Observational Field Assessment of Invasiveness for Candidate Biofuels in Hawai‘i

Prepared for the

U.S. Department of Energy
Office of Electricity Delivery and Energy Reliability

Under Cooperative Agreement No. DE-FC26-06NT42847
Hawai‘i Distributed Energy Resource Technologies for Energy Security

Subtask 12.1 Deliverable (item 3)
Report on Bioenergy Analyses

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And submitted to

Hawai‘i Natural Energy Institute
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September 2012

Acknowledgement: This material is based upon work supported by the United States Department of Energy under Cooperative Agreement Number DE-FC-06NT42847.

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August 2012

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Summary

Five biofuel crops were observed from May-August 2012 for evidence of escape and invasiveness. Observations were made around field plantings of banagrass, Jatropha (*Jatropha curcas*), *Eucalyptus grandis*, African oil palm (*Elaeis guineensis*) and arboreal Leucaenas found on Oahu, Maui, Hawai‘i and Moloka‘i . Observations are reported on distance and degree of spread away from plantings. Risks are assessed and recommendations are made for each species, based on our current field experience and evidence of invasiveness in Hawai‘i. Behavior of these plants could change in the future. Growers should adopt standard mitigation practices in order to minimize invasion risks and impacts of biofuel crops.

Background

The Hawaii Bioenergy Master Plan (HBMP) identifies potential invasiveness as an important risk to be considered in choosing biofuel crops in Hawai‘i. Invasive species in Hawai‘i have already imparted substantial economic costs as well as ecological harm in the Hawaiian Islands, so serious efforts should be made to avoid invasive biofuels. Weed Risk Assessment (WRA) was identified by HBMP as an established tool for evaluating risk of invasiveness among candidate biofuels. The Hawai‘i-Pacific Weed Risk Assessment (HPWRA) is modeled after the Australian WRA system and uses a series of questions about a plant's ecology, history of weediness in other parts of the world, noxious traits, and climatic tolerance to derive a risk score. A high score (> 6) reflects a high level of risk. During development of the HBMP, several candidate biofuels were evaluated using HPWRA. A number of number of plants with strong biofuel potential received high HPWRA scores and were rated as high risk (Table 1)

Table 1. Weed risk assessment results for selected candidate biofuels.

Biofuel Crop	**HPWRA score**	**Weed Risk**
Sugarcane (*Saccharum officinarum*)	-2	Low
Banagrass (*Pennisetum purpureum?*)	16	High
Eucalyptus (*Eucalyptus grandis)*	11	High
Leucaena (*Leucaena leucocephala*)	15	High
Jatropha (*Jatropha curcas*)	17	High
African Oil Palm (*Elaeis guineensis*)	10	High

Sugarcane, which has a long history of widespread planting in the Hawaiian Islands, was rated as low risk of becoming a weed, while the other major biofuel candidates were rates as 'high risk' by HPWRA (note that HPWRA was not used to rate algae and potential invasiveness of biofuel algae is not addressed in this report).

The overall accuracy of the HPWRA system in identifying invasive pest plants is 80-85%. Although HPWRA scores provide a good general assessment of risk that a plant will become an agricultural or environmental weed (i.e. an invasive plant), in some cases, species with high HPWRA scores may not become invasive weeds.

The HPWRA method of assessment relies primarily on general information about the species and its behavior elsewhere. However, if a plant already has a history of planting in Hawai‘i, then field observations from Hawai‘i should also be factored into an assessment of risk. Most of the major biofuel candidates (Table 1) have already been planted in Hawai‘i, but in general, formal field observations have not been made to assess evidence of their escape from plantings or their state of naturalization and spread (if any) from around established plantings.

To address this information gap, we made observational field assessments of candidate biofuels that have already been planted in Hawai‘i. Field assessments consisted of visiting plantings and quantifying any evidence of spread away from plantings as well as discussing the plants'

behavior with experts who are familiar with the plantings. We record information on presence of any self-sown adult plants, seedlings, and/or vegetative spread away from original plantings. We focused on five candidate species: *Pennisetum purpureum, Eucalyptus grandis, Jatropha curcas, Elaeis guineensis,* and *Leucaena* improved arboreal hybrids. Field sites for observation of these species included Oahu, Hawai‘i, Moloka‘i and Maui.

Methods

Field sites

Planting sites were located through the assistance of information provided by ISCs (island invasive species programs), agriculturalists, foresters, land managers, and professional botanists. The target was to identify and visit four or five field sites per species listed in Table 1 (with the exception of sugar cane, which was not assessed). Upon identifying candidate sites, permission was obtained from land owners and/or plant owners to make observations around the plants. Whenever possible, information on the approximate age of plantings was recorded.

Field surveys

At each planting site, line transect surveys were made to quantify any escape from the original plantings. After noting the extent of each planting, 50 m long transects were established on each of four sides (whenever possible) around the planting. The transects were placed parallel to the planting at distances of 1 m, 5m, and 20 m. If the planting are was smaller than 50 x 50 m, then the survey transect at 1 m from the planting was defined as the actual length of the planting on each side. Escaped (self-sown) biofuel plants (including seedlings) were then counted within a 1 m wide belt along each transect. Upon completing the transect surveys, a broader search for escapees was made, recording the furthest distance(s) of any escapes from the original planting.

Results and Discussion

A total of 50 field plantings were visited between May and August 2012 on the islands of Oahu, Maui, Moloka‘i and Hawai‘i (Appendix 1). The degree of spread seen for each plant species often varied by site, and this variability is presented by summary graphs for each species. General description of spread and apparent risks are also provided for each species.

Banagrass observations

The species status of ‘banagrass’ in Hawaii is uncertain. It could be a hybrid between *Pennisetum purpureum* (napier grass) and *P. glaucum* (pearl millet), or it could be a variety of napier grass, or both taxa might be present in Hawai‘i. We observed at least two distinct forms of banagrass (green and purple) (figure 1). The green form was variable in phenotype (size, degree of pubescence, etc), this morphological variability might reflect genetic variability, or it could be due to different growing environments or ages of the observed plants.

Purple banagrass was observed on Oahu, Maui and Molokai, and Hawai‘i. Purple banagrass appears to have been introduced to Hawai‘i in the 1970’s or earlier. We never observed flowering, and everyone familiar with this plant indicated that it does not flower.

Vegetative propagation has been used to establish new plantings at different sites. It is possible that purple banagrass in Hawai‘i represents a single genetic clone. If purple banagrass does not flower, there is no risk of spread by seeds. We found no purple banagrass seedlings. Vegetative spread remains a possibility (e.g. through broken stems or plowing) and this was observed in the field at Mealani Research Station (Site ID 1).

Figure 1 Purple banagrass with sugar cane in the background, HC&S, Maui.

Unlike purple banagrass, green banagrass was observed to produce flowers. Flowering adds a new element of risk because the seeds are wind-dispersed, and if fertile seeds are produced, then banagrass spread could potentially be rapid. Eight inflorescence samples were examined from Waimanalo and Kunia sites (Oahu). Dissection of the spikelets showed that 6 of 8 samples were completely sterile; however in two samples (one each from Waimanalo and Kunia), caryopses (grass seeds) were observed in almost every spikelet. The caryopses were in varying degrees of development (Figs. 1 and 2), and germinability was not tested. Nevertheless, it is feasible that among the potentially millions of caryopses produced by these plants, at least some of them will be viable. The reason for variability in caryopses development among plants is unknown.

Figure 2. Banagrass caryopses from a plant growing at Kunia, Oahu. Scale bar = 1 mm

Figure 3. Banagrass caryopses from a plant growing at Waimanalo, Oahu. Scale bar = 1 mm

Some evidence of spread was found among 41% of the surveyed banagrass plantings (7 out of 17). When evidence of spread was seen, it was often due to vegetative spread, with stems sprouting within 1-2 m of the original plantings. Rooting of fallen stalks was observed at several sites (figure 4). The maximum distance that banagrass was recorded away from the original plantings was 20 m (figure 5). In many cases, observed plants located between 2 and 20 m from original planters were probably vegetative fragments. Vegetative fragments could have been spread during plowing of fields that border many of the plantings. In some cases, seedling establishment was strongly suspected, however we found no young seedlings, which could have provided clearer evidence of spread by seeds, and all sites where spread was seen were subjected to plowing or disking, which could have spread vegetative fragments. All individuals found away from original plantings were recorded growing on open ground, with little or no vegetation in their immediate surroundings (e.g. figure 6). Staff at the USDA Plant Materials Center and staff at the CTAHR Waimanalo Research Station said that green banagrass produces keiki by seed there, though only occasionally, and they are controlled when seen.

