The Potential for Restoration to Break the Grass-Fire Cycle in Dryland Ecosystems in Hawaii

Problem Statement

Tropical dry forest resources in Hawaii and the Pacific are declining at alarming rates. (< 10% their original cover). This loss of habitat for threatened and endangered species is largely a result of fire, that originates with invasion of native ecosystems by fire-prone exotic grass and shrub species (Fig. 1). These novel fire regimes have serious impacts to cultural and natural resources, and the health and safety of the region's citizens. We hypothesize that native forest rehabilitation and restoration may be the most cost-effective management tool to reduce fuel loads, fire danger, and fire impacts while also controlling invasive species establishment and spread.

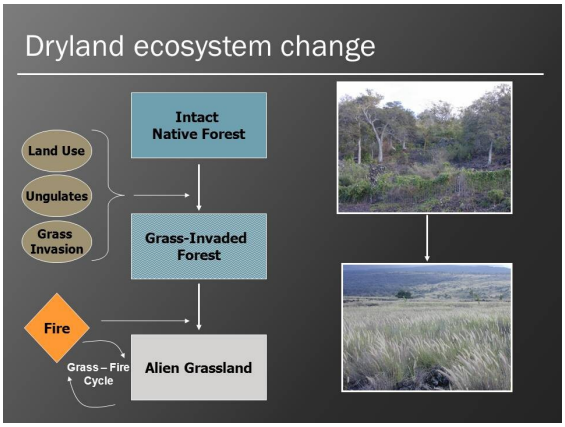

Fig. 1. *Our analysis of spatial patterns from historic records and remotely sensed data suggest that the primary driver for the conversion of native dry forests to exotic grass dominated systems is fire.*

Research Objectives

We are combining newly developed remotely sensed information with field based studies in dry forest regions on the Island of Hawaii. (Fig. 2) to:

- Define the current condition and historical changes to tropical dry forest ecosystems in Hawaii
- Develop technology for regional restoration planning and ecosystem monitoring
- Quantify restoration potential and develop restoration prescriptions for remnant Hawaiian dry forests and shrublands
- Develop effective fuel and fire risk reduction measures that protect dry forest fragments and initiate succession of degraded grasslands into native woody communities

Remote sensing methods include: a) analysis of historical aerial photography, b) high-resolution ecosystem mapping, c) field validation of remotely sensed data, and d) web-based satellite monitoring. Field based methods will address the potential for restoration of native species to alter ecosystem structure in a manner that reduces fine fuels and fire danger. This field-based effort includes: a) addressing the major barriers to restoration (i.e. grazing by non-native ungulates; invasion of non-native grasses; lack of native species seed and/or propagules; and absence of suitable microhabitat for native species) in a sequential manner across remnant native community types, and b) developing and testing the effectiveness of a firebreak design that incorporates traditional fuel breaks (i.e. strips with fuels removed mechanically) grading into "greenstrips" planted with fire resistant native species.

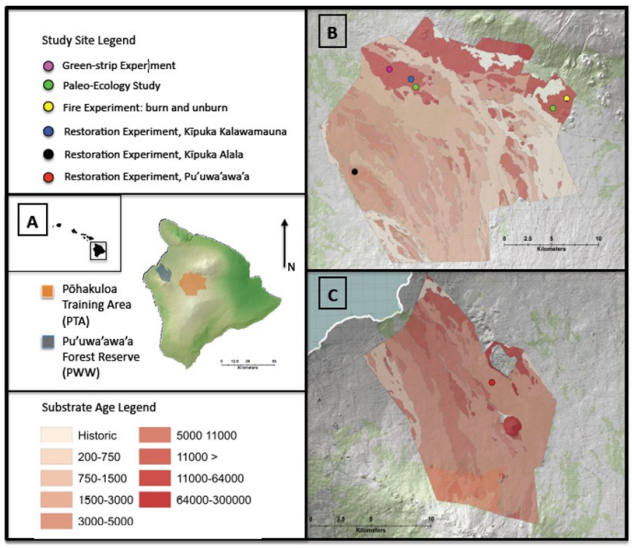

Fig. 2. *Map of research sites in dryland ecosystems in Pōhakuloa Military Training Area and the Hawaii Experimental Tropical Forest on the Island of Hawaii.*

Research Collaborators

- Carnegie Institution for Science
- University of Puerto Rico-Mayaguez
- University of Maryland
- California State Polytechnic University- Pomona
- University of Hawaii -Manoa

Funding and Support

- US Department of Defense
- Strategic Environmental Research and Development Program
- Pōhakuloa Military Training Area
- Hawaii Experimental Tropical Forest

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Pacific Southwest Research Station

Prioritizing Landscapes for Restoration

Native forest restoration may be the most effective management tool to reduce fire danger while also enhancing habitat quality and controlling the establishment and spread of invasive species. Natural resource managers are often faced with managing landscapes for multi-use activities. Better tools are required to make quantitatively based, transparent and un-biased decisions. Effective partitioning of the landscape will not only enhance native biodiversity but could potentially reduce management costs and alleviate social tension often associated with decision making. For example our work on vegetation composition in a large fenced unit at PTA indicates that while the fence unit is necessary to protect native habitat, it also increased fuel loading as a result of decreased grazing pressure (Fig. 3). Alternatively, native forest restoration may be the most effective management tool to reduce fire danger while also enhancing habitat quality and controlling the establishment and spread of invasive species. Fig.4 highlights areas of the landscape most suitable for differing land management scenarios.

