Santa Barbara
Botanic Garden

CDFW Prop 1 – Grant Agreement P1896038

Final Progress Report Narrative

Mapping, Assessment and Planning for Recovery and Resiliency in
Fire-Damaged Watershed in the Thomas Fire and Whittier Fire Recovery Zones

Executive Summary of Value of Citizen Engagement

Habitat restoration and the management of invasive species are important strategies for conserving biodiversity, but receive a small portion of the overall conservation budget and must prioritize actions effectively to best use limited funds. This project applied a new approach for combining the data-gathering potential of community science (i.e. citizen science) with decision science to help managers prioritize habitat restoration locations and projects. Our approach combines the benefits of field observations with GIS and remote sensing data to create a more complete model of conditions on the ground.

In this case study, we focused on the question of where restoration should be prioritized on US Forest Service land within the Thomas and Whittier fire scars in Southern California. We recruited and trained 97 community scientists who gathered field observations for the locations of invasive plant species, rare plant species, trail damage, erosion, and landscape monitoring stations. These volunteers surveyed 84 miles of trail over two field seasons. Our professional scientists gathered the same data for 257 miles of trail, 50 of which overlapped with the community scientists.

We combined collected field observations with data from other data sources and regional geographic data in a "tree-based" multicriteria decision analysis known as the Environmental Evaluation Modeling System (EEMS). We developed a model using three branches: invasive species presence, geomorphology and erosion risk, and natural species regeneration capacity. We used the Weed Heuristics: Invasive Population Prioritization for Eradication Tool (WHIPPET) framework as a starting point for the invasive species branch of our logic model, and the Postfire Restoration Priority (PReP) tool in our regeneration branch. We evaluated and honed the resulting EEMS with local experts and end-users, and provided it online for use by decision-makers and further evaluation by the scientific community.

We found that volunteer scientists were generally successful at finding populations of large, showy invasive species, but were less thorough when mapping large, continuous patches of weeds. The data collected by volunteer scientists supplemented and complemented the data collected by professional surveyors, and we feel strongly that future post-fire surveying efforts would benefit from the collection of data by volunteer scientists.

Finally, we found that volunteers donated at least $140/net mile surveyed in their time, while the cost of staff surveying came to be approximately $120/net mile surveyed, not including the prep or planning time for either group. Furthermore, for a total time contribution of $11,987 from volunteers, staff time required to train and verify data cost approximately $11,832, for a 100% return on investment. Thus, we feel strongly that training volunteers to collect invasive species location data using iNaturalist is an effective way to complement other forms of data gathering when large but accessible areas need to be surveyed.

Background

In the Western United States, wildfires are becoming increasingly large because of climate change, regional drought, and decades of fire suppression that in many places has yielded an abundance of fire fuels (Higuera and Abatzoglou 2021). High intensity wildfires can burn the crowns of trees and shrubs and they can also scorch the soil, leading to severe and sometimes fatal mudslides during the following rainy season. For example, the Montecito debris flow of 2018 was the result of high precipitation following the Thomas Fire. Additionally, fires are often followed by opportunistic colonization and expansion of invasive plants that are detrimental to the native ecosystem, which can result in further alteration of the fire cycle (D'Antonio and Vitousek, 1992). The spread of invasive species negatively affects biodiversity and ecosystem services worldwide, and is the second most frequent threat causing native species extinctions since the year 1500 (Gentili et al. 2021).

Land managers often seek to combat the interrelated threats of the post-wildfire landscape, namely the arrival of invasive species and rampant erosion, through ecological habitat restoration. Habitat restoration can include a range of activities, including the physical removal of newly arriving invasive species, protecting natural native plant recruitment, and the seeding and planting of native plants. Trails and roads are often hotspots of erosion and are common vectors for the spread of invasive species (Trombulak & Frissell 2000), so trail and road restoration is a key subset of habitat restoration.

Funding for restoration efforts is typically limited, and the scale of the overall problem is immense and rapidly growing, suggesting an urgent need for a framework to prioritize sites for restoration. However, prioritizing locations for successful restoration work is challenging, because site-specific GIS data are often missing or incomplete. Furthermore, information about post-fire soil erosion, where invasive species are located and spreading, and the ability of the landscape to regenerate is limited. In addition, the need to meet multiple objectives and make decisions often requires weighing each of these criteria in a spatial model.

There are two promising ways to cut costs to allow the scaling up of treatment: (1) better leverage the passion of volunteers willing to help the cause, and (2) the use of advanced geographic information science. The first goal of this research is to analyze and evaluate the relative costs and benefits of asking volunteer “community scientists” to fill data gaps. This goal is embodied by the question “are volunteers able to effectively collect post-fire data”? The second goal is to create and evaluate a novel and transferrable system architecture for integrating spatial data layers, models and tools into an online App that will support decision-making about restoration actions.

We used a case study approach, with the driving applied goal of determining where to prioritize restoration on US Forest Service land within the Thomas and Whittier fire scars in southern California.

The goals of this project were twofold:

1. To conduct post-fire assessments of the erosion, plant invasion, and restoration needs in the Thomas and Whittier Fire scar landscapes
2. To assess the value of volunteer data collection as a supplement or alternative for professional assessment data collection

Project Methods

Project Scope and Area

In order to build an accurate model for areas in need of post-fire restoration, we used data collected from the ground, as well as wall-to-wall spatial data. The data was collected by both SBBG staff and volunteers recruited and trained for the program. We collected data for two fire scars located in Santa Barbara and Ventura Counties, California. The Whittier Fire burned from July 7th to July 28th, 2017, covering a total of 18,430 acres. The Thomas Fire began in December 2017, and burned until January 2018, spanning a total of 281,893 acres in Santa Barbara and Ventura counties. The Thomas Fire was the largest fire on record in the state of California at the time of containment but has since been surpassed numerous times.

Spatial Decision-making Support System

This project's Spatial Decision-making Support System (SDSS) consists of several key spatial data layers to help land managers make informed decisions about where to conduct post-fire restoration work (Figure 1). Our SDSS is hosted on DataBasin.org, an online spatial data viewing and analysis platform designed to allow users to explore and interact with complex data layers easily (Bachelet et al. 2010). These data layers include the collected project data, the results of the Environmental Evaluation Modeling System for potential restoration locations, and information about site access, roads, and trails.

The core of our SDSS architecture is the Environmental Evaluation Modeling System (EEMS): a platform-independent, flexible, and transparent logic modeling framework for spatial decision support (Bachelet et al. 2010; Sheehan & Gough 2016). An EEMS is a tree-based, logic modeling system, in which data from different sources and numerical domains can be combined to answer various questions. This includes topics such as current and future potential habitat value, ecological/development conflict, and landscape vulnerability to climate change. For this project, EEMS modeling was used to determine the areas in the study region that are most in need of post-fire restoration efforts (Figure 2).

System Architecture and EEMS Construction

To use EEMS, a user builds a tree-based logic model in which the leaf nodes represent the initial data inputs. A foundation of EEMS modeling is the input reporting units. The reporting unit feature class is typically a vector-based grid that represents the summarization and aggregation of all the input data used in the model for individual subregion units on the landscape. The most important decision in generating the reporting units is deciding the size and shape of the feature's geometry. We use 180 m by 180 m square grid cells spanning the extent of the study area. Every input dataset is summarized to each reporting unit, such as the mean value of the input data for the reporting unit. The dataset is then normalized so that all values fit within a predefined numerical range (we use a range of 0 to 1).

Input data in each of these reporting units are then combined, using operators and weights according to the logic model developed for the EEMS. These input data will then yield a map to answer a high-level management question about the landscape (i.e., where are areas most in need of restoration efforts?). Our EEMS uses three branches to help land managers identify key areas on the landscape where restoration is needed. There is the invasive species management branch, the erosion management branch, and the regenerative capacity branch.

Invasive Species Management Priority Branch

Our first branch is concerned with populations of invasive species. In this branch, historical and project-collected data were used to generate population polygons for the invasive species of interest to the project. Project data included all observations made by staff and volunteers, which were recorded with population, % cover, and area information. Other data included in the population modeling component were recent CCH2 records, CalFlora records, and non-project iNaturalist data. Because these data were not associated with population size, % cover, or area data, we supplied them with the mean values for each species generated by the project data. These points were then transformed into polygons using the population size, percent cover, and area data.

We drew heavily on the California Invasive Plant Council's Weed Heuristics: Invasive Population Prioritization and Eradication Tool (WHIPPET), to inform the structure of the invasive species management priority branch (Skurka Darin et al. 2011). For each invasive species population, the value of restoration (removal) was calculated in the model as a function of the impact, the invasiveness, and the management feasibility of the population. These values were then combined across a single species and across all species.

The Impact branch value for each invasive species population was based on the value of the underlying landscape of the population (Figure 3). The data informing this value include the Santa Barbara Conservation Blueprint of Flora and Fauna, known locations of rare species, and CDFW high-value areas. The value of the landscape was then combined with the location of the population to determine the potential impact of that population.

The Invasiveness Threat branch for each invasive species population was calculated using the distance to dispersal vectors (mines, roads, and rivers; higher value for those nearer to vectors), the distance to other populations of the same species (higher values for those far from other populations), and the Cal-IPC value for the inherent ability of the plant to spread rapidly (Figure 4).

Finally, the management feasibility branch of the invasive plant management value branch uses information about the size of the infestation, accessibility of the population, and effectiveness of control methods to generate a value for the feasibility of removing each population (Figure 5). Accessibility was calculated using Tobler's hiking function, which converts slope and walking speed into a travel time based on hiking, and modified this to reflect that on-trail hiking is easier than off-trail travel.

These three sub-branches are then combined for all invasive species populations across an EEMS grid cell to generate a value for the overall invasive management priority of the grid cell.

Erosion Management Priority Branch

For the erosion management branch, we combined field observation data with wall-to-wall GIS datasets to represent actual and potential post-fire erosion (Figure 6, Figure 7). The field data collected by staff and volunteers included observations of actual and potential erosion and observations of trail damage. The landscape-level datasets included information about erosion risk, derived from soil burn severity information, landslide susceptibility, shake potential, and slope.