Figure 4. Fallen banagrass stalk, sprouting roots and shoots, Mealani agriculture station.

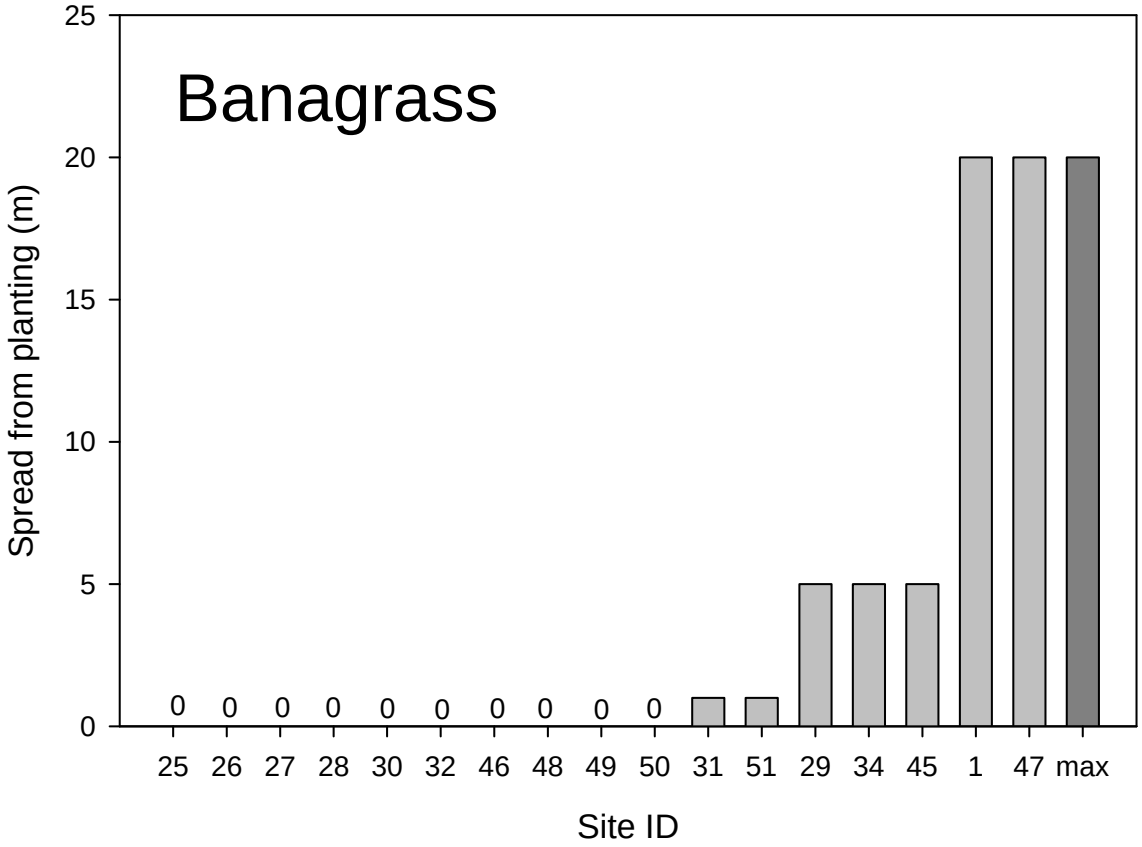

Figure 5. Spread of banagrass away from original plantings, arranged by distance of observed spread in surveyed transects. Maximum observed distance among all sites (max) is given by the last bar. Details about each site ID are given in Appendix 1.

Figure 6. A small banagrass plant (foreground) located ~ 20 m down-wind from flowering banagrass (background). This small plant might have established from a vegetative fragment, or it could be a seedling (Kunia, Oahu). Dry conditions at the time of observation had caused some die-back in the small plant, but it is poised to grow quickly in response to future rain.

Banagrass risk synthesis

The original HPWRA for banagrass was based on information obtained from *Pennisetum purpureum,* and the resulting risk score was very high (16, where >6 indicates high weed risk). *Pennisetum purpureum* is one of the world's worst agricultural weeds (Holm et al. 1977), and its dense growth prevents establishment of native plants on other Pacific islands such as the Galapagos (Mauchamp 1997). In Florida *P. purpureum* is a category 1 invader because it is "altering native plant communities by displacing native species, changing community structures or ecological functions" (http://www.fleppc.org/list/2011PlantList.pdf). In Hawai'i, *P. purpureum* is widely naturalized and weedy, found in mesic pastures, fields and along roadsides, with the first documented planting in 1922 (Wagner et al 1990). Banagrass being grown for biofuel trials is probably not wild-type *Pennisetum purpureum,* but its status in Hawai'i as a hybrid or domesticated cultivar(s) remains uncertain. Chromosome counts could be used to quickly assess whether banagrass varieties in Hawai'i are hybrids.

Purple banagrass is not documented as a weed anywhere in the world, and its lack of flowering and spread in Hawai‘i suggests that it poses little or no risk of becoming invasive. The situation for green banagrass is less clear. There might be more than one variety of green banagrass in Hawai‘i, and risks may differ among them, especially if they have different degrees of seed fertility. Introduction of new banagrass varieties could also increase seed production by allowing more opportunities for cross-pollination, which is generally required for seed production in *P. purpureum* (Holm et al. 1977). Establishment from wind-blown seeds, if it occurs, will be most frequent in mesic environments. We found occasional suspected seedlings growing around banagrass plantings, but we could not exclude the possibility that those plants originated from vegetative fragments. All of the escaped plants were in open areas, suggesting that establishment requires soil disturbance. In many situations in Hawai‘i, well-established, weedy grasses like Guinea grass (*Panicum* [*Megathyrsus*] *maximum*), may inhibit establishment of banagrass seedlings or vegetative fragments. Roadsides provide potentially suitable open sites for invasion, so care should be taken when transporting harvested materials. Banagrass generally provides good fodder for cattle, and we found evidence that it is attractive to grazing deer and feral ungulates. Grazers could play a role in controlling banagrass (and wild *P. purpureum*) in Hawai‘i, but only anecdotal evidence is available.

Based on field evidence obtained to date, from fairly recent plantings (usually < 10 years old), green banagrass has not become an invasive pest and it does not show signs of becoming a serious invader in Hawai‘i. With increasing planting acreage, sites at highest risk for initial spread are mesic roadsides, streamsides, and open, disturbed habitats. Such areas should be monitored in the vicinity of plantings, and any escapes can be eliminated with herbicide (e.g. glyphosate).

Jatropha observations

Jatropha curcas (Jatropha) produces a large crop of seeds, which can be harvested to produce biodiesel. Seedlings were found in great abundance at most planting sites. Some evidence of spread was found among 89% of the surveyed jatropha sites (8 out of 9). Among the more recent plantings on flat ground, most spread was within 1-2 m of the plantings; however at older and larger planting sites, evidence of much further spread was observed (Figure 7). Original plantings at the old plantation village at Hilea, Hawai‘i (Kau district) have spread over the last century to cover hundreds of acres of pasture and gullies. The seeds are easily dispersed by water and/or gravity. Another place where widespread dispersal away from an older planting can be seen is along Piilani Hwy, Maui (GPS coordinate 20.616635, -156.266882). Dispersal of seeds by machinery during harvest and seed processing helps to spread the plant quickly over long distances (Figure 9). Seedlings have a thick, succulent stem that allows them to tolerate drought after initial germination (Figure 8). In addition, cut or broken stem pieces on the ground were observed to root and resprout (Figure 10).