Honohono (Haplostachys haplostachya) is one of 19 listed endangered species found in PTA. Department of Defense military installations in Hawaii contain more endangered species than in any other state.

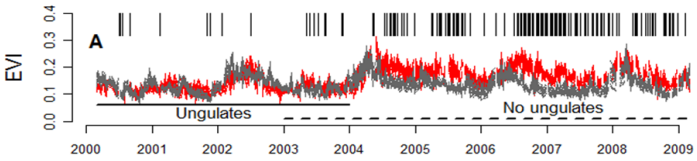


Fig. 3. *Enhanced vegetation index (EVI) is an index of vegetative "greenness" shown in a time series from MODIS for a dry forest community. The data contrasts a fenced area (red lines) in which exotic ungulate herbivores were removed in 2003 and a control site (gray lines) where ungulate numbers were not manipulated..*

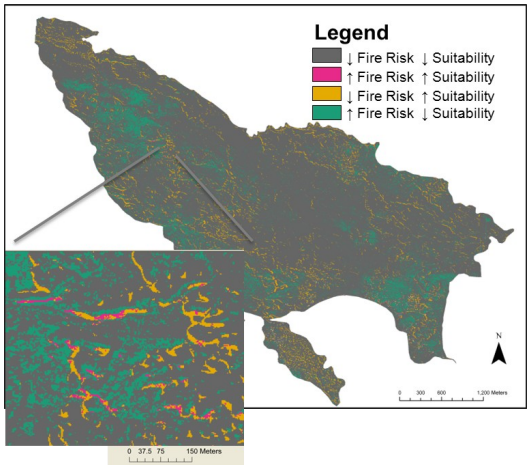


Fig. 4. *Combined Fire Fuels and Topographic Suitability maps to identify areas here particular restoration activities are likely to have the greatest impact.*

Assessing Restoration Potential

We have established field experiments that will simultaneously provide baseline data on small-scale fuel conditions and potential fire behavior within a range of dry forest community types, develop strategies for establishing sustainable populations of native species, and test the effectiveness of restoration of native woody cover as a tool to reduce fine fuel loads and potential fire danger.

Our ability to accurately predict habitat suitability for threatened and endangered species and native communities continues to improve as we now have plant performance data (plant physiology, growth, and functional traits), micro-climatic data, and species occurrence data from high and low suitability sites at PTA. Additionally, data on ungulate movement patterns and habitat use can refine our ability to effectively manage both the natural resources and the threats to those resources.

There is ample evidence that non-native ungulates (such as feral goats and sheep) negatively affect populations of native species in Hawaii, and most restoration practitioners remove ungulates at early stages in restoration.

Our results support the idea that microtopographic position and canopy condition can positively affect plant function and performance in dry ecosystems (Fig. 5). At the community level, plant heights, nutrients, and favorable micro-climate were greater in high suitability plots.

Our future work will evaluate how this technology can be applied to other DoD installations in order to guide endangered species management to increase plant survival, expand the extent of plant populations, and reduce costs associated with endangered species management programs.

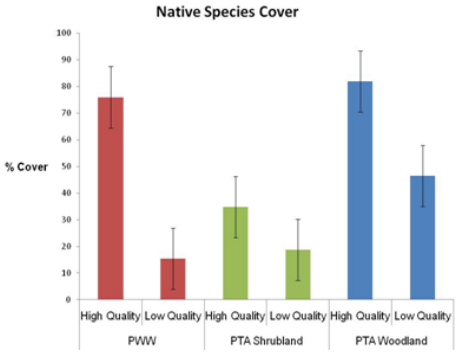
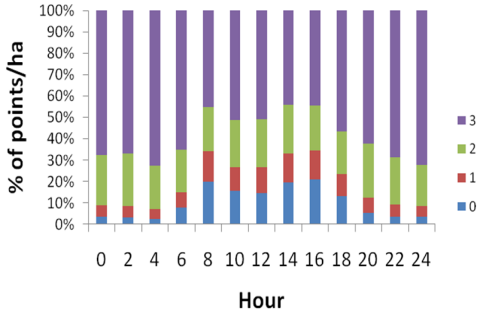


Fig. 5. *Cover of native species is greater in high suitability areas.*



Preliminary results on ungulate behavior indicate strong diurnal associations of animal movement and activity with vegetation structure and condition. A pooled analysis for location fixes by habitat type revealed an overall preference for Myoporum habitat (33%), a native shrubland. Feral goats spend a disproportionate amount of time in high suitability areas (Fig. 6).

