Invasive plant species mapping in the Santa Ana River Watershed

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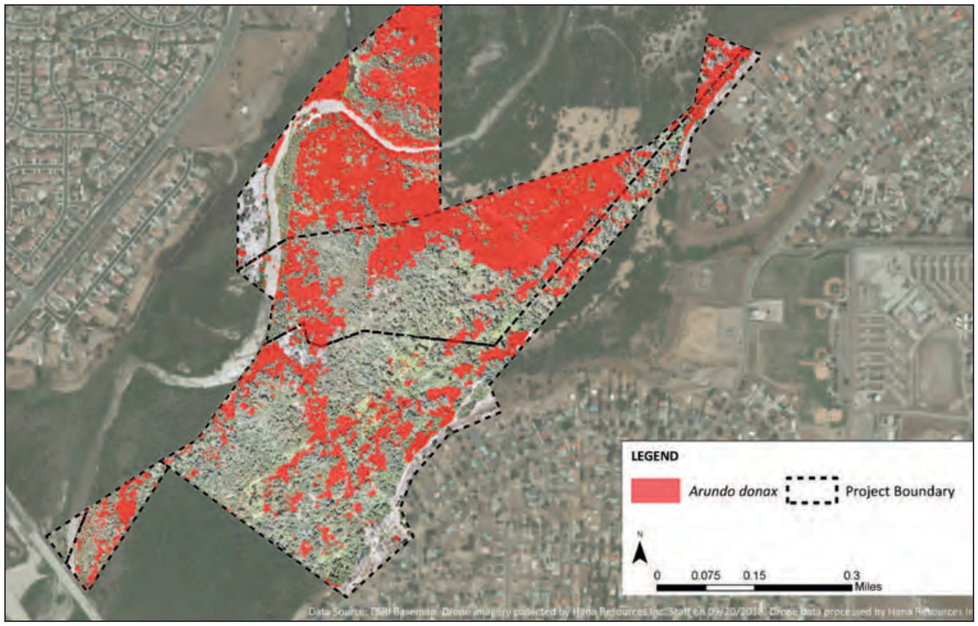
Removing invasive giant cane or giant reed (*Arundo donax*) from the Santa Ana River Watershed has been a goal for many resource conservation and habitat restoration entities for decades. For land managers, its towering size and impenetrable stands make its biomass difficult to quantify, which makes it difficult to estimate removal cost. This article describes an instance where an emerging technology has cracked this case.

In October 2018, the Santa Ana Watershed Association (SAWA) partnered with HANA Resources, Inc. (HANA) to determine the amount of *Arundo* on a 211-acre project site along the Santa Ana River in Norco, California. This consisted of an unmanned aerial vehicle (UAV) flight to obtain high-resolution aerial images and then processing those images through a computer vision algorithm to identify the plant species.

In older methodologies of computer vision through artificial intelligence, an algorithm was hand-defined to quantify a particular aspect of an image such as the image's shape, texture, or color. Given an input image, we would apply our hand-defined algorithm to the pixels of the image, and in return, we would receive a matrix of values or "features" quantifying the image contents. This matrix of values was what we were truly interested in, as they served as inputs to our machine learning models.

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"



Project map showing Arundo concentration within the 211-acre project site using aerial imagery and HANA's deep learning species recognition software (U.S. Patent No. 9,984,455).