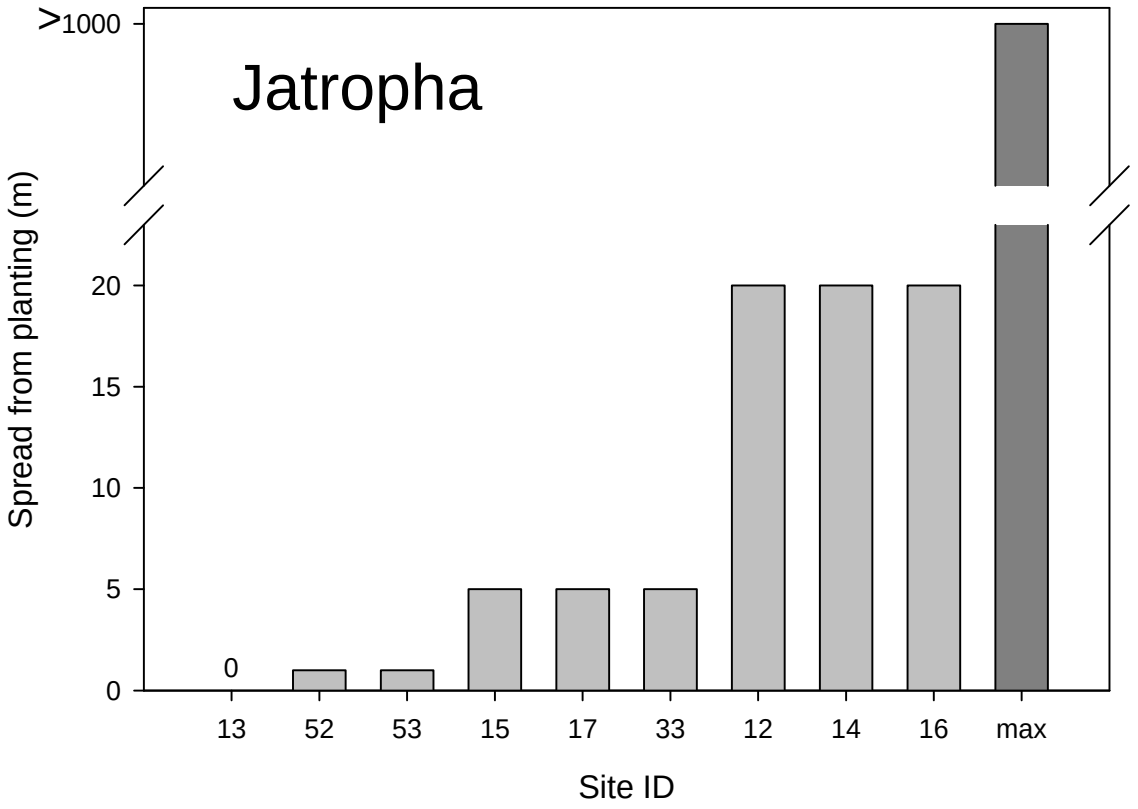

Figure 7. Spread of Jatropha away from original plantings, arranged by distance of observed spread in surveyed transects. Maximum observed distance among all sites (max) is given by the last bar. Note the break in the y-axis scale. Spread across hundreds of acres was documented at site 14. Details about each site ID are given in Appendix 1.

Figure 8. These Jatropha seedlings have dropped their leaves due to drought, however leaves will re-grow from their succulent green stems following rain.

Figure 9. Jatropha seedlings around a seed processing facility, Hilo Hawai‘i.

Figure 10. A cut Jatropha log has re-rooted (root seen at bottom) and is sprouting new leaves. Small cut stems that fall to the ground can also grow into new trees.

Jatropha risk synthesis

The original HPWRA for Jatropha indicated a very high risk score (17, where >6 indicates high weed risk). *Jatropha curcas* has spread as a weed around the world in almost every tropical environment in which it has been introduced. This behavior elsewhere helps to account for its high HPWRA score. Other factors contributing to the high score include propensity for accidental dispersal, toxicity to animals, and toxicity to humans. The main issue of controversy is whether *J. curcas* has become a serious weed (as opposed to a minor weed) where it has been introduced around the world (Hannan-Jones and Csurhes. 2008). From observations made in Hawai‘i during this study, it is obvious that *J. curcas* has great potential for extensive accidental spread during harvest and processing, as well as spread by water during seasonal rains. The main uncertainty is whether escaped Jatropha will develop into extensive thickets over time, resulting in important negative impacts on ranching or agriculture, and promoting further decline of rare native forests in seasonally dry habitats. A previous report from outside Hawai‘i indicates that Jatropha “can spread rather easily and create dense stands on uncultivated lands”

(Benge 2006) but no further details were given. Based on ~ 100 years of spread from a few trees planted at one site in Kau, Hawai‘i , Jatropha is now mainly growing as scattered plants or in small groups, although denser patches have developed in gulches. This trend is likely to continue over larger areas as more plantings are made. In the absence of active management, small patches may eventually coalesce to form large patches in pasture and drylands. The rate of Jatropha spread away from biofuel plantings could be slowed by restricting plantings to flat areas away from gulches, and by locating processing facilities close to plantings.

***Eucalyptus grandis* observations**

Eucalyptus grandis is a heavy seeder with seedlings and saplings regularly found under and near parent trees (100% of 10 sites surveyed, Figure 9). Seedlings were mainly found on bare soil such as road cuts or other disturbed areas. In areas where there is a thick layer of grass or other aggressive vegetation, seedlings were more inhibited. Seeds are tiny and can be carried by wind, although many capsules fall directly to the forest floor. The maximum observed distance of escaped plants was around 50 m. At this site on the Hamakua Coast (site ID 2), 1-2 m tall saplings were observed invading pasture. Considering that the height of *E. grandis* can exceed 40 m, seed rain can be expected within a radius of around double the tree's height (e.g. Cremer 1977), so some natural dispersal up to ~80 m could be expected for very large trees.

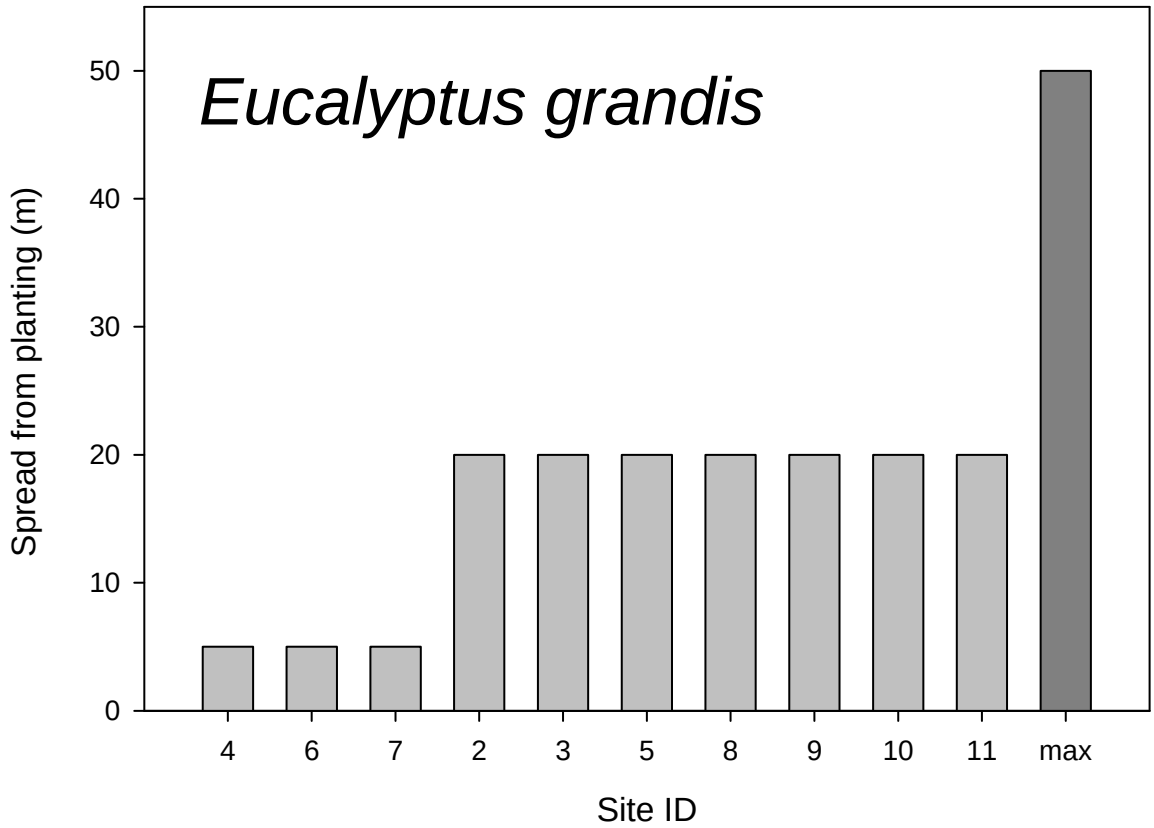

Figure 11. Spread of *Eucalyptus grandis* away from original plantings, arranged by distance of observed spread in surveyed transects. Maximum observed distance among all sites (max) is given by the last bar. Details about each site ID are given in Appendix 1.

