Are we making progress? A bird's-eye view of change in invasive plant cover in central-coastal Orange County

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Effective wildland weed management means not only getting out there and doing the field work, but also strategizing where to go, which species to prioritize, and, critically, how to track and evaluate progress. For many of us, progress is usually — at its best — tracked annually and evaluates how many acres or populations were treated, how many plants were removed, and/or how many hours were spent doing the work. That's called tracking effort, and it tells us a lot about progress at a local scale.

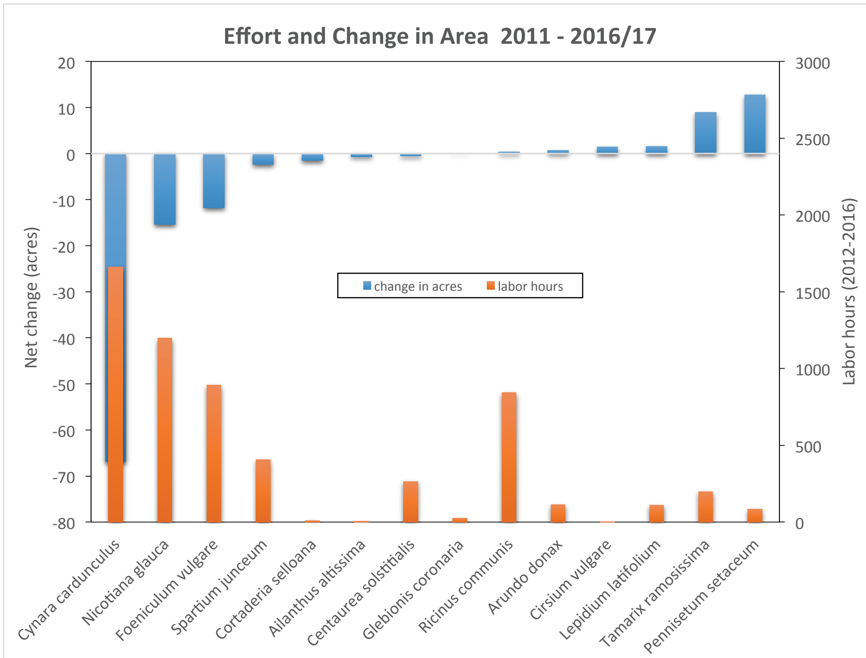

Figure 1. *Gains and losses in net acreage of select invasive plant species prioritized for control 2012-2016.*

What we really want to know as land managers, is whether we are making progress at a landscape scale by reducing the number of populations or acreage of high-priority species, eradicating high-risk species that are at low density in an area, or recovering native habitat. Tracking this type of change doesn't just mean monitoring the populations that we've found; it also extends to locating any new populations that have emerged or ones that we have missed.

One would think that this is easy to do, but it is surprisingly difficult. Resources are usually not available to perform comprehensive surveys. Target species are each unique in their degree of difficulty, both to control and to detect. Invasive plant populations do not tend to respect property boundaries, meaning that surveys that end strictly at property lines may miss major source populations just beyond their reach.

Cal-IPC was recently given the opportunity to track landscape-level changes in invasive plant species using data from two helicopter surveys conducted over the same area, five years apart. The area is a portion of the Nature Reserve of Orange County (a Natural Community Conservation Plan/Habitat Conservation Plan – NCCP/HCP — reserve complex) and adjacent Nature Conservancy easement lands, totaling over 30,000 acres of mostly rugged terrain. The first survey was conducted in 2011 by Native Range and the second in 2016/2017 by Wildlands Conservation Science. Surveys were funded in part by a Local Assistance Grant from the California Dept. of Fish & Wildlife, with matching funds from a land manager collaborative comprising the Natural Communities Coalition (NCC), the Irvine Ranch Conservancy (IRC), Orange County Parks (OC Parks), and The Nature Conservancy (TNC). NCC, as the ringleader for tracking reserve-wide change, hired Cal-IPC to compare results from the two surveys.

Helicopter view of coastal sage scrub, oak woodland and grassland habitats in Limestone Canyon, Orange County. Photo: John Gump.

A lightweight turbine helicopter was used for both surveys, with pilots skilled at maneuvering at low altitudes and across steep terrain. Botanists on board were able to identify and map plant populations literally on the fly. Each survey covered approximately 31,000 acres, collected 4,253 (2011) and 3,722 data points (2016/2017) and conducted flight surveys in the span of only 12 working days. Flight transects followed the landscape's contours. Invasive plant populations were mapped as points, lines, or polygons in

2011 and primarily mapped as polygons in 2016/2017. Gross area was estimated by using either patch radius or length x width and net area was derived from percent cover estimates. In all, 24 invasive plant species were recorded consistently by both surveys for comparison.

For each species, we assessed change in gross area, net area, and number of populations. These changes were compared with labor effort spent controlling that species. The survey area was divided into invasive plant management units (IPMUs) to account for spatial variation in species cover and management actions. IPMUs spanned management and land ownership boundaries, but matched hydrological boundaries with the intention of also matching likely movement patterns of invasive plants. The primary land managers involved in the project were IRC and OC Parks, with California State Parks invested in a small portion of the study area.

