Drone-Based Land Management

Integrating drone technology into habitat monitoring at the Tejon Ranch Conservancy

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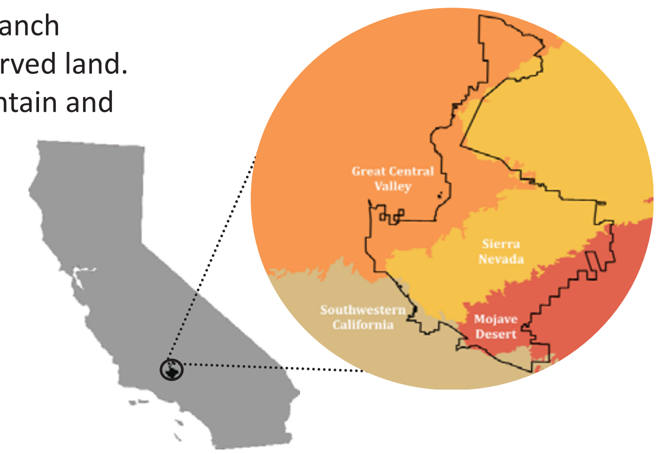
Background: The Tejon Ranch Conservancy

The Tejon Ranch Conservancy, in collaboration with the Tejon Ranch Company, oversees the management of 240,000 acres of conserved land. The Conservancy aims to develop stewardship practices to maintain and restore the ecosystems that cover the Ranch, and expand understanding of the Ranch's unique and extraordinary natural resources. Tejon Ranch contains a large diversity of plants and animals due to its unique location at the convergence of four major ecological regions (Sierra Nevada, Mojave Desert, Great Central Valley, and Southwestern California), and is a critical wildlife corridor for several endangered species.



THE PROBLEM

The Conservancy is responsible for monitoring expansive land parcels, but its management resources are limited. How can the Conservancy enhance its habitat monitoring activities given this constraint?

OUR SOLUTION

Our research assessed how predictive modeling and high-resolution landscape mapping using unmanned aerial vehichles (UAVs or drones) and/or satellite imagery could help the Conservancy optimize its limited resources.

Case Study: Tamarisk (*Tamarix spp.*)

The Conservancy closely monitors the invasive riparian weed tamarisk because large infestations can dramatically alter the landscape, making it unsuitable for native plants and animals. Our project focused on identifying tamarisk as a proof of concept for expanding habitat monitoring activities using an air-ground-based monitoring approach.

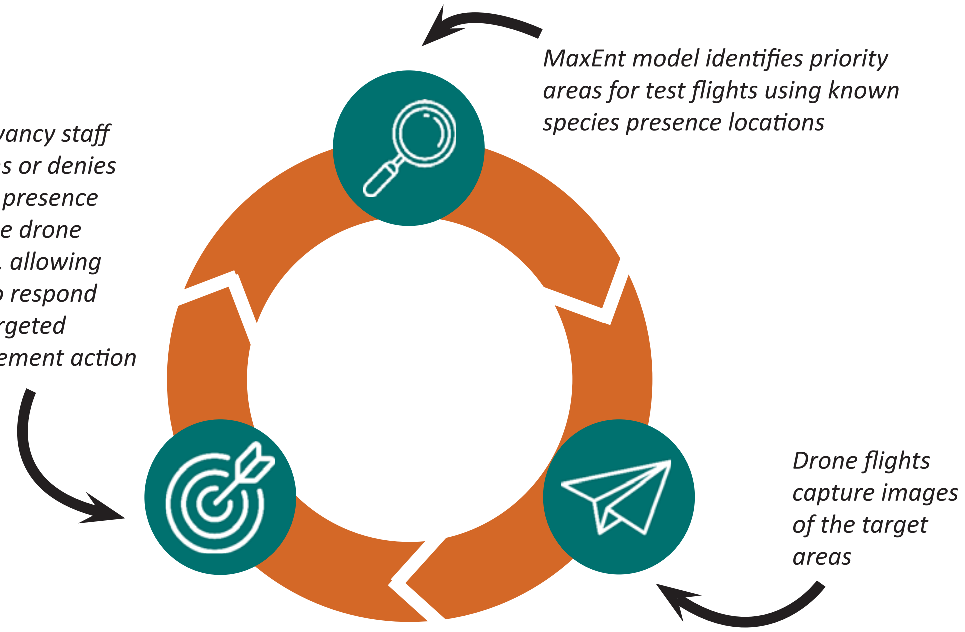
Objectives

In order to evaluate our solution, our objectives were to:

- Identify areas that are susceptible to tamarisk
- Complete flights and analyze images
- Determine the financial feasibility of drone monitoring

Conclusion

Our research confirmed that drones, if properly utilized, can be a useful tool to expand the monitoring reach of the Tejon Ranch Conservancy. However, Tejon Ranch is too large and variable in terrain to monitor in its entirety, multiple times per year, as would be desirable to detect invasive plant presence. Therefore, the Conservancy must prioritize specific areas to target for drone surveys. Through our MaxEnt model, the Conservancy can identify highly susceptible areas to conduct flights. The plant presence data that would be gathered from these flights could then be used as additional inputs for new iterations of the MaxEnt workflow to more accurately predict future invasive plant dispersal. This creates a positive feedback loop, in which the workflow is continually updated with environmental data and new presence data, and the overall monitoring framework becomes more robust and efficient. Over time, the Conservancy could also adapt this monitoring framework to include other conservation interests such as conifer mortality and endangered species monitoring. We believe that this framework may have potential applications for similarly resource-constrained organizations, facilitating conservation activities despite these limitations.



Acknowledgments

We would like to thank the following individuals and organizations for their support of this project: our advisors including James Frew, Ashley Larsen, and David Theobald; our clients and collaborators at the Tejon Ranch Conservancy including Laura Pavliscak, Michael White, and Ben Teton; and our drone consultants including Todd White at RoboHawk Aerial Video & Imaging and Mark Dufau at AeroVironment, Inc. Panofsky Field site image courtesy of RoboHawk Aerial Video & Imaging.

ROBOHAWK AERIAL VIDEO & IMAGING
AeroVironment™
Tejon Ranch CONSERVANCY

Contact Information

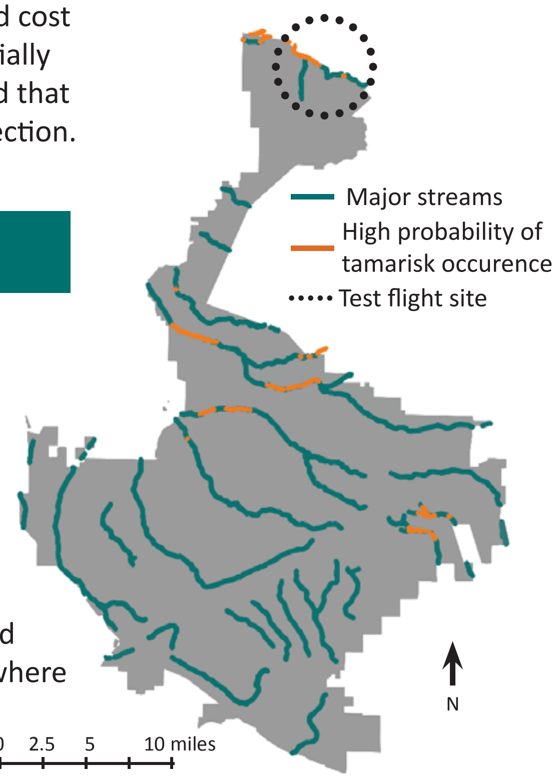
If you are interested in learning more about our project, please visit our team website: www.tejon-ranch-drones.weebly.com.

We began by completing a literature review to assess the usefulness and cost effectiveness of different remote sensing and UAV technologies. We initially explored satellite imagery as a tool for tamarisk management, but found that the resolution of satellite sources is not fine enough for early-stage detection.