Regenerative Capacity Branch

For the regenerative capacity branch, we incorporated model outputs from the Post-fire Restoration Prioritization (PReP) tool (Underwood et al. 2021). This tool uses vegetation type information, recent drought and fire history, and competition with annual plants to generate a map of the high, medium, and low regeneration areas within a regional landscape.

EEMS model data sources

Data for the SDSS and EEMS models comes from many sources. In the table of EEMS branches data, we provide links to data sources and information about the branch of the model in which they were used.

Data collection and processing

We collected observation data for invasive species occurrences, areas experiencing erosion, trail damage, and weedy patches using two smartphone apps. For specific species observations, we used the iNaturalist app, while landscape observations (erosion, trail damage, and weedy patches) were collected in the *AnecData.org* app.

Species data (iNaturalist)

Species-level data for both focal invasive and rare plants were collected in iNaturalist. Volunteers collected data for the species they signed up to survey, though in many cases they also collected data for non-focal species through misidentification of a non-focal plant as a focal species, or interest in a non-focal species. In addition to the location data and a photo of the plant, the species-level data included three fields: number of plants, the area covered, and percent cover of the plants. For each field, several bins of values were available (eg. 1-20 plants, 21-100 plants, etc.). Plant species observations were then verified by staff and other local experts on iNaturalist. When photos were not of sufficiently high quality or did not show the necessary structure to make an ID, observations were identified to the finest possible taxonomic level (eg. “*Asteraceae*” or “*Malacothrix*”). We only included research-grade iNaturalist data in the SDSS.

iNaturalist data were processed before being used in the model. Data that were collected with low spatial accuracy (>250 ft) were removed from the dataset, as well as data with missing attributes, or those data points collected during the training activities.

Landscape data (AnecData.org)

Landscape observations of erosion, trail damage, and weedy patches were collected in the AnecData.org. Like the iNaturalist observations, these data points were collected with location data, a photo, and several fields informing the area and severity of the issue identified.

Volunteer training and data

We advertised for volunteers through our existing volunteer network (local colleges, restoration groups, etc.). Additionally, we partnered with REI to advertise our training activities, widening our potential audience to include individuals not familiar with the garden. In 2020, our volunteer training was interrupted by the COVID-19 pandemic. In our initial signups, which occurred before the pandemic, we had approximately 200 volunteers register. Of these volunteers, 130 attended in-person classroom and field training sessions prior to March 2020. Due to the pandemic, we canceled the last two field training sessions. In 2021, we again advertised training through our network and REI.

Volunteer training covered an introduction to fire ecology and local ecosystems, a lesson on why the model was useful, how to collect data, and a brief overview of twelve focal weeds and where to find additional plant ID resources. Volunteers were also given two booklets with information on how to use the data collection apps and a guide to the species they would search for. During signup, participants chose how many species they wanted to search for, and self-identified their botanical skill level on a 4-point scale (Table 2).

Participants also chose how many species they wanted to search for: 12 invasive species (“group 1 species”), 24 invasive species (“group 2 species”), or 24 invasive species and rare species (Table 3). Staff searched for 47 invasive species, as well as the 50 rare taxa.

We asked participants to always record invasive species from their list, and encouraged them to record species they did not know, thought might be invasive, or just wanted to learn about.

We estimated the time volunteers spent on the project by calculating the time between the timestamps of the first and last observations they submitted to iNaturalist per day for the project, and added 20 minutes to this value to reflect hiking time before and after the first and last observations were made. In cases where a volunteer uploaded only one observation, we assumed they spent at least 20 minutes hiking for the project to gather that observation. Thus, we are underestimating the amount of time volunteers spent.

Comparison of staff and volunteer data

To examine the quality of the data collected by staff and volunteers, we isolated data from 50 miles of trail that had been hiked by both staff and volunteers. Volunteers were not made aware that staff would also hike their trails, or which trails would be compared. We then generated population polygons from these point data, and compared the polygons created from volunteer and staff data.

Comparison of staff and volunteer costs

We estimated the time volunteers spent in the field by calculating the time between the timestamps of the first and last observations they submitted to iNaturalist per day for the project, and adding 20 minutes to this time to reflect estimated time before and at the end of the hike during which they did not collect data. In cases where a volunteer uploaded only one observation, we assumed they spent at least 20 minutes hiking for the project to gather that observation. The time spent attending trainings was estimated at 4 hours per volunteer that attended in 2020, and 2 hours per volunteer in 2021. All estimates have a large margin of error, and are designed to be underestimates rather than overestimates. The volunteer in-kind contribution was estimated using the federal rate of $28.54 per hour. Staff used time tracking and invoice data to estimate the time spent on materials prep and volunteer training. We multiplied the hours spent on these tasks by the burdened rate of staff time.

Project Outcomes

Survey areas and data collected

Staff and volunteers surveyed a net 287 miles of trails, roads, and other paths out of a goal of 300 miles of roads and trails (Figure 8). Staff surveyed a net 250 miles and gross 281 miles, while volunteers surveyed a net of 62 miles. Because volunteers did not track their time or mileage, we are unable to report the gross miles that volunteers surveyed. Staff spent a total of roughly 880 hours to survey those gross 281 miles. We were unable to survey several key trails and roads due to inaccessibility or closure post-fire. These are shown on the map below, and more detail is provided in the section titled “Project Challenges”.

Staff and volunteers collected a total of over 5,000 plant observations for the project, of which just over 2,320 were research-grade observations of focal plant species.

Volunteer identity and retention

We had 58 volunteers conduct survey hikes in 2020, and 50 volunteers conduct hikes in 2021, for a total of 97 unique volunteers (11 volunteers collected data in both years). A total of 58 volunteers collected and contributed data in 2020, for a retention rate of 44.6% of fully trained volunteers. A total of 83 individuals attended online trainings in 2021, of which 50 collected data for a retention rate of 60%.

Volunteers had a range of plant ID experience based on self-reported skill level - from no experience to high experience (Figure 9). The majority of our volunteers had at least some experience identifying plants. There was no statistical difference in the ID experience of those who collected data vs. those who did not contribute to the project after attending training (chi-square test, $p = 0.778$; Figure 9). Volunteers who self-identified as having higher botanical ID skills also were more likely to select to look for a greater number of species (Figure 10).

Comparison of staff and volunteer data

We found that volunteers are effective data collectors for many common, easily seen, and readily identified species, but that they struggled with uncommon or challenging species. Furthermore, we found that staff data often generated larger polygons than volunteer data, though volunteers did identify several species not recorded by staff. Overall, volunteers appeared capable of collecting data to identify the locations of some noxious invasive species, though they appear to be less thorough than professional botanists when surveying through large, continuous populations of species.

Eight staff routes and 64 project volunteers hiked 50 miles of comparison routes, which amounts to 17% of the total project mileage and 60% of the volunteer mileage. In total, these two groups collected 145 and 233 observations of focal invasive species, respectively. After processing these observations into polygons, we tallied the number of populations and total area of each species by who collected the data (staff or volunteers).

To determine if volunteers were finding as many populations as staff, we did an overlay analysis of populations and used a chi-square test to compare the number of populations found by each observer group. We first pooled all populations, and then recorded whether the population was discovered by both staff and volunteers, by staff only, or by volunteers only. We then used a chi-square test to determine whether there was a significant difference in the number of populations found by staff and volunteers. For both group 1 and group 2 species, there was no significant difference in the number of populations found by staff and volunteers in the overlay analysis (Table 4, $p = 0.79$ for group 1 and $p = 0.12$ for group 2).

However, though it appears that staff and volunteer data produced the same total number of populations, these populations were not always overlapping, and we found some key differences in the sizes of populations generated by staff and volunteers (Table 5). Staff observations resulted in larger areas of *Arundo donax*, *Foeniculum vulgare*, *Centaurea melitensis*, *Centaurea solstitialis*, *Genista monspessulana*, and *Vinca major*. For the *Centuarea* and *Arundo* species, we hypothesize that this is because these species can be difficult to identify, and and not always immediately obvious on the landscape. Similarly, the staff observations of *Genista* occurred at a time when the plant was not flowering - a challenge for volunteers to ID, as they often rely on the showy flowers to notice and identify plants. However, volunteer data resulted in much larger areas than staff data for several species: *Nicotiana glauca*, *Ricinus communis*, and *Spartium junceum*. Each of these species is large, and generally very slowly with colorful foliage and/or flowers.

Comparison of staff and volunteer costs

Staff (N = 8) surveyed a net total of 257 miles of trails and roads over 880 total man-hours, or 440 hours per person on paired trips. Thus, the total cost of staff survey time was approximately $31,000 at a burdened rate, not including the time it took to scout, prepare routes, or interface with landowners about access. Thus, the staff rate for surveying was approximately $120 per net mile.

Volunteers contributed an estimated 420 hours of time in training and surveying, not including the time taken to drive to trailheads or training locations. Volunteers surveyed a net of 84 miles, of which 34 miles were surveyed only by volunteers. This amounts to an in-kind (time) contribution worth $11,986.80 from volunteers. Using these numbers, volunteers donated approximately $140 of their time per net mile surveyed. Additionally, staff time spent an estimated 300 hours advertising trainings, preparing materials for trainings, administering the trainings, and answering email queries. Staff spent another 50 hours verifying or disputing iNaturalist identifications online. Hence, the staff cost to train volunteers and check their data was approximately $11,832.00.

Overall, these cost data suggest that training volunteers to collect data through an easy-to-use app platform is an effective way to gather invasive species location information. Additionally, because training materials only need to be developed once, and can be modified for use across large regions, the staff cost of training volunteers would decline over successive years of surveying or across large areas. This would allow a greater return on investment than the nearly 1:1 match we found in our project. In areas where the proportion of trails that are accessible is larger, the returns may be even larger. A key challenge we faced in our project was that a large portion of the survey area is behind locked Forest Service gates, requires navigating through private land, or is only accessible to experienced hikers or backpackers.