Figure 12 *Eucalyptus grandis* saplings spreading from a plantation on the Hamakua Coast, Hawai‘i.

Eucalyptus grandis risk synthesis

The original HPWRA for *Eucalyptus grandis* indicated a fairly high risk score (11, where >6 indicated high weed risk). Four of the 11 points are attributed to *E. grandis*'s status as an environmental weed in South Africa. In South Africa, *E. grandis* is legally classified as a category 2 invader, meaning that it must be controlled and planting is prohibited unless within an approved planting zone. Nyoka (2003) subsequently ranked introduced trees in South Africa using an invasiveness scale (1-5, where 5 is the highest). Interestingly, among 8 Eucalypts rated by Nyoka (2003), *E. grandis* was the only one given a rating of 1 (lowest possible rating). Although *E. grandis* has clearly escaped from plantations in South Africa, there appears to be conflicting information about its status as an important environmental weed.

Our finding of escaped saplings ~ 50 m from planted trees in Hawai‘i raises concerns about the species' capacity to spread. On the other hand, saplings, which generally require bare soil and open areas to establish (Booth 2012), are relatively easy to spot and target for control. Also, control and /or eradication efforts are relatively easy because Eucalyptus seeds have a short lifespan, and any escaped plants will not produce seeds of their own for several years (Booth

2012), which provides more opportunity for effective control. The University of Florida Institute of Food and Agricultural Sciences (IFAS) has developed guidelines for planting *E. grandis* in Florida (http://plants.ifas.ufl.edu/assessment/), and some of those guidelines could help reduce *E. grandis* invasion risks in Hawai‘i: 1) Producer maintains at least a 75 ft. buffer between production area and all waterways and wetland areas 2) Producer annually monitors and eradicates all *Eucalyptus grandis* seedlings within a buffer of at least 200 ft. around the production area.

Oil palm (*Elaeis guineensis*) observations

Fruits of oil palm are harvested to make fuel, so plants that produce a large fruit crop (and many seeds) are desirable for this biofuel crop. At most of the visited sites (6 out of 8), no seedlings were observed (Figure 13), but these were mainly young plantings (around 5 years old). Although the young plants had already produced some fruits, opportunities for spread were limited. Among a few older plantings that were visited (>12 years old), seedlings were observed only within 5 m of plantings, and most seedlings were seen directly beneath the parent tree (Figure 14).

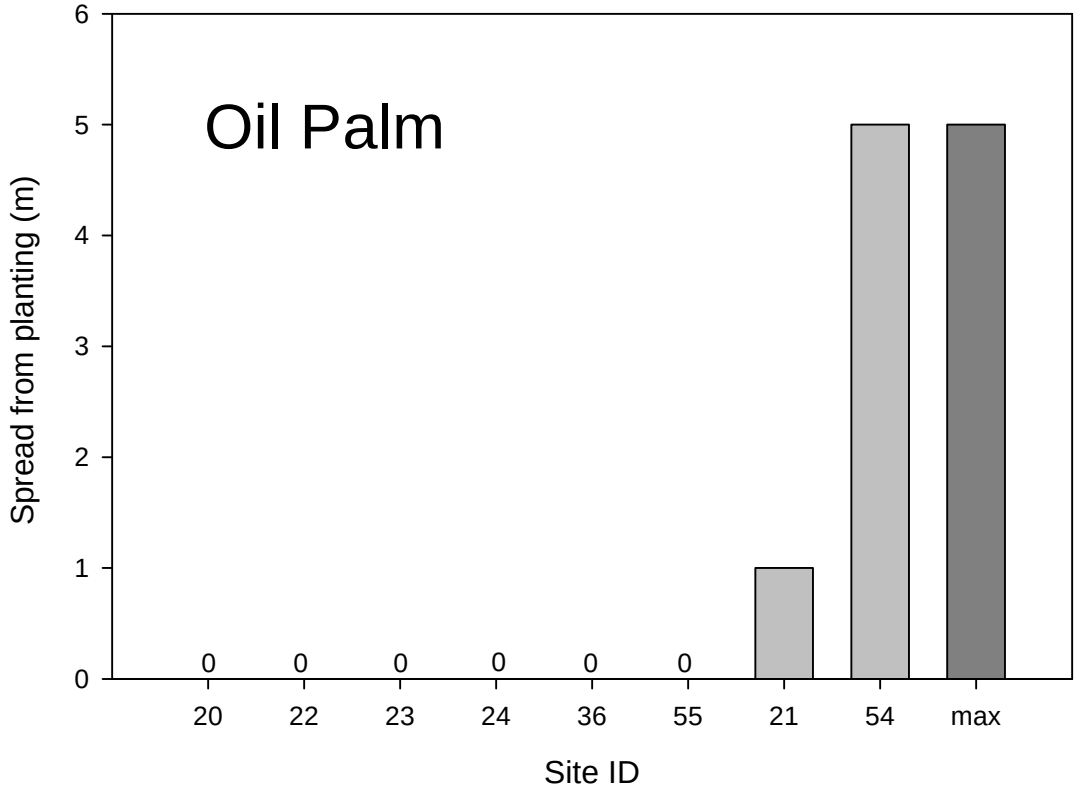

Figure 13. Spread of oil palm away from original plantings, arranged by distance of observed spread in surveyed transects. Maximum observed distance among all sites (max) is given by the last bar. Details about each site ID are given in Appendix 1.


Figure 14. Seedlings found beneath an oil palm plant growing on the UH Hilo campus.

Oil palm risk synthesis

The original HPWRA for oil palm (*Elaeis guineensis*) indicated a fairly high risk score (10, where >6 indicated high weed risk). Oil palm was not recognized as a "weed elsewhere" in the HPWRA. Instead, its high score was due to a suite of traits that together increase the risk that this species will become recognized as a weed. Those traits include prolific seed production, dispersal by birds, growth in a wide range of soils, resprouting after cutting or fire, sharp spines that can cause injuries, and pollen that is recognized as an important allergen in people.

In our field observations, we found no evidence that oil palm is spreading in an invasive manner in Hawai'i. The important caveat is that most of the plantings are only a few years old. One factor that may limit dispersal in Hawai'i is that the fruits are quite large (commonly exceeding 2.5 cm) and the birds currently present in Hawai'i may be unable to disperse the seeds. Feral pigs and rats are known to be attracted to the fruits (Donald 2004). Whether these animals will become effective dispersers of oil palm in Hawai'i is unknown. Oil palm has become locally naturalized from plantings on some Pacific Islands (e.g. Pohnpei and Raiatea). A similar situation might eventually be expected in Hawai'i, but widespread or dense invasion by oil palm seems unlikely.