Arundo Acreages

APN Areas	APN Acreage	Acres of *Arundo*	% *Arundo*
130080012	1.27	0.02	1.58%
130080015	7.11	2.12	29.82%
130090002	90.73	19.06	21.01%
130090001	63.34	29.22	46.13%
130080007	48.91	27.61	56.45%
Total	**211.36**	**78.03**	**36.92%**

This table shows the APN versus Arundo *acreage values within the project boundary calculated using the algorithm.*

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

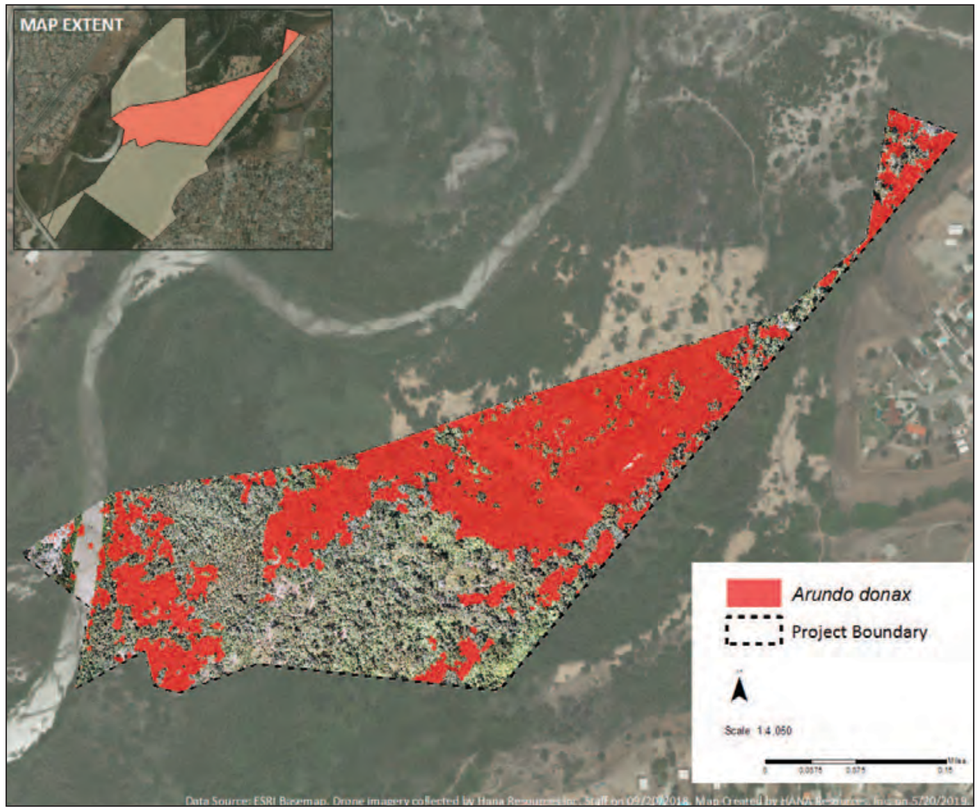
filters that were able to detect edges and structures in lowerlevel layers of the network. The network then used the edges and structures as "building blocks," eventually detecting higher-level objects such as faces or plant species. This process of using the lower-level layers to learn to identify higher-level 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.)

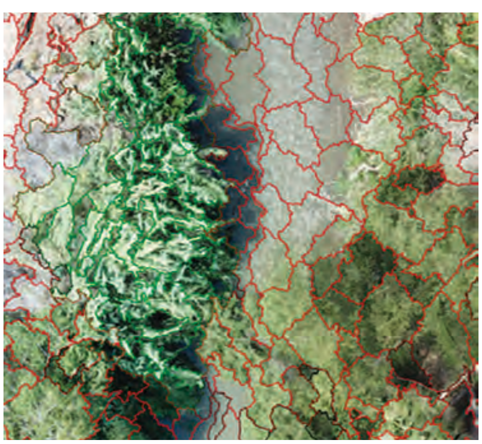
The positive samples included a sufficiently large dataset of *Arundo* images collected via UAV by HANA. In order to prevent overfitting, validation data was used by preserving and then utilizing a portion of the training data. Negative samples included an equally large dataset of images of plants and 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.

All images courtesy HANA Resources, Inc.



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.



A segmentation layer applied to the detection layer for high-accuracy acreage estimates.

Tracking progress in Orange County

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one survey technique is a silver bullet: helicopter surveys do not detect all 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.