Helicopter surveys provided landscape-scale distribution data for invasive plant species that allowed for revisions in strategic planning for their control. Significant reductions in several target species were documented. Most notably, cover of five species prioritized for control work declined significantly: artichoke thistle (*Cynara cardunculus*) cover decreased 93% (from 291,653m^2 to 21,086m^2), tree-of-heaven (*Ailanthus altissima*) decreased 88% (from 3063m^2 to 366 m^2), Spanish broom (*Spartium junceum*) dropped 98% (from 9831m^2 to 190 m^2), yellow starthistle (*Centaurea solstitialis)* dropped from 2080m^2 to 3m^2 (in surveyed areas), and garland chrysanthemum (*Glebionis coronaria*) decreased from 28m^2 to undetectable levels (Figure 1). All these species, with exception of artichoke thistle (see Figure 2) were relatively localized to begin with and therefore could be managed comprehensively within the survey area.

However, news was not all good. We

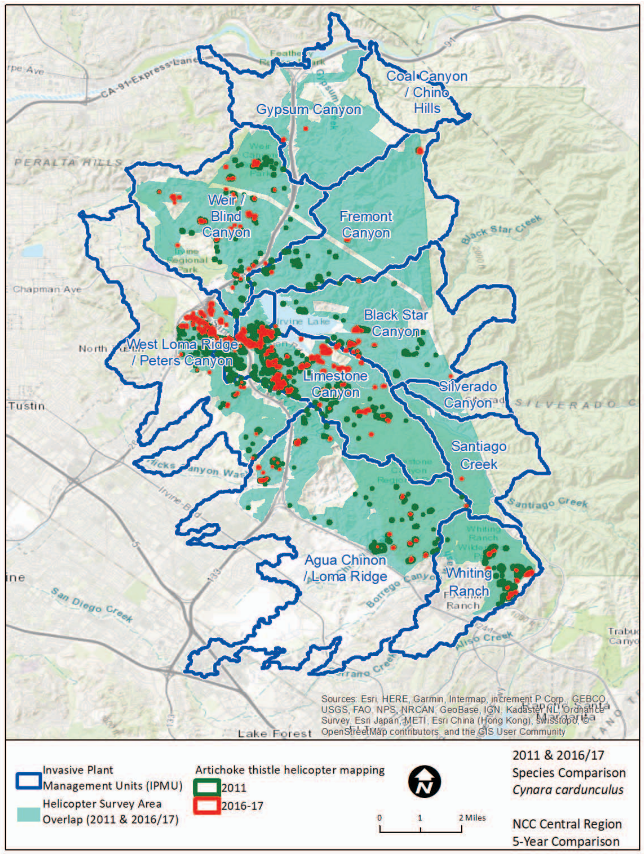

Figure 2. *Change in artichoke thistle (*Cynara cardunculus*) distribution 2011-2016/2017.*

observed the following worrisome increases in invasive plant cover despite local control efforts: fountain grass (*Pennisetum setaceum*) exploded by nearly ten times its initial area, giant reed *(Arundo donax*) tripled in area, tamarisk (*Tamarix ramosissima*) quadrupled in area, and castor bean (*Ricinus communis*) increased 14%. Increases for all species except fountain grass were localized to specific IPMUs, suggesting that these overall patterns of increase were driven by portions of the study area that were either de-prioritized or not under management. In addition, fine-scale differences in survey outlines inadvertently excluded a lake perimeter in which significant giant reed control work had taken place between 2011 and 2016, making comparisons along the lake untenable. This information can be used to determine whether existing strategies need to be adjusted to address these species.

It is a rare opportunity to have two "snapshots in time" that can show change in abundance and distribution for the number of species and scale of area surveyed here. The comparison is strengthened by the fact that similar methodologies were employed, which provided invaluable information on population expansions, new infestations, and management progress. Some species (not reviewed here) showed dramatic increases or decreases in cover that, upon further investigation, appeared to be mostly the result in observer-based differences in estimations of percent cover or fine-scale differences in survey effort. Future large-scale surveys would benefit from a written methodology which (1) outlines assumptions made for cover estimates and population delimitation, (2) identifies the criteria for mapping points or polygons, and (3) standardizes survey area, flight transect spacing, and time of year to ensure similar effort and detectability of plants.

Data on treatment effort are essential for deducing likely causes for decreases (or increases) in species cover. In our case, these data could have been collected more consistently. Only one land manager (IRC) was able to provide labor hours invested into each target species across each IPMU. Therefore, our estimates of labor effort are underestimates. Gains in acreage of high priority species could also have been addressed by improved participation and expansion in the invasive plant management collaborative.