Spatial Decision-making Support System

Model Outputs and future work prescriptions

The SDSS is available on DataBasin, where it can be accessed by the public (https://databasin.org/maps/2d2da5a28d8d4b5ab41a7ee948362d24/). The SDSS and EEMS model map suggest several key areas within the Los Padres National Foreset Administrative Boundary that may benefit from restoration following the Thomas and Whittier fire scars: along front country trails above Montecito, at several locations near and along Matilija Creek, and finally, along Romero Camuesa Road as is passes near Pendola Station in the Santa Barbara Backcountry (Figure 11, Figure 12). Here we briefly describe what parts of the model are driving the importance of these areas, and what restoration activities could occur in these regions.

Front country trails above Montecito

The hills above Montecito are among the most well-loved and well-traveled trails in the Los Padres National Forest. This region represents the area where the 2018 deadly mudslide originated and hosts a number of overlapping invasive species populations, all of which drive up the priority value of the area. Along Romero Canyon Trail, East Cold Spring Trail, and Hot Springs Trail, multiple large populations of widespread invasive species are present (Fennel, *Ageratina*, Cape ivy, castor bean), as well as some isolated populations of uncommon invasive species (French broom) near vectors for dispersal, such as along creeks.

The matrix of land ownership in these areas complicates future work possible in these areas. We recommend working with these private landowners to remove the isolated and particularly invaded stretches of trail, such as the French broom and castor bean near the top of Hot Springs trail, where many visitors visiting the springs might be ready vectors for future invasive species spread.

Matilija Creek

The areas along Matilija Creek that were highlighted by the model have both high erosion management priority and invasive species priority values, though they received PReP branch scores indicating high regeneration potential. There are many common weeds present in

Matilija creek, including tree tobacco, fennel, star thistles, though the model also prioritized these areas due to isolated populations of Spanish and French broom, as well as *Tamarix*. Furthermore, areas within this region scored high in their risk of soil slips, though no records of observed erosion were made in these areas. As with the regions in the Santa Barbara front country, there is a mix of public and private land ownership along Matilija creek, complicating the prospect of future work.

Pendola Station

The areas near Pendola station in need of restoration are several large, flat staging areas used during firefighting activities in the Thomas Fire. These areas may likely be old grazing pastures and are now dominated by invasive star thistle species. These areas received high priority values in the model because they were identified in the regeneration capacity branch of the EEMS model to have low regeneration capacity. We propose that these areas would be excellent sites to trial different restoration techniques for restoring heavy star thistle invasions back into native chaparral, scrub, and oak woodland ecosystems. Furthermore, these areas are all clearly on Forest Service land, making them key areas to plan future work.

Project Challenges

COVID-19 Pandemic

One of the key challenges we faced during our project was the COVID-19 pandemic. The first lockdowns for the pandemic began at the tail end of our volunteer training in Year 1 of the project, and we canceled the final two field training events we had scheduled. We continued to engage volunteers through email and newsletter updates, but likely had decreased participation due to fear surrounding COVID and safety engaging in outdoor activities near others. In the Year 2 of our project, we transitioned to online training and developed a short video to help users with the project methods to overcome this challenge. Overall, we were able to meet our goal of at least 100 volunteer participants across both years.

Closed roads/trails

A second key challenge we encountered during our project was limited access along Forest Service roads. In several cases, routes had not been maintained since the Thomas Fire, and access in these places was impossible. In other cases, roads we had originally planned to survey were closed off by privately owned locked gates, or in some cases, roads had been decommissioned by the Forest Service. This, in combination with COVID restrictions on traveling together in vehicles early in the pandemic, resulted in our covering fewer miles than we expected over the duration of the project. In Task 4 of the grant as proposed, we outlined that we would survey 300-500 miles of trails over two years. However, we were able to survey only a net 287 miles, though staff and volunteers covered a gross length of at least 350 survey miles.

Data Collection Apps

We encountered several difficulties with data upload and access using the iNaturalist and AnecData.org apps in the duration of the project. These occasional bugs included upload problems, failures to load datasheets properly when the phone was put into offline mode, and duplication of data during upload leading to artificially high observation numbers. We handled these challenges by reporting the bugs to the app programmers through their forums, emailing developers directly, and curating the data after download to remove duplicates. In the end, we may have had a minor loss in data quality due to these issues, though only one volunteer reported problems to SBBG staff with app use.

Data Geoprocessing

There were major delays and issues in meeting our goals with regards to Task 2: Database and Software Setup and Integration. The bulk of Task 2 was completed by our partner and subcontractor, the Conservation Biology Institute (CBI). Unfortunately, due to communication challenges between the CBI's principal investigator for this project and their GIS analyst, the Spatial Decision-making Support System and EEMS model for this project took considerably longer than expected. This challenge resulted in the failure to produce an SDSS long-term management plan, though aspects of this topic are covered in the draft journal article's supplemental materials 1. It also prevented us from completing our agency meetings to share our findings about the project, though we have met with several USFS personnel to discuss the project and potential improvements to our model throughout the grant period.

Project materials produced

Materials produced as a part of this project are listed in the table below. These have been uploaded to the FTP site for CDFW when possible.

Web Link	Purpose or Description
iOS Booklet	Training booklets. These booklets were printed and distributed to volunteers

Android Booklet 12 Species Guide 24 Species Guide Rare Species Guide	in 2020, and were sent in electronic form in 2021, to guide volunteers in the identification of focal species. We also created training booklets to help volunteers use the apps (iNaturalist and AnecData) on iPhones and Android devices.
2021 Training Video	Training video. Due to the pandemic, we took our trainings entirely online in 2021. To aid in this process, we created a quick online training video to guide volunteers in how to make an observation.
2021 Outreach presentation with Los Padres Forest Association	Outreach presentation. A presentation for the Los Padres Forest Association about weeds in Ventura and Santa Barbara Counties. April 22, 2021.
2021 Santa Cruz Natural History Museum outreach presentation	Outreach presentation. A presentation for the Santa Cruz Natural History Museum about the initial findings of our project. September 10, 2021.
Cal-IPC 2021 Symposium Talk: Session 5, New Mapping Tools.	Outreach presentation. Community Scientists Help to Map Post-Fire Recovery on California's Central Coast. California Invasive Plant Council's Annual Symposium. October 28, 2021. https://www.cal-ipc.org/resources/symposium/program/
2021 Outreach Presentation through CBI	Outreach presentation. Community Science and Stewardship: The Big Picture and an Exciting Santa Barbara/Ventura Opportunity. April 28, 2021.
DataBasin Project Group page	DataBasin Project Group Page.
Santa Barbara County Conservation Blueprint Page	Page for the project on the Santa Barbara County Conservation Blueprint.

Figures and Tables

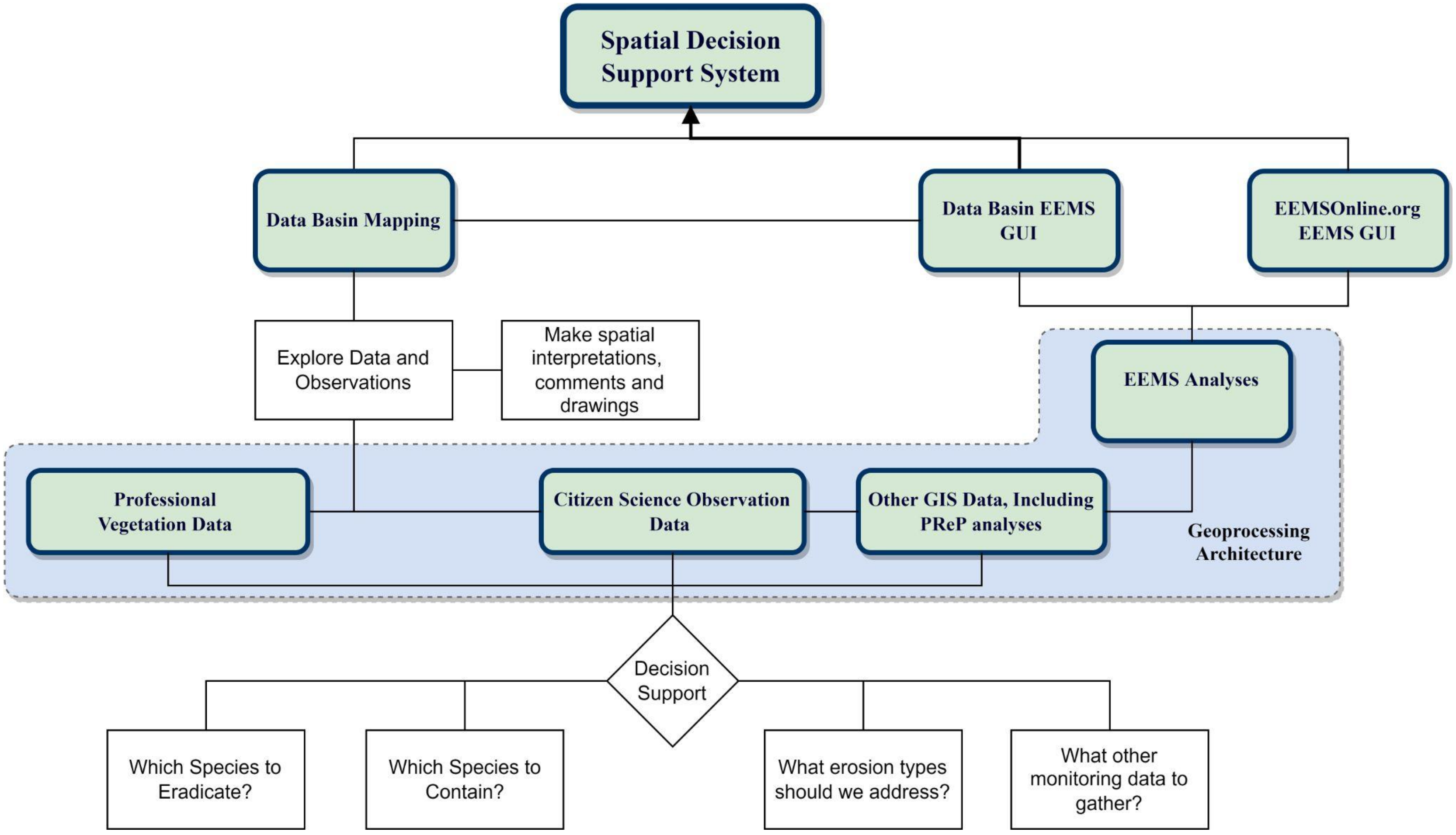

Figure 1. The architecture of the Spatial Decision Support System, including the data used and relevant questions.

