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FEASIBILITY OF ROOFTOP LANDSCAPING WITH NATIVE HAWAIIAN PLANTS IN URBAN DISTRICTS OF HAWAI`I

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Abstract

In 2006, Hawai`i State Senate passed Resolution 86 requesting information on the feasibility of a program promoting rooftop landscaping and agriculture in urban areas of Hawai`i. Prior legislation, Endangered Species Acts 73 and 236 requires Hawaiian native plants to be used in State-funded projects, where feasible. If green roofs are to be assisted financially by proposed legislation, we need to identify native plants that are suitable for green roofs. This paper identifies resources available for promoting these objectives through the use of native plants on green roofs. Challenges arising from local conditions and the potentially conflicting requirements for the realization of different green roof benefits are discussed. Current use of Hawai`i's native plants in landscaping, native plant growers' ability to supply plants for green roof projects, and the availability of informational resources are evaluated.

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Hawai`i's Ecosystems

Hawai`i is one of the world's most popular vacation destinations with approximately seven million visitors a year (8). The aesthetic beauty of the landscape makes Hawai`i a popular travel destination and place to live. Vegetation and natural environments, such as riparian and ocean systems found in Hawai`i are currently under extreme pressure, especially in

densely populated areas such as Honolulu. In order to address the concerns of existing and future development and the loss of vegetation, greening of urban and industrial rooftops holds promise. The green roof movement is in its nascent stages in Hawai`i, with political interest rapidly growing, particularly given the increasingly salient need to abate storm water runoff that causes reef die off and threatens human safety and enjoyment of coastal waters, mitigation of the urban heat island effect and the improvement of urban aesthetics in tourist areas in Honolulu and urban districts throughout the islands.

The Hawaiian Islands are situated in the tropics, between 19 degrees and 28 degrees N latitude being the most isolated island chain on earth. Essentially two seasons, summer from May to September and winter from October to April, exist with a maximum seasonal difference in day length of 2.5 hours (24). The constancy of day length differentiates Hawai`i from many other places where green roofs have already become popular, and will extend the cooling and roof preservation benefits associated with green roofs. The topography of the islands results in extreme local differences in rainfall patterns. The Leeward coasts are typically the driest areas, being in the rain-shadow of wet upper mountain slopes. Low leeward dry areas receive most of their precipitation from a few heavy winter rains, whereas windward and upland areas receive more frequent rains carried by the northeasterly trade winds that prevail in summer. Downtown Honolulu, just below the University of Hawai`i's Manoa Campus, receives an annual average of 610mm (24 in.) of rain. However, occasional heavy storms can pour 430mm (17 in.) of rain over the city in a single day. Average temperature in Hawai`i fluctuates between a high of 27^0C (80.6 deg. F) in September and low of 23^0C (73.4 deg. F) in March, whereas diurnal temperature fluctuations can cover twice that range (24).

The abundance of local dry land ecosystems in Hawai`i offers an exciting diversity of drought-adapted plants for potential green roof applications. Dry coasts along the leeward side of each island are among the natural environments where potentially suitable green roof plants can be found. Plant communities in these areas are adapted to drought conditions that result from the high solar exposure, infrequent rain and swift drainage of sandy soils (4; 22). They are often species rich, harboring many low-growing plants that can withstand battering winds. Vegetation types characteristic of coastal dry lands extend up to 300m (984 ft.) elevation and receive less than 1,200mm (42 in.) of annual rainfall, most of which occurs in winter. Plant growth generally ceases in the drought conditions of summer (24).