Leucaena observations

Observations focused on arboreal Leucaena. There are plantings of many different species / hybrids / varieties, which probably differ substantially in their potential for invasiveness. No single species /hybrid / variety has, as yet, been identified as the primary candidate for biofuel. A total of seven plantings were visited, however at two of the sites (site ID 19 and 56), plantings of different varieties were so close together that it was impossible to attribute escaped plants to any specific Leaucaena species /hybrid / variety. Nevertheless, escaped arboreal plants were recorded 300 m or more from original planting areas and seedlings were often abundant around escaped trees (figure 15).

At the USDA Plant Materials Center on Molokai, observations were made on a few isolated arboreal plantings. Leucaena K1000 (*L. esculenta* x *L. leucocephala* ssp. *glabrata*) was planted around 10 years ago and shows no evidence of spread. The plants produce flowers, but apparently seeds are rarely produced or the plants may be sterile. In contrast, Leucaena K8 (a giant arboreal variety of *L. leucocephala*) was planted around 30 years ago and is fertile. Hundreds of seedlings were observed at distances as far as 50 m from the original planting. In general, the surrounding area was actively managed by mowing, but escapes were easily found. Leucaena KX3 (*L. diversifolia* x *L. leucocephala* ssp. *glabrata*) was planted around 10 years ago and produces flowers and pods but many seeds may be non-viable at this site. No spread from these plantings was observed.

At another site (Piiholo, Maui, site ID 57) with older plantings of *L. diversifolia* x *L. leucocephala* ssp. *glabrata*, escaped plants were spread across hundreds of meters in the vicinity of old NifTAL plantings (figure 16). At that site, the Maui Invasive Species Committee (MISC) has initiated control efforts, but plants quickly regrow from seeds in the seedbank. Another site where escape of arboreal Leucaena can be readily observed is at Puunene, Maui (Figure 17, GPS coordinate 20.874862,-156.440077)

Figure 15. Abundant arboreal Leucaena pods and seedlings around experimental plantings, Waimea, Hawai‘i Island.

Figure 16. Escaped arboreal Leucaena forming thicket at Haleakala Station - Piiholo, Maui (former NifTAL planting site) These plants were identified as hybrids between *L. leucocephala* and *L. diversifolia* (*L.* x *spontanea*) by taxonomists at the Bishop Museum herbarium.

Figure 17. Arboreal Leucaena spreading from a windbreak planting at Puunene, Maui. Escaped plants were found several hundred meters from the original planting.

Leucaena risk synthesis

The original HPWRA for *Leucaena leucocephala* indicated a very high risk score (15, where >6 indicated high weed risk). This species is a well-known invasive weed, and it forms extensive naturalized stands in dry areas across the Hawaiian Islands. The weedy plants are so far mainly a shrubby variety of *L. leucocephala* that can also develop into a small tree. However, "giant" Leucaenas and hybrids between different species can be found in experimental plantings. These taxa can have different growth characteristics and tolerances from shrubby *L. leucocephala*, and some of these taxa are of potential interest as biofuels. Sterile hybrids (e.g. the triploid hybrid between *L. esculenta* x *L. leucocephala* ssp. *glabrata*) seem to pose relatively little risk and could be propagated vegetatively (Sun et al. 1998). However, vegetative propagation at the scale required for biofuel would likely be cost-prohibitive, so seed-bearing varieties are the more likely biofuel candidates.

Field observations from Hawai'i indicate that seed-bearing arboreal Leucaenas are spreading from experimental plantings and also from recent plantings for windbreaks, and spread distances

are substantial (at least 300 m). Despite the limited number of plantings to date, money has already been spent by MISC in an effort to control escaping arboreal Leucaenas. Spread would probably be accelerated by large-scale biofuel plantings. Because Leucaena develops a persistent soil seed bank (Kuo 2003), preventing unwanted spread of these plants will be difficult over the longterm, and control costs are likely to be high.

Conclusions

All five biofuel crops examined in this study were rated as "high risk" by the Hawai'i-Pacific Weed Risk Assessment, and all five crops were observed reproducing in the field in Hawai'i. Nevertheless, three of the five crops (banagrass, oil palm and *Eucalyptus grandis*) showed little evidence of spread >100 m beyond plantings. Based on their current behavior and their ecology, these species seem unlikely to become serious weeds in Hawai'i. After establishing a formal management plan, escapes of these crops should be relatively easy to detect and control. Jatropha and Leucaena were observed at greater distances from plantings, and they sometimes developed into naturalized thickets. Jatropha plantings on slopes or near gullies pose substantial risk of spreading into neighboring habitats, and seed spillage during transport to processing facilities could greatly enhance Jatropha invasion rates in Hawai'i. Arboreal Leucaenas are highly variable. Some forms are sterile and pose little risk, but seed-bearing plants quickly build up a long-lived seed bank that can develop into Leucaena thickets at substantial distances from plantings. Seed-bearing Leucaenas will require persistent management at many sites to prevent their spread as weeds, and management of the germinating seedbank may be required for many years, even after plantings are removed or abandoned.

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Appendix 1. Field sites visited

ID	Species	Island	General Location	Specific Location	Slope	Dominant Wind Direction	General Vegetation	Notes about Planting
1	Banagrass	Hawaii	Waimea	Mealani Research Station	Flat to very slight	Trades, though occasional strong Kona as well	Maintaned station with trial plantings and mowed lawns. Surrounded by mid-elevation mesic pastures.	Planted as part of grass trials.
25	Banagrass	Maui	Kahului, Hawaiian Commercial & Sugar Company	Hansen Rd.	Flat	Strong trades	Old cane fields.	Planted for trials and cattle forage. Heavily browsed by deer, especially the purple bana.
26	Banagrass	Maui	Paia, Hawaiian Commercial & Sugar Company	Sunny Side Rd.	Flat	Strong trades	Cane fields.	Planted for energy trials, with secondary purpose of cattle.
27	Banagrass	Maui	Makawao, Hawaiian Commercial & Sugar Company	Pukalani	Moderate	Trades	Cane fields.	Grass trials.
28	Banagrass	Maui	Kahului, Hawaiian Commercial & Sugar Company	Waikapu	Flat	Trades	Cane field.	Part of grass trials.
29	Banagrass	Maui	Kula	Kula Experiment Station	Flat in planting, steep beyond terrace	Light winds	Maintained Experiment Station with mowed lawns.	Part of grass trials.
30	Banagrass	Maui	Ulupalakua Ranch	Greenhouse	Flat	Light trades	Greenhouse bordering pasture.	Planted for different forage trials. Plants not fenced are eaten by deer.

Appendix 1. Field sites visited

ID	Species	Number of Plants	Age of Planting	Flowering	Fruiting	Reproduction	<1m from Planting	1-5m
1	Banagrass	20m x 5m planting.	Original plantings in early 2000's. Currentplantings new, perhaps <2 years.	None.	None.	A bit of spread vegetatively by machinery used to plow field.	Occastionally rooting where canes fall over and touch ground.	A few canes were caught in tractor, tilled into nearby soil, and established new plants.
25	Banagrass	A couple plantings, both about 20m x 75m.	One section is about 4 months old, another is >1 yr. and has been cut back about 5 times.	None.	None.	None.	0	0
26	Banagrass	100m x 100m.	2 months	None.	None.	None.	0	0
27	Banagrass	50m x 50m.	~1 yr.	None.	None.	None.	0	0
28	Banagrass	50m x 20m	< 1 yr.	None.	None.	None.	0	0
29	Banagrass	A few replicates of 3m x 3m plantings.	One planting ~1 yr. old, another >2 years old.	None.	None.	Occasional rooting at nodes from canes that fall over.	Occasional rooting at nodes from canes that fall over.	Occasional rooting at nodes from canes that fall over.
30	Banagrass	One 2m x 2m planting and a 15m x 1m row.	~1 yr.	Green bana flowers, purple does not.	Green bana produces inflorescences, purple does not.	None.	0	0