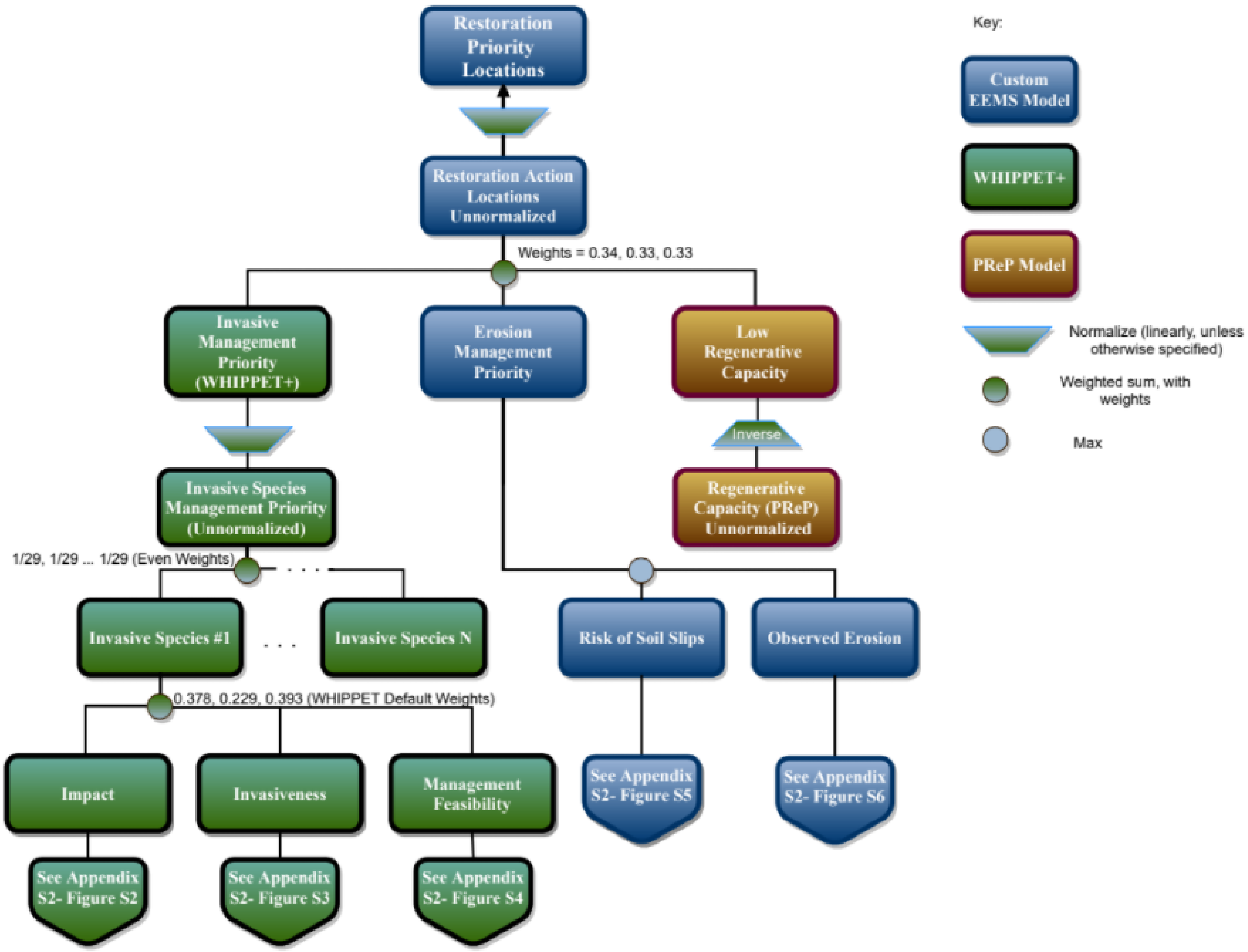

Figure 2. The EEMS model, including all three major branches.

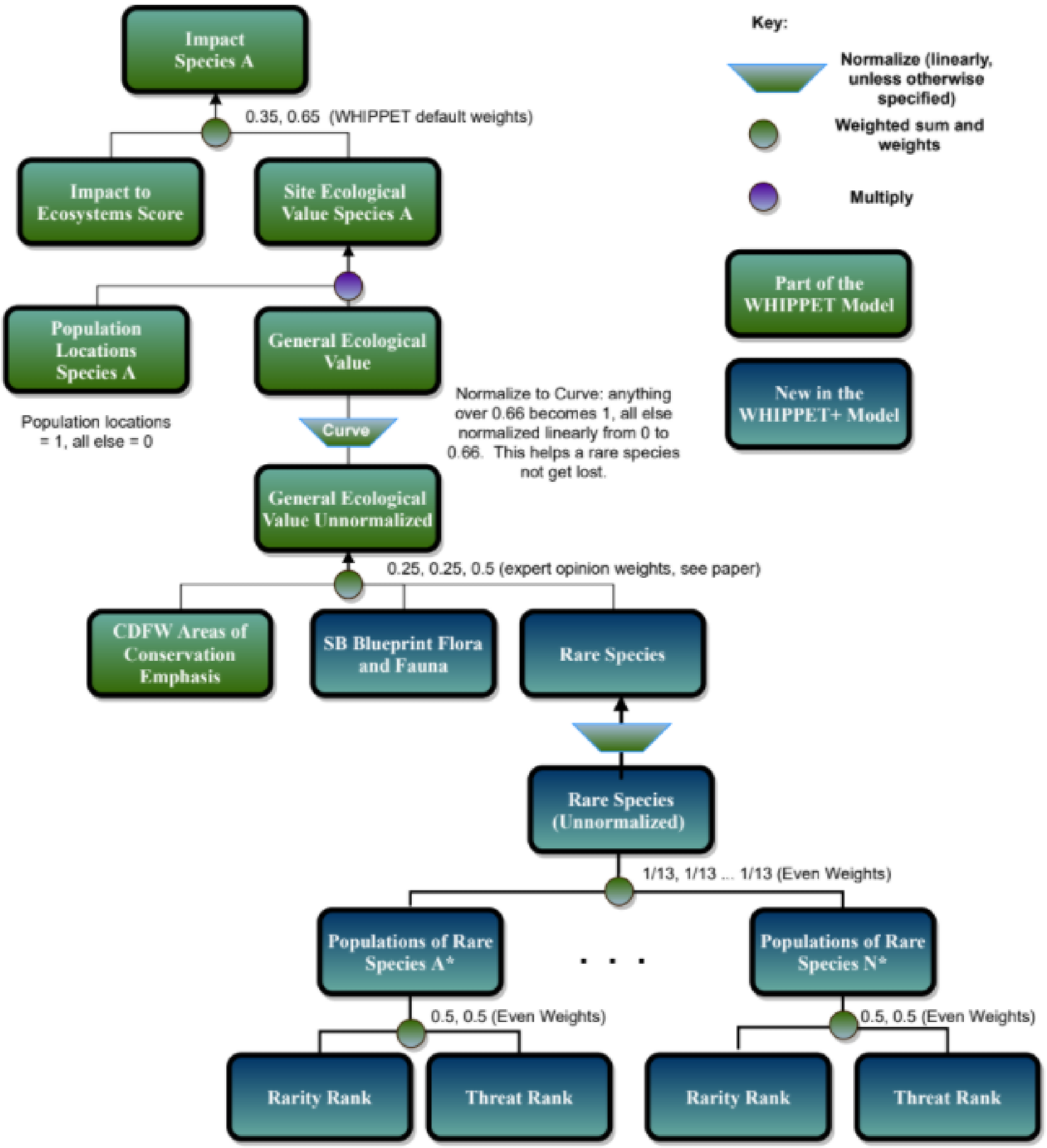

Figure 3. The impact sub-branch of the invasive species branch of the EEMS model.