Fig. 6. *Pooled data retrieved from collared feral goats indicate that goats spend the majority of the day in high suitability areas (shown in purple).*

New Tools to Reduce Fuel Loads and Increase Restoration Success

Greenstrip Planting to Reduce Fuel Loads

Greenstrip planting may be an effective fire reduction tool to protect remaining dry forest fragments and stop the spread of large fires across grass-dominated landscapes. Within large areas that have been completely converted to grasslands, restoration-based approaches should be targeted to enhance other fire and fuel reduction measures that are in place. Our experimental design that includes traditional fuel breaks (i.e. strips with fuels removed mechanically) in areas prone to ignition as well as "greenstrips" planted with fire resistant native species (Fig. 7). To assess the potential feasibility and effectiveness of greenstripping in Hawaii, we are addressing the following questions:

- What native species are suitable candidates for use in greenstrips?
- What site preparation and planting strategies are best to maximize success of greenstrip plantings?
- Do greenstrip plantings reduce fuel loads and alter fuel continuity in such a way as to reduce fire spread and intensity?
- Do greenstrip plantings reduce the spread of invasive species?

Fig. 7. *A greenstrip experiment in PTA, Hawaii*

Exotic grasses, such as fountain grass (Pennisetum setaceum), contribute high amounts of fine fuels that are able to carry fire across a dry forest landscape in Hawaii.

Webtool for Monitoring Fire Risk Conditions

This research webtool (http://hawaiifire.stanford.edu) combines Carnegie and NASA technology for monitoring of near-current and historical fire risk conditions on the Island of Hawaii. The glider at the bottom of the screen allows the user to change the satellite date of the image and a click on the map provides the history of any point on the ground back to 2005 (Fig. 8). Each time-graph is downloadable.

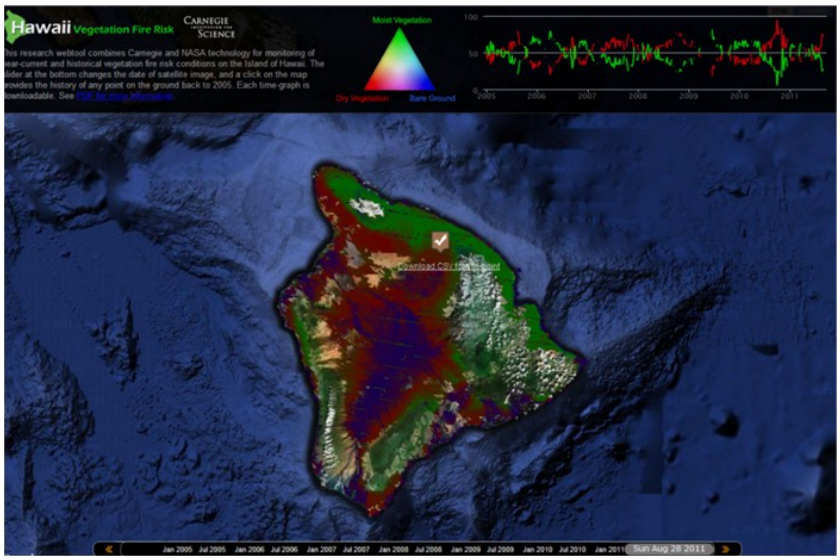


Fig. 8. *User interface of the webtool*

"We have developed a web-based version of our fire fuel index algorithm that covers the entire Island of Hawaii to allow land managers to track both current and historical (since 2005) high fire risk days for their operations"

New Tools and Approaches to Managing Wildfire

In Hawaii, wildfires have deleterious effects on native plants and animals, water quality, human life, and property with future climate warming anticipated to greatly exacerbate wildfire hazards. Land managers and decisions makers are requesting improved capacity to predict fire behavior and effects. A workshop for land managers, decision makers, and scientists was held in November 2011 at the Institute of Pacific Islands Forestry in Hilo, Hawaii (Fig. 9) to highlight:

Fig. 9. *A break out discussion during the fire workshop*

- Current and relevant wildfire science
- Expand our fire predicative capacity

Results from our SERDP funded project have also catalyzed 2 important efforts related to altered fire regimes; 1) we have secured funding to expand our fire modeling efforts at PTA to include scenario building comprising the anticipated role of climate change on fire in dry systems in Hawaii; and 2) the formation of the Pacific Fire Science Consortium – A means of transferring knowledge between scientists, resource managers, decision-makers, fire suppression agencies, and communities in Hawaii and the U.S. Affiliated Pacific and a structured forum and process for identifying and prioritizing critical new areas of fire research.

