HAWAI'I ISLAND DRYLAND RESTORATION SCIENCE

AN OVERVIEW AND LIST OF REFERENCE PAPERS

From Dr. Susan Cordell

OVERVIEW

Destruction of the world's tropical rain forests has received tremendous media attention, yet globally tropical dry forests are far more endangered. In Hawaii, over 90% of the original dry forests are now gone, compared with 42% of Hawaii's original rain forests. Remnant patches of Hawaii's diverse and once extensive native dry forests continue to be degraded as a result of land development, fire, grazing by nonnative ungulates, and invasion by alien plants. This degradation is so extensive that there is little hope these systems can recover without active management including the reintroduction of native species. Even within a nearly pristine dry forest fragment on the Island of Hawaii (the Kaupulehu Preserve) where ungulates have been excluded for 40+ years, invading understory grasses have completely eliminated the regeneration of native canopy trees. Historically restoration efforts have focused on the reduction of competition by problematic existing vegetation (Gomez-Aparicio 2009) and species replacement with an emphasis on late successional and often rare and federally listed endangered species (Cordell et al. 2008). This approach has limited success (see outplant paper), is cost prohibitive, and provides virtually no solid blueprint towards ecosystem level restoration.

APPROACH

To understand how this endangered ecosystem can be saved, a team of scientists, students, and collaborators, have conducted research over the past decade to understand the reproductive, physiological and environmental constraints on the regeneration of native dry forest species. Our results have shown that with appropriate management native species can persist. Further, once native species are established, long-term efforts to control re-invasion by exotic grasses are greatly minimized. Our research has been critical to designing the first prescriptions for dry forest restoration in Hawaii, including science based procedures and products for controlling invasive grasses, amending the system with an appropriate native species mix to gain control of the understory, follow up weeding, and continued protection of existing and developing regeneration from animals and fire (See Tables 1 and 2). Our research has provided the first successful demonstrations of dry forest restoration in Hawaii while raising awareness of invasive species impacts on the biodiversity and functioning of this endangered ecosystem. Today, we continue to provide leadership and information to private landowners and country, state and federal agencies designing and managing native plant restoration efforts in Hawaii. Our work has been published in a variety of journals and popular press pieces, and has gained international attention.

Table 1: The impact of various restoration activities on tropical dry forest restoration. A + indicates a positive response, a – equals a negative response, and a +/- indicates a response that could either be positive or negative. A dry forest restoration prescription can be interpreted by the use of a sequential set of activities with positive responses. For example, using this table, native species persistence is likely if the area is fenced, followed by invasive species control, favorable sites are selected for early succesional species amendments with supplemental water, and follow up invasive species control.

Restoration Activities	Citation	Response				
		Reduced ungulate damage	Decrease in invasive species	Increased native propagule availability	Improved micro-climate	Sustainability of practice
Fencing	1	+	+/-	NA	NA	+
Invasive species control*	1-17	-	+	+/-	+	+/-
Favorable site selection	2,5,6,15	-	-	+/-	+/-	+
Initial and supplemental water	2,3,5,6,14	-	+/-	+/-	+	+/-
Early successional native species amendments	2,5,6, 11, 12,13,14, 15	-	+	+	+	+/-
Late succesional native species amendments	2,5,6, 11, 12,13,14, 15	-	-	+/-	+/-	+/-
Post removal weeding	14, 15	-	-	+/-	+/-	+
Prescribed fire	16,17	+/-	-	-	+/-	-

Table 2: Science based results and information towards restoration of native species, impacts of *Pennisetum setaceum* (fountain grass), and traits of dry forest species within a tropical dry forest in Hawaii