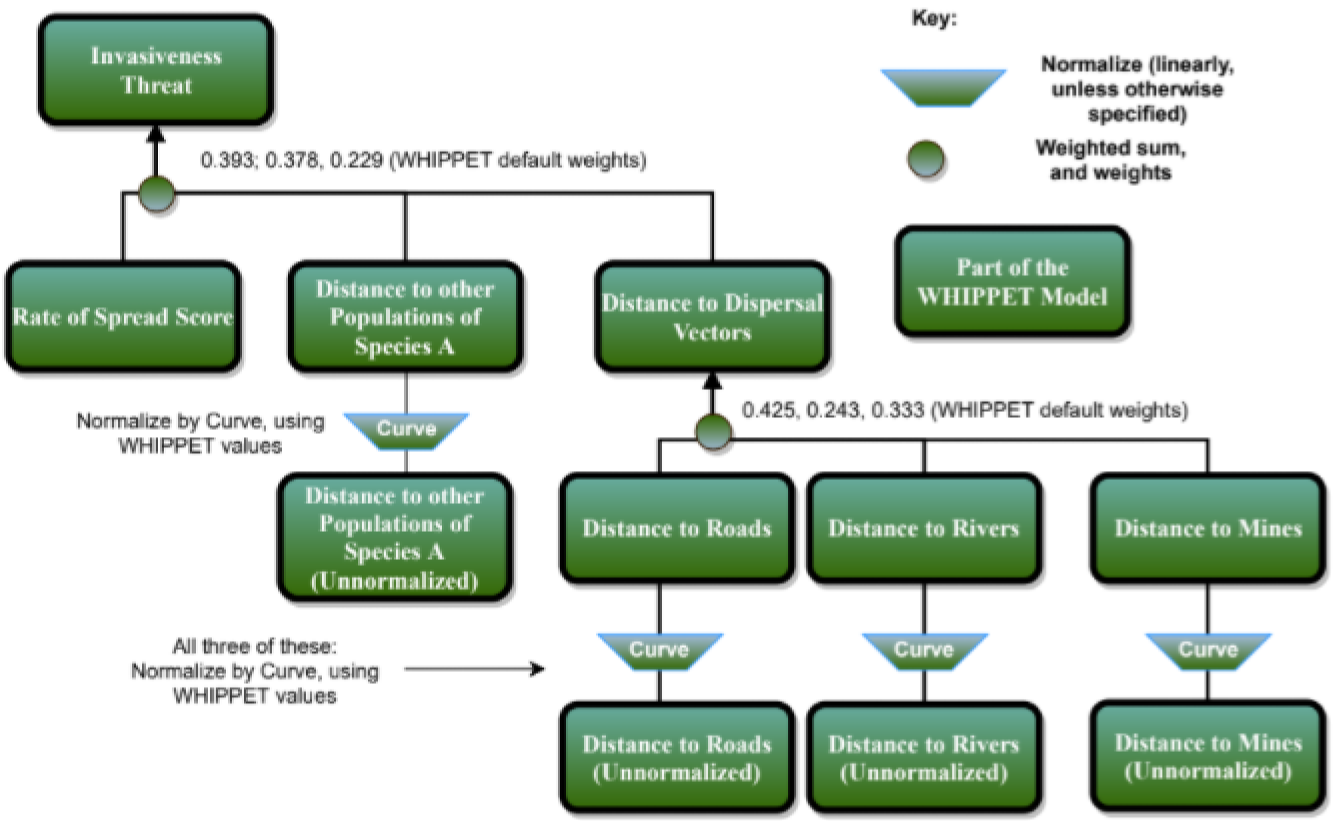

Figure 4. The invasiveness threat sub-branch of the invasive species branch of the EEMS model.

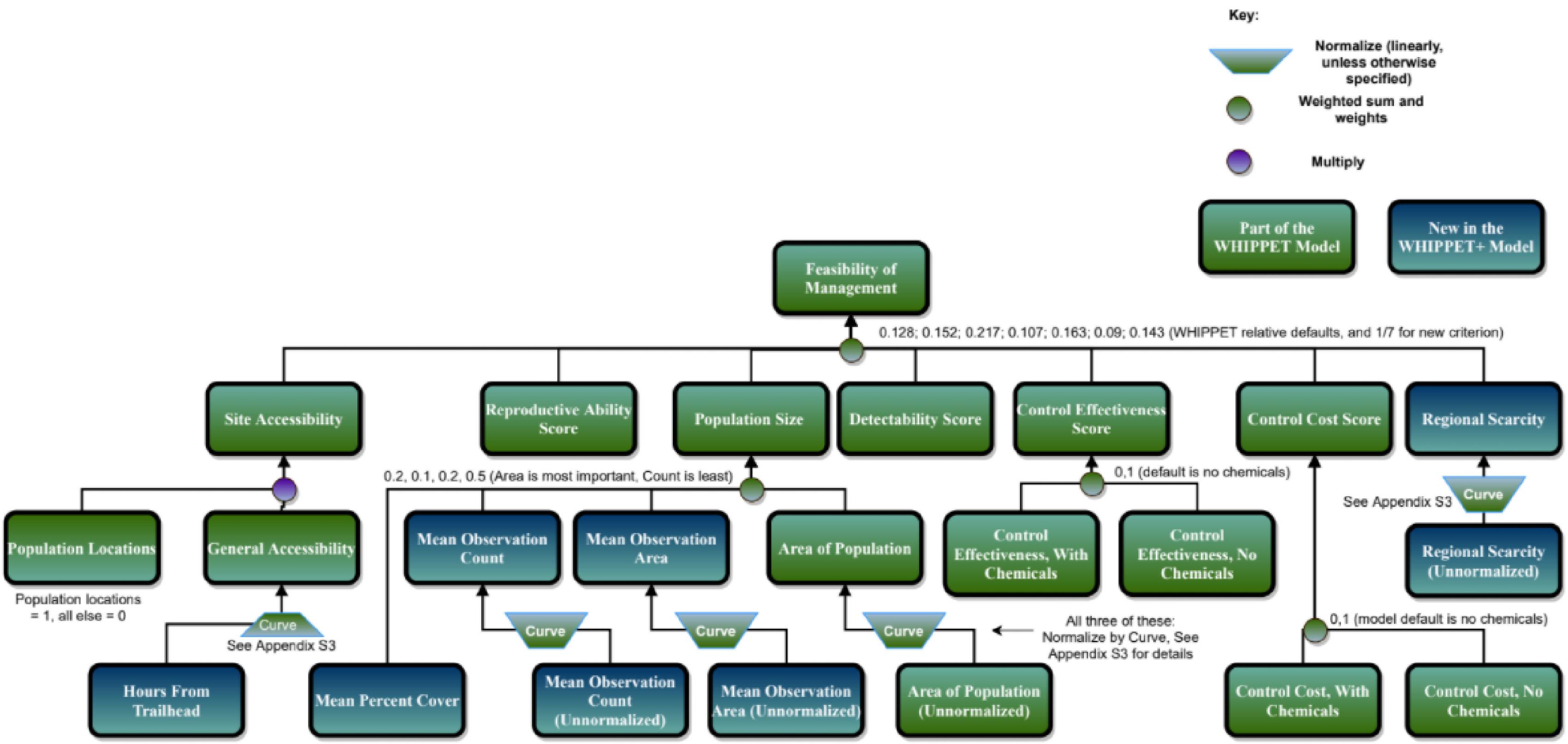

Figure 5. The feasibility of management sub-branch of the invasive species branch of the EEMS model.

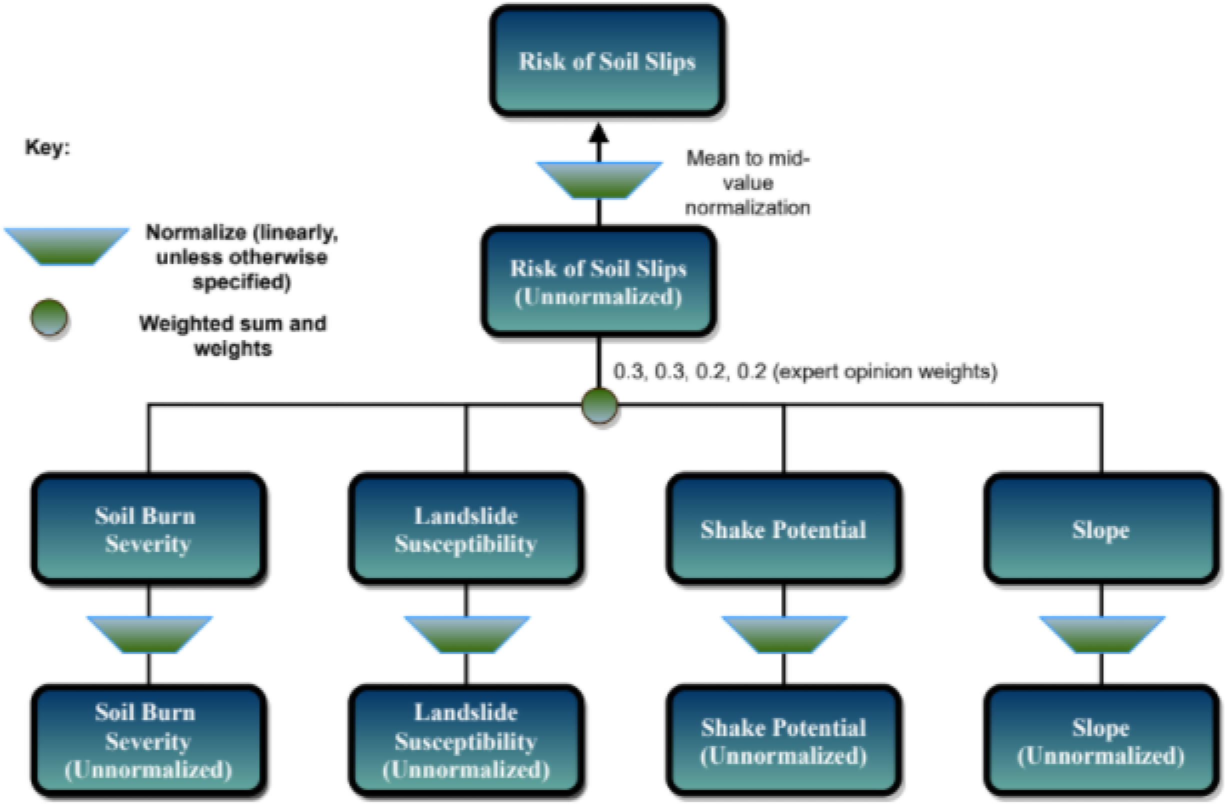

Figure 6. The risk of soil slips sub-branch of the erosion priority branch of the EEMS model

