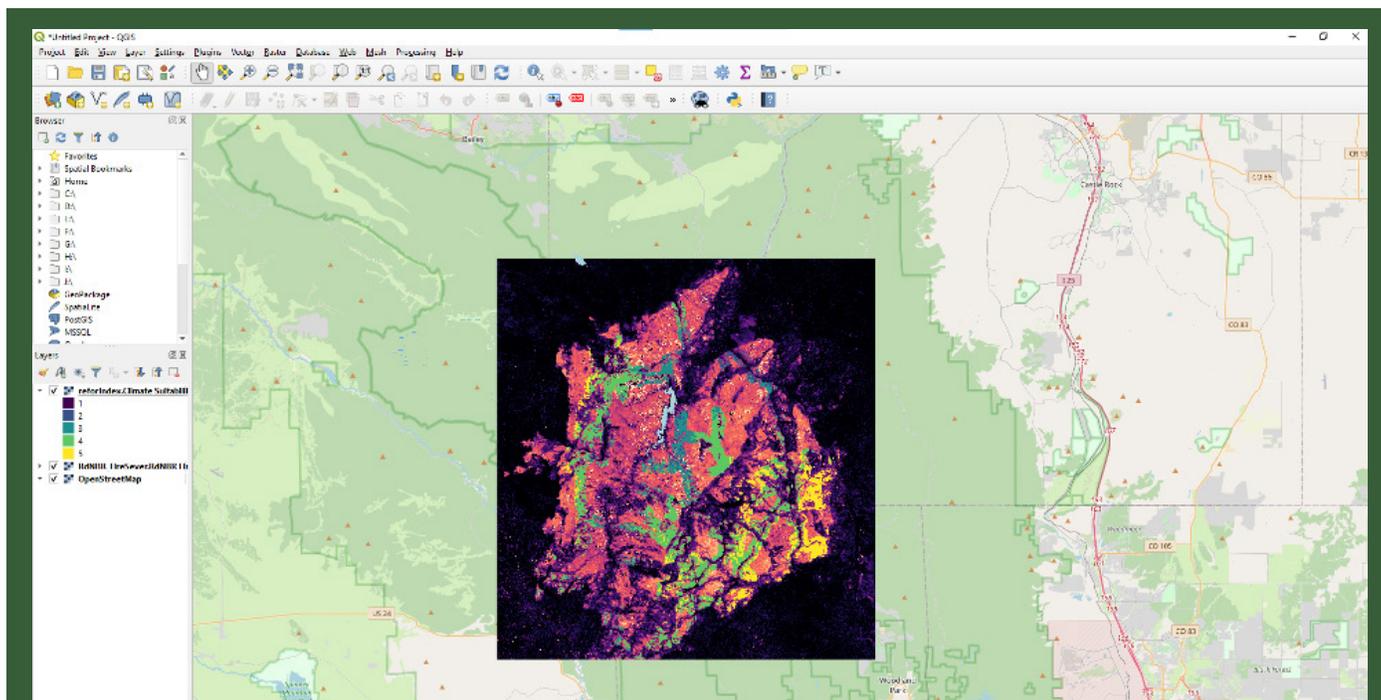
Figure 14—After the layers calculated by the web application are downloaded, these layers can be opened using standard GIS software (e.g., ArcGIS, QGIS) for additional use in project planning and comparisons with local road maps and prior planting locations.

Conclusion

Postfire activities, including reforestation, are an important component of forest management in Southern Rocky Mountains ponderosa pine and Douglas-fir forests and will become increasingly important in upcoming years. Simple decision support tools that use best available science, such as SRRT, will be key to ensuring that these activities are conducted in a manner that optimizes success. We encourage users to reach out to us with any questions or any input about how this tool can be improved or incorporated into local management plans.

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2021 photo of an area near Woodland Park, CO, that was burned by the Hayman Fire in 2002 and planted a few years later. USDA Forest Service photo by Paula Fornwalt.