Where ecological diversity is concerned, Hawai`i is a state of superlatives. The wide range of environmental conditions has encouraged the development of 106 unique types of extant plant communities, which are comprised of an outstandingly high proportion (89%) of endemic species (24). These have developed from only around 270 colonizing species (20). Where these specialized communities have encountered human development, invasive species and other pressures, staggering losses have been sustained. According to the Implementation of the Endangered Species Act 1992, Hawai`i, having only 0.20 percent of the total land mass in the United States, has suffered 70 percent of the nation's documented plant or animal extinctions earning Hawai`i the title "extinction capital of the world" (23). Hawai`i currently has 161 listed endangered plants and animals, only 32 of which have recovery plans. Coastal species are particularly hard hit due to development of their habitat for residences, hotels and golf courses (23). These are the same plant communities from which the best green roof plants are likely to be derived, given the similarity of dry coastal environments to rooftop conditions (4).

The potential for invasive rooftop plants is, thus, an issue that bears special consideration in Hawai`i. Given rooftop plantings' high wind exposure and tendency to attract

birds, any plant with wind or bird dispersed propagules should have a good chance of becoming invasive if it can germinate and grow in local conditions, and among the local flora. Plants that spread by root or rhizome are less of a threat on green roofs, which are usually, but not always, separated from the surrounding vegetation (4).

Plants and Hawaiian Culture

Hawai`i's human cultures have a bond with the plant communities that exist throughout the islands. Many modern Hawaiians relate to the native plants that, like the ancestors of the Hawaiian people, voyaged to the islands and there developed into distinctive communities whose form and identity are linked inextricably with the local environment. Native plants, like native Hawaiian cultures, are under threat from external pressures, so that native plants have come to represent the living cultures that struggle for existence in the islands. In the past 30 years, Hawaiian cultures have undergone a renaissance, demonstrated by the re-popularization of Hawaiian traditions such as *hula* (dance), *la`au lapa`au* (medical practice involving plants), and the creation of lei (garlands) (12). Conservationists encourage the cultivation of culturally important plants as a means of relieving pressure on native ecosystems. This also presents potential for the cultivation of culturally important plants on rooftops for commercial and personal use.

Striking a balance between providing enough built amenities with natural areas is a challenge in a state where the number-one industry is tourism. Green roof technologies present one way to address this challenge. For instance, in Waikiki, the most densely tourist impacted area of the islands, rooftop square footage for hotels between 14.6 and 43.9m (48 and 144 ft.), is 1,743,958 sqft. With standard roofing practices, this represents a tremendous loss in vegetative, permeable, area. Not only are there negative environmental effects, but the views tourists encounter from their hotel rooms are predominantly of bare rooftops. This can be translated into a negative recreational benefit, which is emotionally unsatisfactory to the visitor, and financially detrimental to the local economy (6).

It is anticipated that State assisted projects will provide much of the impetus for the popularization of green roofs in Hawai`i. The selection of plants for such projects will be affected by legislation that mandates the use of native plants in State-funded developments. Citing the unique "scientific, medicinal, education, environmental and economic value" of native Hawaiian plant species (17;18), the Hawai`i State Senate passed Endangered Species Act 73, mandating the use of native Hawaiian plants, and Act 236, which added Polynesian introduced plants, in State-funded landscaping projects, provided the planting material can be obtained without jeopardizing local ecosystems. The Acts stipulate that plantings should consist of plants native to the island on which the installation is constructed, and are to be signposted with information that encourages appreciation of the species and of the threat to their survival. It is also hoped that the demand for native plants in public projects will encourage much-needed research on propagation and care.

Since the passage of the Acts, several changes have been made concerning the use of native plants in horticulture. In light of the devastating effects invasive plants have had on local ecosystems, Hawai`i's present policy of allowing all horticultural introductions is being reconsidered in favor of tighter restrictions (21). This will mean that it may be harder to import and use "tried and true" green roof plants in Hawai`i, which further increases the need to identify suitable Hawaiian plant resources.