Identify flight locations

MAXENT

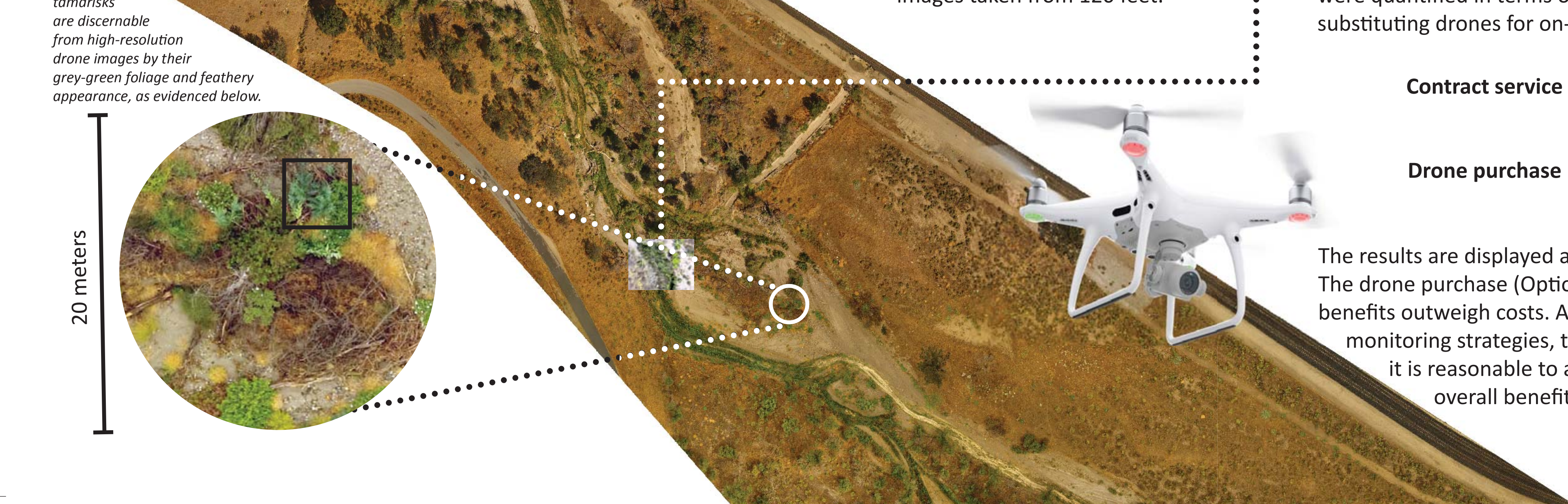
Because early-stage detection is critical to weed mitigation, we moved on to consider UAV or drone imagery, as it provides resolution on a much finer scale. Due to the sheer size of Tejon Ranch, it was impractical to fly over the entire property. Therefore, MaxEnt, a species distribution computer program, was used to identify areas with high risk of tamarisk invasion. Inputs to the model included known locations of tamarisk and environmental variables such as slope, precipitation, and temperature. One of the vulnerable locations included Caliente Creek, where a 20-acre site called Panofsky Field was selected for test flights.