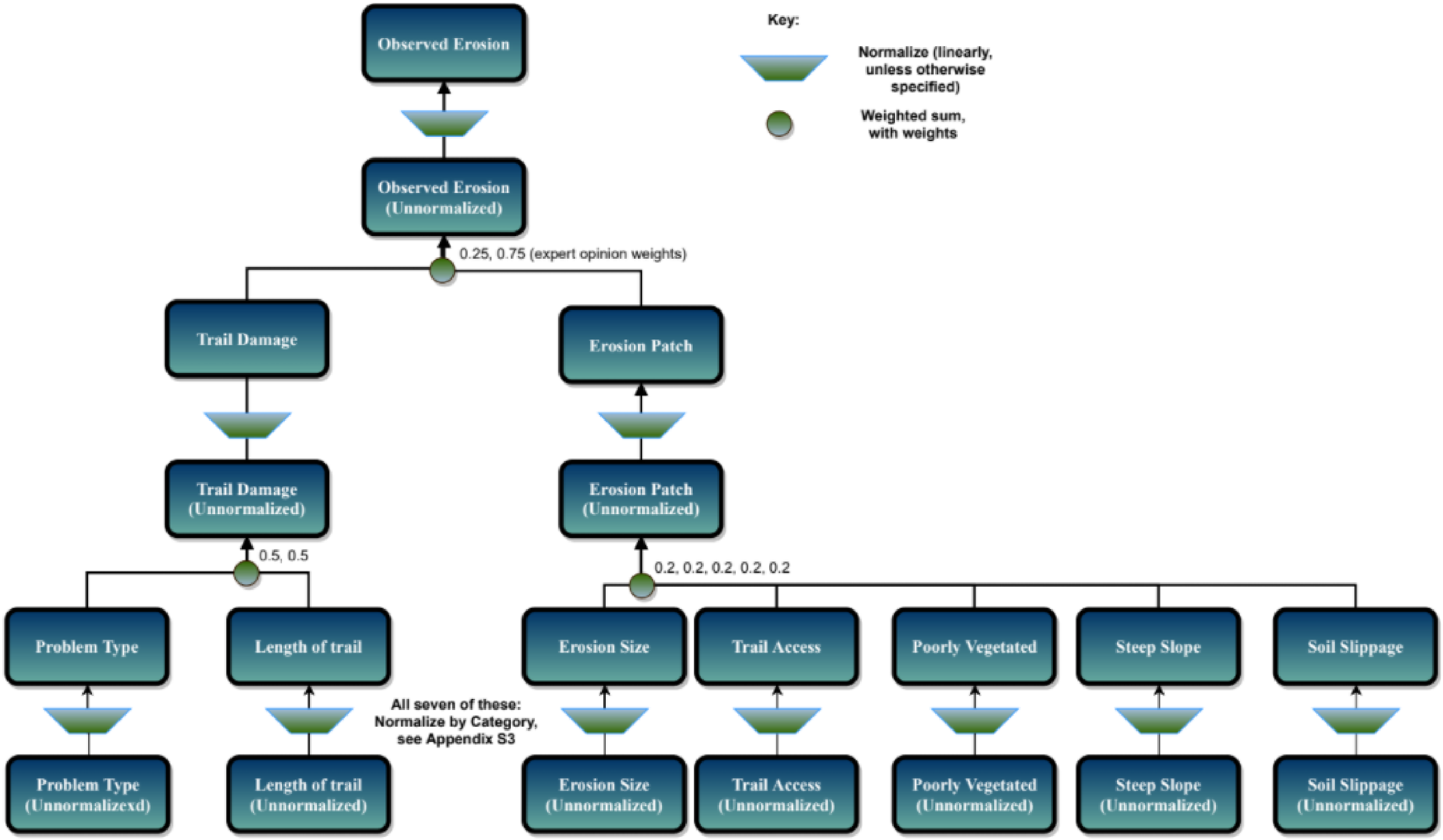

Figure 7. The observed erosion sub-branch of the erosion priority branch of the EEMS model.

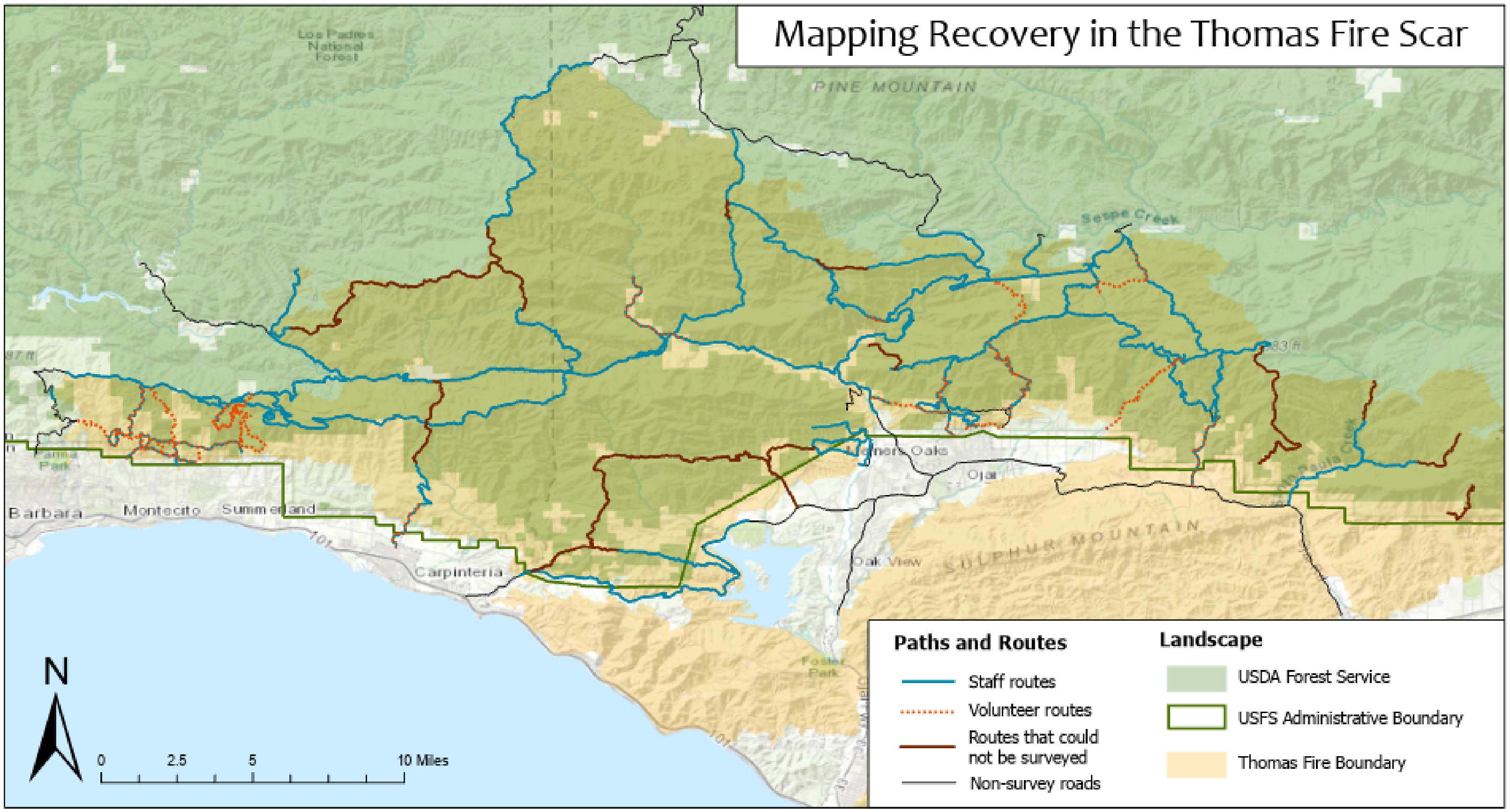

Figure 8. Map showing the survey routes within the Thomas Fire scar.

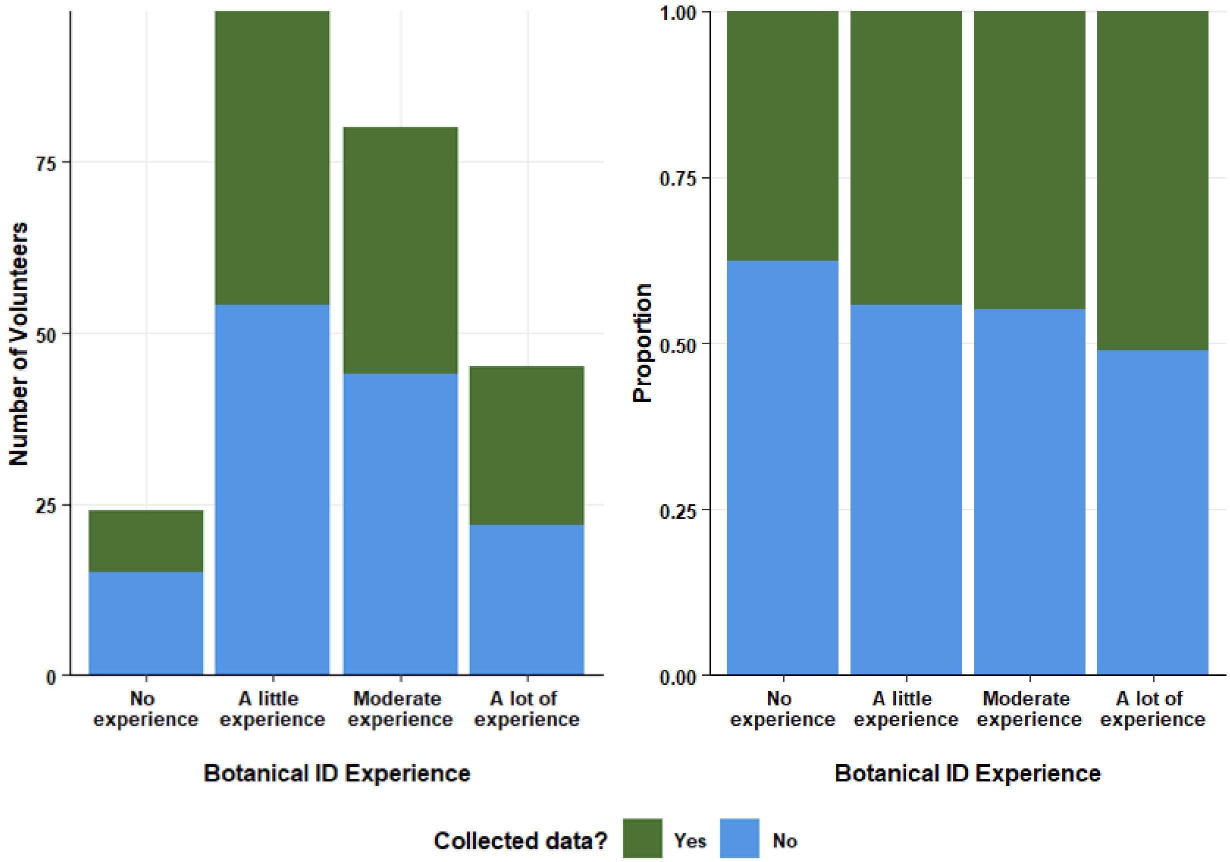

Figure 9. The number of volunteers at each botanical identification experience level, by whether they collected data or left the project.