Appendix 1. Field sites visited

ID	Species	5-20m	Maximum Distance Observed (m)	Date	Lat	Long
1	Banagrass	A few canes were caught in tractor, tilled into nearby soil, and established new plants.	15	20120718	20.03475415	-155.6075041
25	Banagrass	0	Spread not seen	20120711	20.8708907	-156.4481116
26	Banagrass	0	Spread not seen	20120711	20.89604471	-156.3993557
27	Banagrass	0	Spread not seen	20120711	20.83126542	-156.3626508
28	Banagrass	0	Spread not seen	20120711	20.85435245	-156.4673287
29	Banagrass	0	3	20120620	20.75654176	-156.3189306
30	Banagrass	0	Spread not seen	20120608	20.64946875	-156.4000113

Appendix 1. Field sites visited

ID	Species	Island	General Location	Specific Location	Slope	Dominant Wind Direction	General Vegetation	Notes about Planting
31	Banagrass	Maui	Ulupalakua Ranch	Old Strawberry Farm	Slight	Trades	Previously cultivated. Now pasture.	Part of forage trials. Grew large until cattle introduced into area. Plants now heavily browsed and barely 1m tall.
32	Banagrass	Maui	Waihee	Residence	Flat at planting, slight beyond	Strong trades	Residential surrounded by abandoned pasture.	Small planting for wind break and forage. Cut back a few times.
34	Banagrass	Molokai	Hoolehua	USDA Plant Materials Center	Moderate	Strong trades	Maintained Experiment Station with mowed lawns. Dry area.	Part of grass trials.
45	Banagrass	Oahu	Waimanalo	CTAHR Waimanalo Research Station	Flat	Trades	Maintained Experiment Station with mowed lawns, some unkept vegetation around plot.	Biofuel trial; green
46	Banagrass	Oahu	Waimanalo	CTAHR Waimanalo Research Station	Flat	Trades	Maintained Experiment Station with mowed lawns, some unkept vegetation around plot.	Biofuel trial; mixed green and some purple
47	Banagrass	Oahu	Waimanalo	CTAHR Waimanalo Research Station	Flat	Trades	Maintained Experiment Station with mowed lawns; recent plowing	Windbreak

Appendix 1. Field sites visited

ID	Species	Number of Plants	Age of Planting	Flowering	Fruiting	Reproduction	<1m from Planting	1-5m
31	Banagrass	Two rows of 100m x 1m.	~ 5 yrs .	None.	None.	Rooting at nodes where canes fall over.	A few.	0
32	Banagrass	2m x 1m.	2 yrs.	None.	None.	Rooting at nodes where canes fall over.	0	0
34	Banagrass	A couple small plantings (2m x 2m) and a long planting 3m x 100m.	Planted in the mid-1980's.	Some on green. None on purple.	Some on green. None on purple.	Slight sexual spread observed by station staff from green bana once and a while, but not a lot. Purple bana regrowing in old spot where it had been cut to the ground and mowed.	Some rooting at nodes where canes touch the ground.	Some rooting at nodes where canes touch the ground.
45	Banagrass	60 x 10 m	1 yr.	Yes.	Low seedset	Yes	49 (included vegetative)	9 (seedlings or fragments)
46	Banagrass	15 X 25 m	1-2 yrs.	Yes.	Low seedset	None	0	0
47	Banagrass	windbreak ~ 2 m wide bordering 65 x 115 m and 55 x 110 m fields,	1 yr.	Yes.	Low seedset	Yes	26	6

Appendix 1. Field sites visited

ID	Species	5-20m	Maximum Distance Observed (m)	Date	Lat	Long
31	Banagrass	0	1	20120608	20.63680117	-156.3798158
32	Banagrass	0	Spread not seen	20120614	20.94832851	-156.5160562
34	Banagrass	None.	2	20120702	21.14238029	-157.100969
45	Banagrass	0	2	20120612	21.336149	-157.71311
46	Banagrass	0	Spread not seen	20120612	21.336149	-157.71311
47	Banagrass	6	20	20120612	21.334967	-157.713351

Appendix 1. Field sites visited

ID	Species	Island	General Location	Specific Location	Slope	Dominant Wind Direction	General Vegetation	Notes about Planting
48	Banagrass	Oahu	Kunia	Hawai'i Agriculture Research Center, Kunia Rd	Flat	Strong trades	Maintained Experiment Station most surroundings recently plowed land.	Biofuel trial
49	Banagrass	Oahu	Kunia	Hawai'i Agriculture Research Center, Kunia Rd	Slight	Strong trades	Maintained Experiment Station most surroundings recently plowed land.	Biofuel trial
50	Banagrass	Oahu	Waialua	CTAHR Poamoho Research Station	Flat	Trades	Maintained Experiment Station with mowed lawns; large gulch with Panicum maximum ~100 m away on one side.	Grass planting trial
51	Banagrass	Oahu	Waialua	CTAHR Poamoho Research Station	Flat	Trades	Maintained Experiment Station with mowed lawns; large gulch with Panicum maximum ~100 m away on one side.	Biofuel trial; recently cut and sprayed with glyphosate for eradication but some regrowth
2	Eucalyptus grandis	Hawaii	Hamakua Coast	Mauka Cane Haul Rd.	Moderate	Trades	Eucalyptus plantation bordered by pasture.	Timber plantation.
3	Eucalyptus grandis	Hawaii	Hamakua Coast	Kalopa Rd. 1	Moderate	Trades	Eucalyptus plantation bordered by pasture.	Timber plantation.

Appendix 1. Field sites visited

ID	Species	Number of Plants	Age of Planting	Flowering	Fruiting	Reproduction	<1m from Planting	1-5m
48	Banagrass	2 x 70 m	1 yr.	Yes.	Low seedset	Yes	0	0
49	Banagrass	3 x 120 m and 2 x 100 m	2 yrs.	Yes.	Low seedset	None	0	0
50	Banagrass	45 x 8 m	10 yrs.	Yes.	Low seedset	None	0	0
51	Banagrass	14 x 14 m	1 yr.	No	No	Yes	3	0
2	Eucalyptus grandis	Many acres.	Planted in late 1990's.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Spreading by seeds in nearby disturbed areas, such as road cuts and bare ground.	None. Thick layer of grass.	25.
3	Eucalyptus grandis	Many acres.	Planted in late 1990's.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Spreading by seeds in nearby disturbed areas.	150 plants up to to 2m tall.	75 up to 3m tall and one 5m tall plant.

Appendix 1. Field sites visited

ID	Species	5-20m	Maximum Distance Observed (m)	Date	Lat	Long
48	Banagrass	0	7	20120530	21.382034	-158.039963
49	Banagrass	0	Spread not seen	20120530	21.387044	-158.035123
50	Banagrass	0	Spread not seen	20120530	21.543013	-158.089019
51	Banagrass	0	1	20120530	21.543013	-158.089019
2	Eucalyptus grandis	20 1-2m tall plants.	50 (About a dozen up to 3m tall growing in pasture across road.)	20120718	20.08912527	-155.4999918
3	Eucalyptus grandis	1 2m tall plant.	15	20120718	20.06909465	-155.4429002

Appendix 1. Field sites visited

ID	Species	Island	General Location	Specific Location	Slope	Dominant Wind Direction	General Vegetation	Notes about Planting
4	Eucalyptus grandis	Hawaii	Hamakua Coast	Kalopa Rd. 2	Moderate	Trades	Eucalyptus plantation bordered by pasture.	Timber plantation.
5	Eucalyptus grandis	Hawaii	Hamakua Coast	Pohakea Rd.	Moderate	Trades	Eucalyptus plantation bordered by pasture and unmaintained gulch.	Timber plantation.
6	Eucalyptus grandis	Hawaii	Hamakua Coast	Antone Deluz Rd.	Moderate	Trades	Eucalyptus plantation bordered by pasture.	Timber plantation.
7	Eucalyptus grandis	Hawaii	Hamakua Coast	Hwy. 19	Moderate	Trades	Eucalyptus plantation bordered by pasture.	Timber plantation.
8	Eucalyptus grandis	Hawaii	Hamakua Coast	Niupea Homestead Rd.	Moderate	Trades	Eucalyptus plantation bordered by pasture.	Timber plantation.