Flights and image analyses

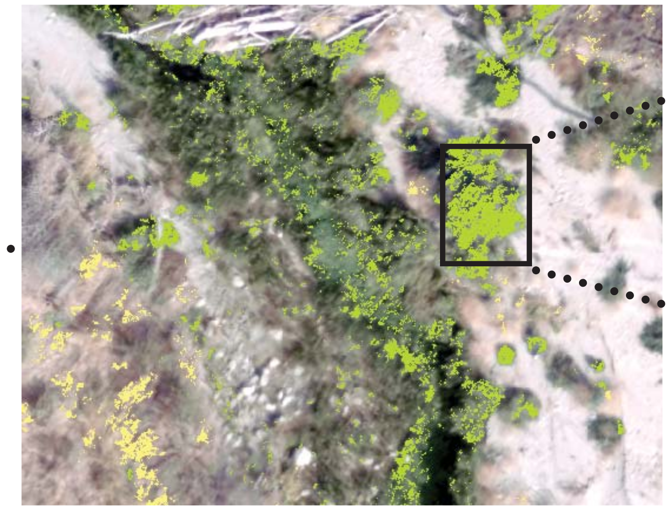
DRONE FLIGHTS

We performed a preliminary ground truth survey to identify and geographically tag invasive and native plant species throughout Panofsky Field. Before each drone flight, we placed marker signs next to the target plants. After the maps were created from the drone images, we created a finalized groundtruth data set using the signs, geographic tags, and visual inspection of the imagery to pinpoint individual plant targets. The image below is an aerial view of the 20-acre Panofsky Field site. It was assembled from over 1000 individual images taken from 120 feet.



Individual tamarisks are discernable from high-resolution drone images by their grey-green foliage and feathery appearance, as evidenced below.

IMAGE CLASSIFICATION



Above is an output from the computer program. The dense cluster of green pixels inside the black box indicates the predicted presence of one tamarisk plant. However, the mis-identification of tamarisk is also evidenced by the green pixels outside of the box. Shortpod mustard plants are denoted by the yellow pixels in the bottom-left corner of this image. The smaller image to the right shows the tamarisk plant beneath the pixels.

We confirmed it is possible to visually identify tamarisk through the drone images, but we were also interested in automating this process to save the Conservancy staff's time. To do this, we used ArcGIS to run an image classification program, in which the program inputs were the marked tamarisks from the ground truth survey. The program referenced visual characteristics, specifically, the relative amounts of red, green, and blue reflected light emitted by each plant, in order to identify other plants in the image that were not marked in the ground truth survey. While the program had moderately high accuracy, it also incorrectly identified several plants as tamarisk. Despite these errors, we observed more accurate identification of shortpod mustard, another invasive plant of concern to the Conservancy. With some fine-tuning, this program could be trained to become more accurate, and thus a powerful tool for analyzing drone-acquired images.

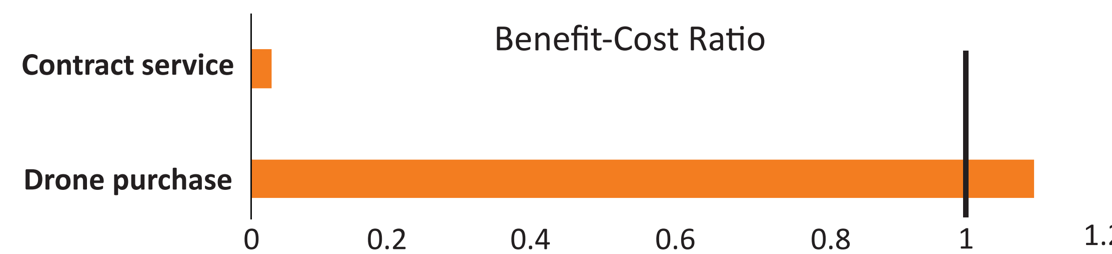
Financial feasibility

COST BENEFIT ANALYSIS

Finally, a cost benefit analysis was completed to evaluate two potential management options that incorporate drones into the Conservancy's tamarisk monitoring activities:

1. **The Conservancy contracts a drone service to conduct flights over the property, or**
2. **The Conservancy purchases a drone and all related accessories and permitting.**

Information about the costs for each option was collected and summed over a five-year period. We chose this short period in recognition of the rapid evolution of drone technology, as the cost of commercially available drones and drone-related services will decrease over time. The benefits of drone technology were quantified in terms of wage-hour time savings, or the amount of money that would be saved because substituting drones for on-the-ground monitoring would result in less staff time in the field.



The results are displayed above as a ratio of the total benefits divided by the total costs of implementation. The drone purchase (Option 2) is the more favorable option because the ratio is greater than 1, meaning that benefits outweigh costs. Although this option is only slightly more favorable than the status quo of current monitoring strategies, this analysis was limited to the benefits of using drones for monitoring weeds, so it is reasonable to assume that if benefits were expanded to include all Conservancy activities, the overall benefits of a drone purchase would only increase while costs remain relatively static.