Study – Restoration of native species	Methods	Results	Conclusion	Citation
Effect of Exclosure	Plant surveys inside and outside of exclosure	No difference	Fencing alone is not an adequate strategy	1
Effect of Weeding	Weed whack and herbicide application across 2.3 ha of a canopy intact, disturbed understory forest	Increase in native weedy shrubs and vines, little regeneration of canopy trees	Forest regeneration requires aggressive management	1,13
Effect of weeding, microsite, and supplemental plants and water	Native species amendments across an experimental design of weeded/non-weeded, watered/non-watered, shaded/non-shaded	Fountain grass is slow to recover, natives survive despite new non-native invaders, species survival was greater under existing canopy trees	Shade is important, native species can persist, weedy natives may promote native restoration	2,5,6
Grass removal techniques	Native species amendment survival across an experimental design of three fountain grass removal techniques: Scraping, black plastic, and herbicide/weed whack	After two years scraping treatment had the lowest abundance of grass and highest percent cover of natives	The bulldozer is an effective tool to control fountain grass	6
Species specific Attributes	Native shrub, vine, and tree survival across all experiments	Native vines and shrubs had the highest survival	These species should be preferentially selected for restoration projects	2,5,12,14
Seed and seedling dynamics	Native and non-native seed dynamics within three restoration units that differed in time since initiation of ungulate exclusion and grass removal	Native seedling abundance was highest in the long term unit	Native species natural recruitment is more likely to occur only when restoration activities have been maintained for several years	11

Broadcast seeding as a tool to reestablish native species in highly degraded systems	Three treatments including broadcast seeding with pre-treated seeds, herbicide, and 3) broadcast seeding with pre-treated seeds and herbicide	Native seed germination was highest in the broadcast seeding and herbicide treatment	Many broadcast seeds did not germinate, however the favorable habitat created from the herbicide facilitated native shrub and vine species to germinate	11
Use of fire to facilitate native species regeneration	Plant community surveys following a prescribed burn	Fountain grass recovered quickly following the prescribed burn, and facilitated recruitment of other problematic non-native species. Very few native species were recruited	Reduction of the fountain grass canopy through fire appears to open a niche for invasion by other dominant non-native species	16,17
Sustainability	Experimental manipulation from experimental plots (i.e. shade structures and supplemental water) were stopped and survival measured 4 years later	The method of initial grass removal affected native species richness and fountain grass abundance	Disturbance influenced invasion by increasing colonization opportunities	15

Study – Impacts of FG				
Competition for Resources	Fountain grass removed from the understory of a native canopy dominated site	In the absence of fountain grass native trees used a higher proportion of water from shallow soil sources, produced thinner leaves, and grew in diameter 40% more than trees growing with fountain grass in the understory	Fountain grass has a negative impact on resource acquisition and use by native trees	10
Fire adaptation	Field studies of fire passing over exposed and buried fountain grass seeds	Fountain grass seeds at the soil surface do not survive fire, however seeds readily germinated it they were >2.5 cm below the surface	Prescribed burns could be a useful tool for fountain grass control in larger degraded sites but only when coupled with additional restoration measures.	16,17
Competition for space	Population structure comparison of native species in a pristine and	In the invaded forest there were no individuals found in the sapling stage	Invaded forests are not adequately regenerating	7

	fountain grass invaded dry forest			
Long term carbon dynamics	Measured carbon pools and fluxes in native, canopy intact and fountain grass converted sites	Above ground biomass was similar in native and canopy intact sites but 93 % lower in converted sites. Only 3% of the carbon pool is derived from grass. Carbon efflux was 40% greater in grass plots	Large changes in carbon sequestration have occurred following widespread grass invasion. Grass invasion in forest ecosystems can increase the flux of C into and out of soils without changing total C pools	7,9

Study – Traits of Dry forest species				
Species diversity	Measured plant diversity in 53 5 x 5 m plots	42 families, 60 genera, and 63 species of plants of which 17 were endemic, 19 were indigenous, and 27 were non-native	Hawaiian dry forests exhibit unique diversity, more native canopy tree species that wet forests	1
Functional diversity	Measured carbon gain, water use and leaf allocation traits for 6 dry forest tree species	Trees ranged from those with high productivity to low(2 fold difference in carbon gain), and from high drought tolerance to low (3 fold difference in water use)	The functional diversity of spans a broad spectrum	8

HAWAII DRYLAND FOREST ECOLOGY RESEARCH TEAM AS OF 2010:

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Dr. Darren Sandquist – Associate Professor, California State University, Fullerton (CSF)
Dr. Creighton Litton – Former: Post-doctoral researcher, CSU and USDAFS, Current position: Assistant Professor NREM Dept. UH Manoa, Honolulu HI
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Alan Urakami – Former: Biological technician, USDAFS, Current position: Retired

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