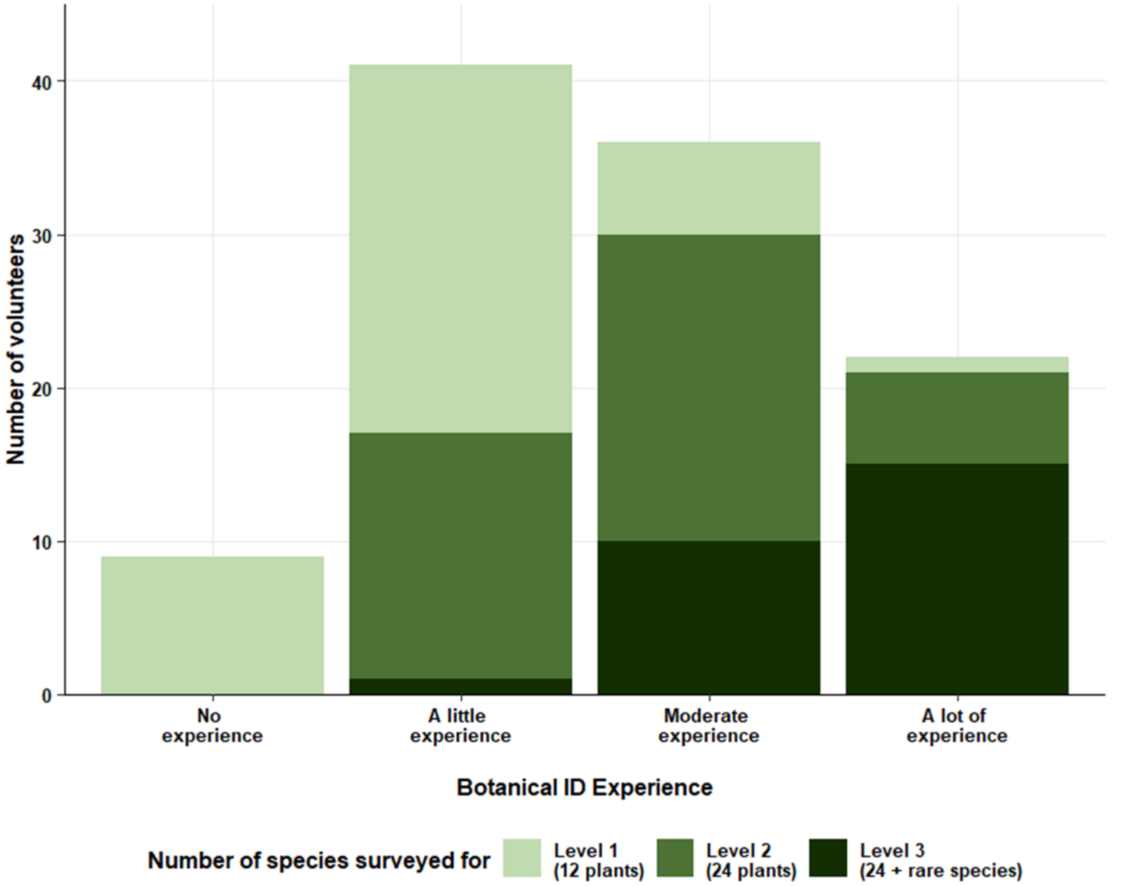

Figure 10. Number of plants surveyed for by volunteer self-identified botanical identification skill level.

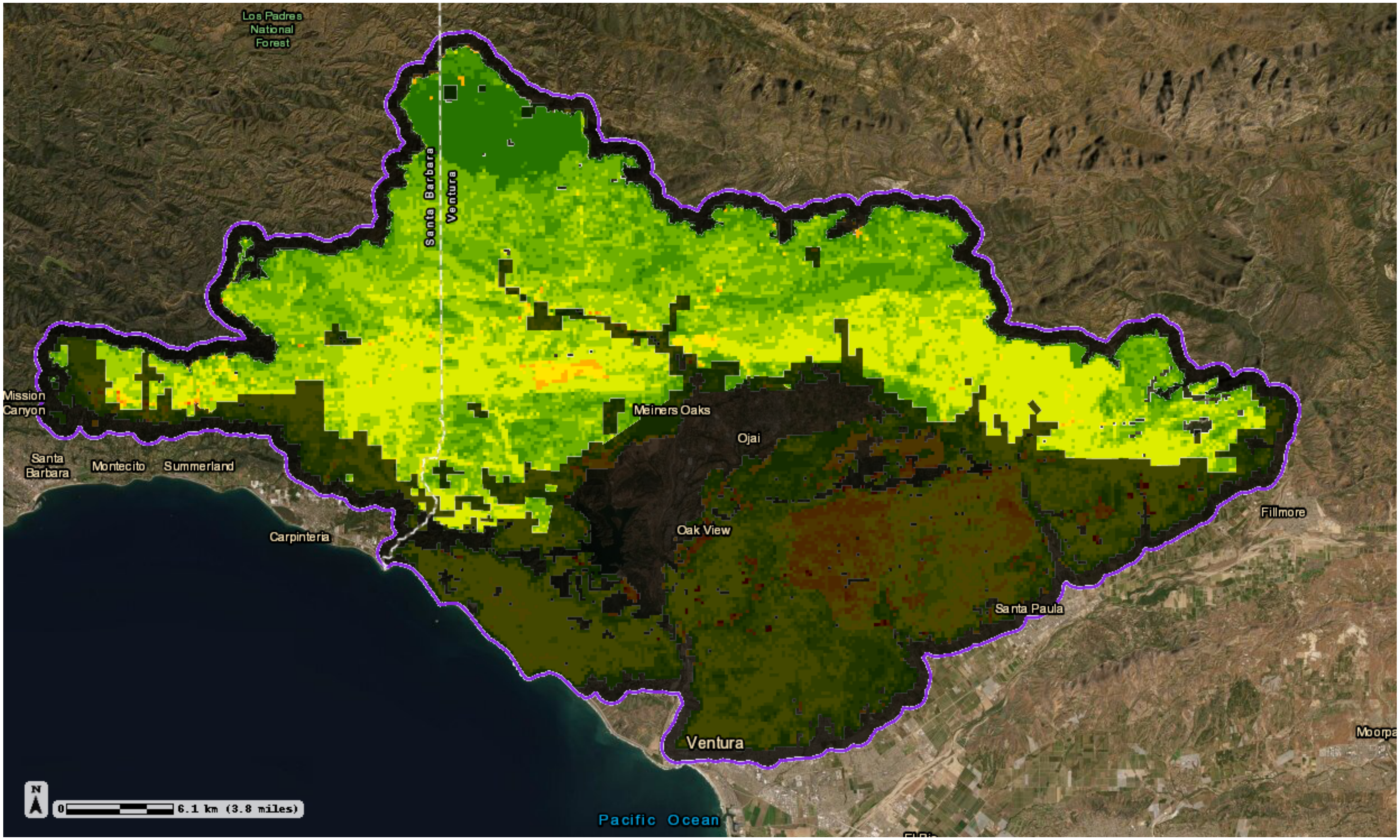

Figure 11. EEMS model output for the Thomas Fire scar, including the PReP model. Green areas are low priority for restoration, red and orange areas are high priority for restoration. Areas with grey overlay are not owned by the Forest Service or were not burned.