Restoration research following a 2010 wildfire that burned critical habitat of the endangered Palila honeycreeper (Loxioides bailleui) in PTA.

Looking at the Past to Look to the Future

Historical Changes in Dryland Ecosystems in Hawaii

An area converted from a tropical dry forest to a grassland dominated by fountain grass (Pennisetum setaceum) on the Island of Hawaii.

Linking historical records with advanced remotely sensed data, such as measurements from airborne LiDAR or imaging spectroscopy, could help to interpret causes of contemporary vegetation patterns. We used aerial photography from 1954 and airborne LiDAR and imaging spectroscopy from 2008 to infer changes in the extent and location of tall-stature woody vegetation in 127 km^2 of subalpine dry forest in PTA (Fig. 10). Total cover of woody vegetation in 1954 was 54.7 km^2 and actually increased to 58.6 km^2 in 2008. However, as noted in figure 10, large tracts of formerly forested land were deforested—and spatial patterns suggest that fires may be the primary driver of forest reduction. Increases in forest cover could be due to regeneration of dry forest trees or measurement errors associated with historical imagery. Areas remaining in woody vegetation cover over the 53-year study interval can be specifically targeted for restoration and management activities.

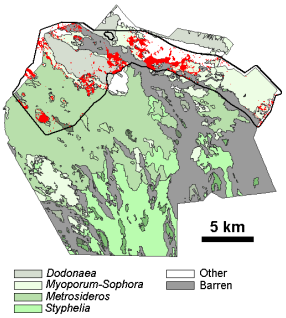


Fig. 10. *Net reduction in woody vegetation cover between 1954 and 2008 (red areas). Many apparent changes were associated with short-stature woody vegetation and could be spurious.*

Working with multiple partners provides unique opportunities to pool resources and effectively evaluate potential restoration actions for land management.

To assess forest decline in dryland ecosystems is a critical first step to developing effective management and restoration efforts. To set dry forest restoration targets managers need to understand the natural baselines and human modifications to the landscape.

This work takes a novel approach using remotely sensed vegetation patterns across a complex array of substrate ages to depict successional trajectories of tropical dry forest in Hawaii. Here we focus on the importance of natural and/or anthropogenic disturbance events in shaping the pathways of primary succession. Primary succession in forests is characterized by a process called long-term forest decline, whereby forests accumulate biomass and three-dimensional stature relatively quickly, but then enter a regressive phase where forest biomass is lost. We characterized the structure and composition of dry forest communities over space and time using a combination of Hyper-Spectral and Light Detection and Ranging (LiDAR) remote sensing with in-situ paleo-geographic techniques (Fig. 11). We argue that the structure and composition of Pōhakuloa's communities decline over time in response to limits in nutrient availability facilitated by fire. These findings offer new insights about the general principles of the long-term feedbacks between biological communities and pedogenic processes, and how these control ecosystem development.

Fig. 11. *Excavating a soil pit to collect charcoal samples for isotope and radiocarbon analysis.*

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Relevant Publications

Refereed Journal Articles:

Thaxton, J.M., Cordell, S., Cabin, R.J., Sandquist, D.R. *In press* Non-native grass *Pennisetum setaceum* decreases water availability and seedling performance during Hawaiian dry forest restoration. Restoration Ecology.

Kellner, J.R. Asner, G.P., Ambagis, S., Cordell, S., Thaxton, J, Kinney, K.M., Kennedy-Bowdoin, T., Knapp, T., Questad, E *In press* Potential and limitations of historical aerial photography to quantify vegetation dynamics in a tropical dry forest in Hawaii. Pacific Science.

Kellner, J.R., Asner, G.P., Kinney, K.M., Loarie, S.R., Knapp, D.E., Kennedy-Bowdoin, T., Questad, E., Cordell, S., and Thaxton, J. 2011. Remote analysis of biological invasion and the impact of enemy release. Ecological Applications. 21(6) 2094-2104.

Chynoweth, M., Litton, C.M.., Lepczyk, C.. and Cordell, S. 2010. Feral goats in the Hawaiian Islands: understanding the behavioral ecology of nonnative ungulates with GPS and remote sensing technology. In: Timm, R.M.; Fagerstone, K.A., eds. Proceedings of the 24th Vertebrate Pest Conference; 2010, 41-45.

Thaxton, J.M., Cole, T.C., Cordell, S., Cabin, R.J., Sandquist, D.R., and Litton, C.M. 2010. Native species regeneration following ungulate exclusion and non-native grass removal in remnant Hawaiian Dry Forest. Pacific Science. 64, 533-544