Appendix 1. Field sites visited

ID	Species	Number of Plants	Age of Planting	Flowering	Fruiting	Reproduction	<1m from Planting	1-5m
4	Eucalyptus grandis	Many acres.	Planted in late 1990's.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Spreading by seeds in nearby disturbed areas, especially on road cut.	250 1-9 m tall.	90 <1m tall. 12 up to 5m tall.
5	Eucalyptus grandis	Many acres.	Planted in late 1990's.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Spreading by seeds in nearby disturbed areas.	12. Tall grass.	None. Tall grass.
6	Eucalyptus grandis	Many acres.	Planted in late 1990's.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Spreading by seeds in nearby disturbed areas.	100	100
7	Eucalyptus grandis	Many acres.	Planted in late 1990's.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Spreading by seeds in nearby disturbed areas. High road cut with seedlings.	Hundreds.	Hundreds.
8	Eucalyptus grandis	Many acres.	Planted in late 1990's.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Spreading by seeds in nearby disturbed areas.	110	165

Appendix 1. Field sites visited

ID	Species	5-20m	Maximum Distance Observed (m)	Date	Lat	Long
4	Eucalyptus grandis	None.	5	20120718	20.06449449	-155.4325261
5	Eucalyptus grandis	24. On road cut.	15	20120718	20.03447318	-155.3893558
6	Eucalyptus grandis	0	5	20120718	20.02439713	-155.3665142
7	Eucalyptus grandis	None.	5	20120718	20.02709889	-155.3387105
8	Eucalyptus grandis	14	15	20120718	20.00040006	-155.3142619

Appendix 1. Field sites visited

ID	Species	Island	General Location	Specific Location	Slope	Dominant Wind Direction	General Vegetation	Notes about Planting
9	Eucalyptus grandis	Hawaii	Hamakua Coast	Stevens Rd.	Moderate	Trades	Eucalyptus plantation bordered by pasture.	Timber plantation.
10	Eucalyptus grandis	Hawaii	Hamakua Coast	Manowaipoae Homestead Rd.	Moderate	Trades	Eucalyptus plantation bordered by pasture.	Timber plantation.
11	Eucalyptus grandis	Hawaii	Hamakua Coast	Lepoloa Rd.	Moderate	Trades	Eucalyptus plantation bordered by pasture.	Timber plantation.
12	Jatropha curcas	Hawaii	Hilo	Twigg-Smith	Slight to none	Light trades	Plantation in wet lowland forest.	The largest Jatropha planting in the state.

Appendix 1. Field sites visited

ID	Species	Number of Plants	Age of Planting	Flowering	Fruiting	Reproduction	<1m from Planting	1-5m
9	Eucalyptus grandis	Many acres.	Planted in late 1990's.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Spreading by seeds in nearby disturbed areas.	1 small plant.	7 small plants.
10	Eucalyptus grandis	Many acres.	Planted in late 1990's.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Spreading by seeds in nearby disturbed areas.	6 up to 5m tall.	None.
11	Eucalyptus grandis	Many acres.	Planted in late 1990's.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Plants appeared sterile at time of survey but appeared to have peviously flowered and fruited.	Spreading by seeds in nearby disturbed areas.	None. Thick layer of uluhe / molasses grass.	None. Thick layer of uluhe / molasses grass.
12	Jatropha curcas	>200 acres	About 5 years old.	Yes.	Yes.	Yes, vegetatively where cuttings fell on the moist ground, and by seed virtually everywhere in the plantation. Spread in the field was mostly near parent trees. Spread elsewhere anywhere seeds fell on the ground, especially the processing facility.	Hundreds.	Hundreds.

Appendix 1. Field sites visited

ID	Species	5-20m	Maximum Distance Observed (m)	Date	Lat	Long
9	Eucalyptus grandis	6 4m tall trees coming up along fenceline.	5	20120718	19.9928888	-155.2653824
10	Eucalyptus grandis	1 at 15m.	15	20120718	19.97161984	-155.2595725
11	Eucalyptus grandis	1 at 10m.	10	20120718	19.90383195	-155.156409
12	Jatropha curcas	No too many.	>1 mile if transport by harvest equipment taken into account.	20120717	19.67588198	-155.0163728

Appendix 1. Field sites visited

ID	Species	Island	General Location	Specific Location	Slope	Dominant Wind Direction	General Vegetation	Notes about Planting
13	Jatropha curcas	Hawaii	Hilo	Amauulu Rd.	Slight	Trades	Pasture.	Planted along fenceline. Most plants almost dead.
14	Jatropha curcas	Hawaii	Kau	Flood Flats	Slight	Strong trades	Dry pasture.	Largest wild population of Jatropha in Hawaii. Scattered over hundreds of acres of pasture. Most common along gullies.
15	Jatropha curcas	Hawaii	Kau	Pahala Roadside 1	Moderate	Trades	Dry pasture.	Planting in pasture.
16	Jatropha curcas	Hawaii	Kau	Pahala Roadside 2	Moderate	Trades	Dry pasture.	Planting in pasture.
17	Jatropha curcas	Hawaii	Kau	Pahala Village	Moderate	Trades	Residential bordering on macadamia nut fields.	Plantings on backside of residential properties.
33	Jatropha curcas	Maui	Kula	Kula Ag. Park	Slight	Light trades	Agricultural Park. Cultivated crops.	Four replicated trials looking at potential yields. Some plants irrigated, others not irrigated.

Appendix 1. Field sites visited

ID	Species	Number of Plants	Age of Planting	Flowering	Fruiting	Reproduction	<1m from Planting	1-5m
13	Jatropha curcas	50 plants	2009	None	None	None	0	0
14	Jatropha curcas	Hundreds of mature trees, seedlings, and saplings.	Originally planted in old plantation village at Hilea, perhaps 100 years ago.	Yes.	Yes.	Yes.	Exact site(s) of original planting not found, town abandoned and swept by flood.	Exact site(s) of original planting not found, town abandoned and swept by flood.
15	Jatropha curcas	~30 trees planted in a couple rows.	Decades.	Yes.	Yes.	Yes, previously, but not spreading.	Seedlings observed previously. Not able to get close to plants this time as there were animals in pasture.	Seedlings observed previously. Not able to get close to plants this time as there were animals in pasture.
16	Jatropha curcas	~24 trees planted in two rows.	Decades.	Yes.	Yes.	Yes, previously, but not spreading.	Seedlings observed previously. Not able to get close to plants this time as there were animals in pasture.	Seedlings observed previously. Not able to get close to plants this time as there were animals in pasture.
17	Jatropha curcas	5	A few years.	Yes.	Yes.	Yes.	Seedlings observed previously. None observed this survey.	Seedlings observed previously. None observed this survey.
33	Jatropha curcas	Hundreds.	Perhaps a couple years.	Yes.	Yes.	Yes.	40.	3

Appendix 1. Field sites visited

ID	Species	5-20m	Maximum Distance Observed (m)	Date	Lat	Long
13	Jatropha curcas	0	Spread not seen	20120716	19.73480916	-155.1344053
14	Jatropha curcas	Exact site(s) of original planting not found, town abandoned and swept by flood.	>1 mile, spread by water.	20120717	19.110753	-155.535716
15	Jatropha curcas	None.	5	20120717	19.18053805	-155.4922519
16	Jatropha curcas	Seedlings observed previously. Not able to get close to plants this time as there were animals in pasture.	20	20120717	19.19647669	-155.4800737
17	Jatropha curcas	None.	5	20120717	19.20526671	-155.4809734
33	Jatropha curcas	None.	5	20120620	20.79591575	-156.3593855

Appendix 1. Field sites visited

ID	Species	Island	General Location	Specific Location	Slope	Dominant Wind Direction	General Vegetation	Notes about Planting
52	Jatropha curcas	Oahu	Waialua	CTAHR Poamoho Research Station	Flat	Trades	Maintained Experiment Station with mowed lawns; large gulch with Panicum maximum ~100 m away on one side.	Biofuel trial
53	Jatropha curcas	Oahu	Kunia	Hawai'i Agriculture Research Center, Kunia Rd	Flat	Strong trades	Maintained Experiment Station most surroundings recently plowed land.	Biofuel trial
19	Leucaena	Hawaii	Waimea	Mealani Research Station	Slight	Trades, but often strong Kona winds	Maintained Experiment Station. Mowed lawns and trial plantings.	Planted for forage and other trials. Planted so close together it was impossible to tell which trees were the parents for the seedlings. Seedlings occasionally sprayed by station staff.
35	Leucaena	Molokai	Hoolehua	USDA Plant Materials Center	Moderate	Strong trades	Dry maintained station. Trial plantings surrounded by mowed lawn.	K1000 (Leucaena leucocephala x L. esculenta). Trial plantings. Seedlings occasionally sprayed and mowed by station staff.
43	Leucaena	Molokai	Hoolehua	USDA Plant Materials Center	Moderate	Strong trades	Dry maintained station. Trial plantings surrounded by mowed lawn.	K8 variety. Planted for trials for potential biofuel.
44	Leucaena	Molokai	Hoolehua	USDA Plant Materials Center	Moderate	Strong trades	Dry maintained station. Trial plantings surrounded by mowed lawn.	KX3 hybrid. Planted for trials for potential biofuel.