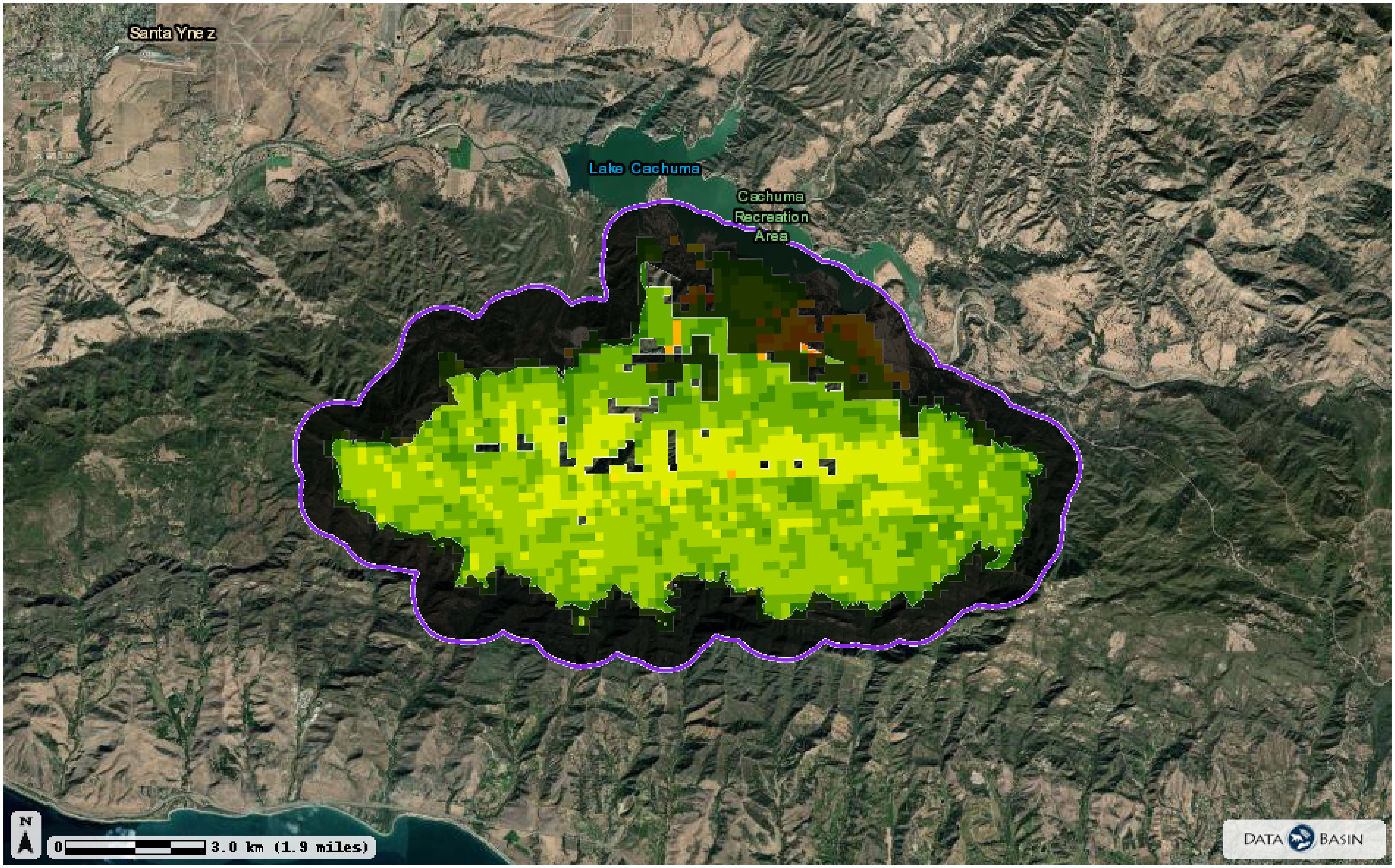

Figure 12. EEMS model output for the Whittier Fire scar, including the PReP model. Green areas are low priority for restoration, red and orange areas are high priority for restoration. Areas with grey overlay are not owned by the Forest Service or were not burned.

Table 1. EEMS branches data sources, links, and notes.

EEMS Branch	Data	Data Source	Notes
Invasive management priority - impact	Species-specific impact values ("impact to ecosystems score")	Cal-IPC impact ratings - invasive species inventory (https://www.cal-ipc.org/plants/inventory/)	
	CDFW Areas of Conservation Emphasis	https://wildlife.ca.gov/Data/Analysis/Ace	
	SB Conservation Blueprint - Flora and Fauna		
	Rare species surface model	https://databasin.org/datasets/94ce1e355049440fbbfa2a2dfeb64f73/	Based on CNDDB and observations of rare plants collected
Invasive management priority - invasiveness threat	Distance to roads	https://sbcblueprint.databasin.org/datasets/f3a18ea448fa4998a2c8a85ac0f8633c/	Euclidean distance, SB Blueprint All CA Roads Centerlines
	Distance to rivers	https://www.usgs.gov/national-hydrography/national-hydrography-dataset	Euclidean Distance (ArcGIS), National Hydrography Dataset
	Distance to mines	https://databasin.org/datasets/f0ea7c8857504b6d87ccca3cbf1e6ab0/	Euclidean Distance (ArcGIS), California Mines Database
	Rate of spread score	Cal-IPC ratings - invasive species inventory (https://www.cal-ipc.org/plants/inventory/)	
Invasive management priority - feasibility	Hours from trailhead	Tobler hiking function; https://databasin.org/datasets/6afe1e8df3da49039d6306ee77964b53/	
	Percent cover	iNaturalist (data collected by staff or community scientists) https://databasin.org/datasets/36346684fbc84b12865e8c6c70145314/	
	Number of Plants	iNaturalist (data collected by staff or community scientists) https://databasin.org/datasets/36346684fbc84b12865e8c6c70145314/	

	Area of Extent	iNaturalist (data collected by staff or community scientists) https://databasin.org/datasets/36346684fbc84b12865e8c6c70145314/	
	Control effectiveness, with and without chemicals	Cal-IPC ratings - invasive species inventory (https://www.cal-ipc.org/plants/inventory/)	
Erosion Management Priority - Risk of soil slips	Soil Burn Severity	Thomas: https://sbcblueprint.databasin.org/datasets/90bec48d06ea4b1a8937c36bfd87cf1e/, Whittier: https://sbcblueprint.databasin.org/datasets/fa7b727ec18d40bfa40b85f054f7bbf0/	
	Landslide susceptibility	https://databasin.org/datasets/5288bd4f9c4d4aa3a59f9cfad936c1d3/ http://www.conservation.ca.gov/cgs/Documents/library-publications/MS58.pdf	Wills C.J., Perez, F., Gutierrez, C., 2011, Susceptibility to deep-seated landslides in California: California Geological Survey, Map Sheet 58.
	Shake Potential	https://databasin.org/datasets/32f71746c22a47e689abcbad3ed0a043/ https://www.conservation.ca.gov/cgs/Documents/Publications/Map-Sheets/MS_048.pdf	California Geological Survey map of “Earthquake Shaking Potential for California”
	Slope	https://databasin.org/datasets/d06b4ed17966430599582103bec36f0c/	Wildland Fire Science, Earth Resources Observation and Science Center, U.S. Geological Survey
Erosion Management Priority - observations	Observed erosion and trail damage	AnecData.org (data collected by staff or community scientists) https://databasin.org/datasets/090427d859024fbf87c030e4f2b682b4/	
Regenerative Capacity Priority	PReP Tool Output	https://onlinelibrary.wiley.com/doi/pdf/10.1111/rec.13513	Underwood, Emma C., et al. "Identifying priorities for post-fire restoration in California chaparral shrublands." Restoration Ecology (2021): e13513.

Table 2. Survey options for volunteers to self-identify their botanical skill level.

How much botanical identification experience do you have?	
0	None (I’m just starting to learn)
1	A little (I know a few local plants)
2	A fair amount (I know many local plants)
3	A lot (I know our local plants well and am comfortable with botanical keys)

Table 3. Focal invasive species, sorted into categories for volunteers to survey for.

12 Species List (Group 1)	24 Species List (Group 2)	24 + Rare Species List
● *Ageratina adenophora (sticky snakeroot; on 24 list in 2020)* ● Araujia sericifera (cruel vine) ● Arundo donax (giant reed) ● Asphodelus fistulosus (onionweed) ● Centaurea maculosa (spotted knapweed) ● Chondrilla juncea (skeletonweed) ● Delairea odorata (Cape Ivy) ● Foeniculum vulgare (wild fennel) ● Nicotiana glauca (tree tobacco) ● Pennisetum setaceum (fountaingrass) ● Ricinus communis (castor bean) ● Stipa (Nasella) tenuissima (feather grass)	● Ailanthus altissima (tree of heaven) ● Brassica tournefortii (Saharan Mustard) ● *Carthamus lanatus (woolly distaff thistle; on 12 list in 2020)* ● Centaurea melitensis (tocalote) ● Centaurea solstitialis (yellow star thistle) ● Cistus incanus (hairy rockrose) ● Cortaderia spp. (pampas grasses) ● Cynara cardunculus (artichoke thistle) ● Cytisus scoparius (Scotch broom) ● Euphorbia terracina (carnation weed) ● Genista monspessulana (French broom) ● Spartium junceum (Spanish broom)	● 24 list plus 50+ rare taxa

Table 4. Number of populations of focal invasive plants found staff, volunteers, or both groups.

			Populations found by…		
Group	**Scientific Name**	**Common Name**	**both staff and volunteers**	**staff only**	**volunteers only**
Group 1	*Ageratina adenophora*	sticky snakeroot	5	2	1
	Araujia sericifera	bladderflower	0	0	0
	Arundo donax	giant reed	1	2	0
	Asphodelus fistulosus	onion-leafed asphodel	1	0	0
	Delairea odorata	cape-ivy	7	2	1
	Foeniculum vulgare	fennel	22	5	13
	Nicotiana glauca	tree tobacco	8	3	1
	Pennisetum setacaum	fountain grass	0	1	1
	Ricinus communis	castor bean	2	1	2
		Total:	**46**	**16**	**19**
		Two-way comparison:	**Chi squared = 0.07; p = 0.79**		
Group 2	*Ailanthus altissima*	tree-of-heaven	0	0	0
	Centaurea melitensis	Maltese star-thistle	3	11	1
	Centaurea solstitalis	yellow star-thistle	0	3	2
	Centaurea stoebe	spotted knapweed	0	0	0
	Cortaderia selloana	pampas grass	0	0	1
	Genista monspessulana	French broom	0	1	0
	Spartium junceum	Spanish broom	1	0	0
	Tribulus terrestris	puncture vine	0	0	1
	Vinca major	greater periwinkle	2	0	1
		Totals:	**6**	**15**	**6**
		Two-way comparison:	**Chi squared = 2.45; p = 0.12**		

Table 5. Comparison of survey data among different groups of observer types.

Group	Scientific Name	Common Name	Number of populations		Sum of Population Area (sq. ft.)	
			Staff	Volunteers	Staff	Volunteers
Group 1	*Ageratina adenophora*	sticky snakeroot	8	8	680,000	670,000
	Araujia sericifera	white bladderflower	0	0	0	0
	Arundo donax	giant reed	3	1	110,000	5,000
	Asphodelus fistulosus	onion-leafed asphodel	1	1	63	58
	Delairea odorata	cape-ivy	9	8	320,000	320,000
	Foeniculum vulgare	fennel	16	20	4,100,000	2,400,000
	Nicotiana glauca	tree tobacco	12	10	120,000	340,000
	Pennisetum setaceum	fountain grass	1	1	5,000	63
	Ricinus communis	castor bean	3	4	43,000	57,000
Group 2	*Ailanthus altissima*	tree-of-heaven	0	0	0	0
	Centaurea melitensis	Maltese star-thistle	16	9	2,600,000	110,000
	Centaurea solstitialis	yellow star-thistle	4	3	11,000	110
	Centaurea stoebe	spotted knapweed	0	0	0	0
	Cortaderia selloana	pampas grass	0	1	0	7
	Genista monspessulana	French broom	1	0	5,000	0
	Spartium junceum	Spanish broom	1	1	1,100	5,000
	Tribulus terrestris	puncture vine	0	1	0	3
	Vinca major	greater periwinkle	4	5	100,000	31,000

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