Prioritizing Green Roof Benefits for Hawai`i

The selection of green roof plant and substrate configurations, as well as the approaches to promoting green roofs, must be informed by the prioritization of green roof functions for Hawaiian contexts. Legislative, public and professional interests need to be addressed with respect to the desired functions of green roofs in Hawai`i, especially in light of the directive from Endangered Species Acts 73 and 236 to preferentially use native species in public landscaping projects. These priorities, along with local precedents from other initiatives and examples from green roof programs around the world, will provide a starting point for developing strategies to promote green roofs in Hawai`i (13). The majority of these important issues are beyond the scope of this study, but are recognized.

Legislative priorities, as articulated in Senate Resolution 86, focus on rooftop landscaping and agriculture in urban districts, specifically for structures zoned for commercial, hotel, industrial or multifamily use, or mixed use with a commercial component. Desired benefits of roof greening include the reduction of pollutants and dust particles in the air and water, of electricity consumption and of the urban heat island effect. Green roofs planted with species native to dry, coastal environments in Hawai`i have a good chance of fulfilling these goals, but, as with any plant configurations, certain tensions exist, which run far beyond the political realm, into the core of the landscape industry itself. Although information about the benefits of green roofs is starting to expand in Hawai`i, a real challenge arises to not only educate, but provide useful plant material for use in the landscape industry.

For example, the use of native plants presents challenges for landscape architects, installation contractors and maintenance personnel due to the limited amount of practical information on the proper use of native Hawaiian plants for landscaping. Compared to common plants, or exotics as they are called, little published information is readily available about native plants with consistent height, width, drought and wind tolerance and other basic qualities that landscape industry people need. Native plants have not been under intense cultivation as commonly used landscape plants in Hawai`i, and they may not possess consistent characteristics due to the lack of hybridization. Currently, this is a major barrier, but given increasing interest in native Hawaiian plants, this will be overcome. Native plants can then better serve practical and aesthetic functions in terrestrial and green roof landscapes. Recent interest in the use of native plants in landscaping has encouraged several useful publications, (1; 2; 14; 22).

At the present time, Hawai`i has few demonstration sites and the State faces a significant challenge given the lack of research in tropical green roofs. Resolution 86 asserts, “The natural beauty of the islands should be evident in urban areas”. The language of Endangered Species Acts 73 and 236 seems to place value on the educational potential, and ability to create a sense of place, of native plantings in public areas, rather than on the re-creation of functional plant communities. Hawai`i has attractive native vegetation, though species from harsh environments are often less showy than their counterparts in sheltered valleys. Interpretation is sometimes needed to encourage public appreciation for these more subtle displays. Landscape architects in Hawai`i are already demonstrating their ability to construct attractive gardens with native plants, but more information is needed regarding the amount of maintenance that is required to maintain attractive plantings with these species. Table 1 reflects some of the species and attributes that may become useful choices in using native plants on green roofs in Hawai`i.