Appendix 1. Field sites visited

ID	Species	Number of Plants	Age of Planting	Flowering	Fruiting	Reproduction	<1m from Planting	1-5m
52	Jatropha curcas	14 x 14 m	5 yrs.	Yes.	Yes	Yes	79	0
53	Jatropha curcas	hundreds of mature trees	4 yrs.	Yes.	Yes	Yes	12	0
19	Leucaena	Hundreds.	Forage taxa planted in 1993. Arboreal taxa planted in 1998.	Yes.	Yes.	Yes.	Thousands.	Thousands.
35	Leucaena	~6 plants, multistemmed.	K1000 planted around 2000.	Yes.	No.	K1000 has flowers but no fruit.	0	0
43	Leucaena	3 plants	K8 planted in 1980.	Yes.	Yes.	K8 has lots of seedlings.	Hundreds of seedlings.	Hundreds of seedlings.
44	Leucaena	3 plants	KX3 planted around 2000.	Yes.	Yes, though seeds apparently rarely, if ever, fertile.	Apparently produces seeds, though seeds not viable.	0	0

ID	Species	5-20m	Maximum Distance Observed (m)	Date	Lat	Long
52	Jatropha curcas	0	2	20120530	21.543013	-158.089019
53	Jatropha curcas	0	2	20120530	21.388358	-158.036529
19	Leucaena	Thousands.	100	20120718	20.03475415	-155.6075041
35	Leucaena	0	Spread not seen	20120702	21.14227409	-157.1027125
43	Leucaena	Dozens of seedlings, some saplings.	50	20120702	21.14265	-157.102041
44	Leucaena	0	0	20120702	21.14227409	-157.1027125

Appendix 1. Field sites visited

ID	Species	Island	General Location	Specific Location	Slope	Dominant Wind Direction	General Vegetation	Notes about Planting
56	Leucaena	Oahu	Waimanalo	CTAHR Waimanalo Research Station	Flat	Trades	Maintained Experiment Station with mowed lawns; some unkept weedy vegetation around plantings.	Experimental planting
57	Leucaena	Maui	Piiholo	Haleakala Research Station	Flat	Trades	'Maintained Experiment Station with mowed lawns; some unkept weedy vegetation around plantings.	Former experimantal plantings (Niftal)
20	Oil palm; *Elaeis guineensis*	Hawaii	Hamakua Coast	HTBG	Steep	Trades	Botanical garden and wild non-native dominated lowland wet forest.	Planted as specimens in botanical garden.
21	Oil palm; *Elaeis guineensis*	Hawaii	Hilo	UH Campus	Flat where trees are Moderate beyond	Light trades	Campus. Next to parking lot in occasionally maintained wayside.	Planted for trials for potential biofuel.
22	Oil palm; *Elaeis guineensis*	Hawaii	Hilo	Amauulu Rd.	Slight	Trades	Open pasture	Planted along driveway.
23	Oil palm; *Elaeis guineensis*	Hawaii	Hilo	UH Experiment Station	Slight	Light trades	Maintained experiment station with mowed lawns, adjacent to lowland wet forest dominated by non-natives.	Planted for trials for potential biofuel.
24	Oil palm; *Elaeis guineensis*	Hawaii	Hilo	Twigg-Smith	Slight to flat	Light trades	Agriculture plantation bordered by lowland wet forest dominated by non-natives.	Planted for trials for potential biofuel.

Appendix 1. Field sites visited

ID	Species	Number of Plants	Age of Planting	Flowering	Fruiting	Reproduction	<1m from Planting	1-5m
56	Leucaena	Many different plantings in close proximity	variable	Yes.	Yes	Yes	many	many
57	Leucaena	Many	1982, 1986	Yes	Yes	Yes	many	many
20	Oil palm; *Elaeis guineensis*	2 mature trees.	25-35 years old.	Yes.	Yes.	No.	0	0
21	Oil palm; *Elaeis guineensis*	3 trees	12 years old.	Yes.	Yes.	Yes. Seedlings noted below trees and in leaf axils.	75	0
22	Oil palm; *Elaeis guineensis*	Dozens.	Recent, small trees.	No	No	No	0	0
23	Oil palm; *Elaeis guineensis*	6 trees	5 yrs.	Yes.	Yes.	No.	0	0
24	Oil palm; *Elaeis guineensis*	3 trees	5 yrs.	Yes.	Yes.	No.	0	0

ID	Species	5-20m	Maximum Distance Observed (m)	Date	Lat	Long
56	Leucaena	many	Not possibile to determine specific source plantings of seedlings because many different plantings were made in close proximity.	20120612	21.334847	-157.710978
57	Leucaena	many	Exact location of original plantings not known but plants were found established in hard to maintain areas across hundreds of meters. Some control efforts by MISC already.	20090804	20.84086	-156.29358
20	Oil palm; *Elaeis guineensis*	0	Spread not seen	20120716	19.81131744	-155.0966077
21	Oil palm; *Elaeis guineensis*	0	1	20120716	19.70265674	-155.0834489
22	Oil palm; *Elaeis guineensis*	0	Spread not seen	20120716	19.73480916	-155.1344053
23	Oil palm; *Elaeis guineensis*	0	Spread not seen	20120716	19.65035533	-155.0487174
24	Oil palm; *Elaeis guineensis*	0	Spread not seen	20120717	19.67605364	-155.0163728

Appendix 1. Field sites visited

ID	Species	Island	General Location	Specific Location	Slope	Dominant Wind Direction	General Vegetation	Notes about Planting
36	Oil palm; *Elaeis guineensis*	Molokai	Hoolehua	USDA Plant Materials Center	Moderate	Strong trades	Dry maintained station. Trial plantings surrounded by mowed lawn.	Planted for trials for potential biofuel. Three different strains.
54	Oil palm; *Elaeis guineensis*	Oahu	Manoa	Lyon Arboretum	Moderate	Trades	Maintained garden and disturbed but dense vegetation	Specimen plant
55	Oil palm; *Elaeis guineensis*	Oahu	Manoa	Lyon Arboretum	Moderate	Trades	Maintained garden and disturbed but dense vegetation	Specimen plant

Appendix 1. Field sites visited

ID	Species	Number of Plants	Age of Planting	Flowering	Fruiting	Reproduction	<1m from Planting	1-5m
36	Oil palm; *Elaeis guineensis*	Dozens.	Planted in 2008.	Yes.	Yes.	No.	0	0
54	Oil palm; *Elaeis guineensis*	1 tree	> 30 yrs.	Yes.	Yes	below tree	41	2
55	Oil palm; *Elaeis guineensis*	1 tree	> 30 yrs.	Yes.	Yes	No	0	0

Appendix 1. Field sites visited

ID	Species	5-20m	Maximum Distance Observed (m)	Date	Lat	Long
36	Oil palm; *Elaeis guineensis*	0	Spread not seen	20120702	21.14157697	-157.1005029
54	Oil palm; *Elaeis guineensis*	0	5	20120525	21.336726	-157.800435
55	Oil palm; *Elaeis guineensis*	0	Spread not seen	20120525	21.332399	-157.801572