Surveys were conducted largely irrespective of property boundaries, but some adjacent populations were undoubtedly missed. For example, though yellow starthistle was significantly reduced within the survey area, known populations persisted on road rights-of-way and adjacent lands just beyond the survey area, and continue to pose a management challenge. Furthermore, no one survey technique is a silver bullet: helicopter surveys do not detect all

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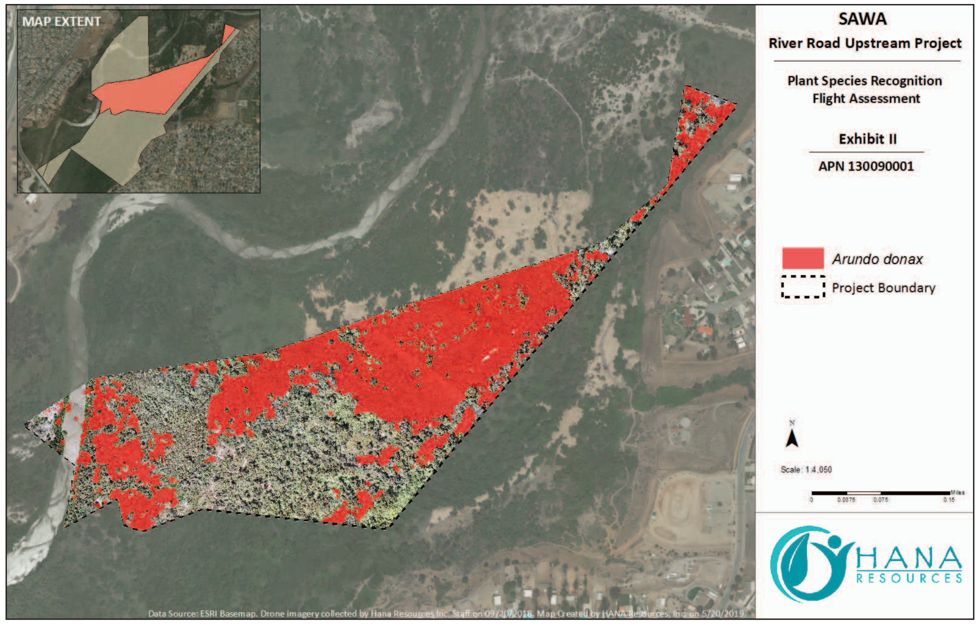
We used a more efficient approach called "deep learning," specifically Convolutional Neural Networks (CNN). Instead of hand-defining a set of rules and algorithms to extract features from an image, these features were instead automatically "learned" from the training process. (For those interested in the technical details, we applied a series of algorithms — convolution filters, nonlinear activation functions, pooling, backpropagation — and the CNN "learned" filters that were able to detect edges and structures in lowerlevel layers of the network. The network then used the edges and structures as "building blocks," eventually detecting higher-level objects such as faces or plant species. This process of using the lower-level layers to learn to identify higher-level features is the defining aspect of CNNs and was made possible by stacking a specific set of layers in a purposeful manner.)

For this project, HANA utilized a deep learning neural network to recognize, identify, and geographically map the *Arundo* plant species. The model was trained using the aerial images of *Arundo* we captured using the UAV. With these images, the model sought to classify images of the invasive plant species that the model had never seen before. (The CNN architecture consisted of convolutional layers, fully connected layers, and a classification layer, and the framework of the model used python code written using Tensorflow and Keras that accepted positive and negative data samples for plant identification.)

The positive samples included a sufficiently large dataset of *Arundo* images collected via UAV by HANA. In order to prevent overfitting, validation data was used by preserving and then utilizing a portion of the training data. Negative samples included an equally large dataset of images of plants and the environment typically found in an *Arundo*-infested area, including willow species. (Since this project's completion, HANA has patented this proprietary process: U.S. Patent No. 9,984,455.)

SAWA used the multispectral imagery depicting *Arundo* acreages to make informed decisions about the amount of *Arundo* removal and the costs of implementing the removal. This technology also allows for long-term site monitoring of this site using ultrahigh resolution aerials to compare *Arundo* growth over time and to detect changes in vegetation on a landscape scale. Limitations associated with conventional methodologies have been overcome by rapidly advancing technology. Remote sensing at a much larger scale removes issues associated with point-based monitoring methods, such as quadrats or transects, and is more representative of the area of interest's performance.



Project map detail showing Arundo concentration within APN 130090001. Notice the tan area just north of the concentration of Arundo. Here, Arundo was removed during another habitat restoration project for the U.S. Army Corps of Engineers.

All images courtesy HANA Resources, Inc.

HANA Resources' Inspire 1 taking off from a helipad along the Santa Ana River.

Tracking progress in Orange County

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populations of target species (Cal-IPC *Dispatch* Spring 2013) and cannot reliably detect several pernicious annuals, such as Saharan mustard or stinknet.

The success of this repeated survey and associated management lies in the strong collaboration of Nature Reserve of Orange County land managers Irvine Ranch Conservancy, OC Parks, and State Parks, and in the leadership and funding brought by NCC. The future success of this program — now complemented with an on-the-ground early detection/rapid response (EDRR) program — will hinge on tight collaboration, regular communication and coordination, and, as always, vigilance. We are excited to hear about this program's future work, including more in-depth local surveys by NCC and partners to track changes in native vegetation associated with control work.

For more information, see our project page at cal-ipc.org/