Scientific Name	Hawaiian Name	Width/Height	Foliage	Light	Wind Resistant	Growth Rate	Form	Water Use	Bloom Time	Flower Color
Bacopa monnieri	*`ae`ae*	0.1-0.6m (0.32-2'/Low	Shiny, Light green	Full sun-part shade	N/A	Fast	Creeping, succulent perennial, herb, roots at nodes.	Only when dry	N/A	White
Carex wahuensis	*makaloa*	N/A	Shiny, light green	N/A	N/A	Fast	Reed	Drought tolerant	N/A	Green
Dianella sandwichensis	*ukiuki*	N/A	Shiny, light green	Full sun-part shade	N/A	Moderate	Clumping, perennial herb	Weekly until established	N/A	Yellow
Gossypium tomentosum	*ma'o*	5-7'(1.5-2m)/2-5'(0.6-1.5m)	Light fuzz, silvery green	Full sun	Yes	Moderate	Low, sprawling, shrub	No irrigation needed. Keep dry.	Summer	Yellow
Heliotropum anomalum var. argenteum	*hinahina*	3-5'(1-1.5m)/6-18" (15-46cm)	Silky, silver, semi-succulent	Full sun	Yes	Moderate	Low sprawling herb	Monthly, and in prolonged drought	N/A	White
Heterpogon contortus	*pili grass*	N/A	Green, red	N/A	Yes	Fast	Bunching grass	N/A	N/A	Purple awns
Ipomoea imperati	*hunakai*	N/A/ Low	Shiny, light green	Full sun	Yes	Fast	Vine	2 wks and in prolonged drought	Nocturnal	White
Ipomoea pes-caprae	*pohuehue*	N/A/ Low	Shiny, light green	Full sun	Yes	Fast	Vine	2 wks and in prolonged drought	Nocturnal	Pink
Jaquemontia ovalifolia subsp. sandwichensis	*pa`uohi`ia ka*	3m (9.8')/Low	Thick, green	Full sun	Yes	Fast	Vine	Monthly, and in prolonged drought	Year round, peaks Dec-July	Light blue
Mariscus javanicus	*ahu awa*	N/A	Light green	N/A	N/A	Moderate	Reed	Monthly, and in prolonged drought	N/A	Brown
Myoporum sandwichense	*naio papa*	N/A/1-15m (3.3-49')	Fleshy, dark green, spear shaped	Full sun	N/A	Moderate	Low, branching, shrub to tree	Monthly, and in prolonged drought	N/A	White
Ostomeles anthyllidifolia	*ulei*	5-15' (1.5-4.6m)/1-15' (0.3-4.6m)	Shiny green, pinnate leaflets	Sun	Yes	Moderate	Low sprawling ground cover to small tree	2 wks and in prolonged drought	Winter-spring	White

Scientific Name	Hawaiian Name	Width/Height	Foliage	Light	Wind Resistant	Growth Rate	Form	Water Use	Bloom Time	Flower Color
Plumbago zeylanica	*`ilie`e*	To 2.5m (8')/0.5-2.5m (1.6-8')	Smooth, oval, green	Full sun-part shade	N/A	Fast	Sprawling shrub, ground cover, roots at nodes	2 wks, and in prolonged drought	N/A	White, blue
Scaevola sericea	beach *naupaka*	N/A	Fleshy, light green	Full sun	Yes	Fast	Woody, low-growing, succulent perennial herb	Drought tolerant	N/A	White
*Sesbania tomentosa**	*`ohai*	14m (46')/to 6m(19.7')	Pinnate, silvery	Full sun	N/A	Fast	Sprawling, prostrate, shrub	Monthly, and in prolonged drought	N/A	Red, orange
Sesuvium portulacastrum	*`akulikuli*	N/A /to 0.5m (1.6')	Succulent, green red	Full sun	Yes	Fast	Low sprawling herb	Drought tolerant	N/A	Pink
Sida fallax	*ilima papa*	3-6'(0.9-1.8m)/6" (15.2cm)	Green/ gray	Full sun	Yes	Fast	Ground cover/small shrub	Drought tolerant	Year round	Light orange
Sporobolus virginicus	*`aki`aki*	N/A	Lanceolate, green	N/A	Yes	Moderate	Grass	Monthly, and in prolonged drought	N/A	Inconspicuous
Vigna marina	*nanea*	Ground level/several m	Hairy, three parted	Full sun	Yes	Fast	Climbing perennial herb	Monthly, and in prolonged drought	Year round	Yellow
Vitex rotundifolia	*po`hinahina*	3-6'(0.9-1.8m)/1-4'(0.3-1.2m)	Round, lightly hairy, gray	Full sun	Yes	Fast	Small shrub	Monthly, and in prolonged drought	Year round	Purple
Wilkstroemia uva ursi	*akia*	2-5'(0.6-1.5m)/2-5' (0.6-1.5m)	Waxy, pale green	Full sun	Yes	Slow to establish	Dense, spreading shrub	Drought tolerant	Year round	Yellow
Wollastonia integrifolia	*nehe*	N/A/6-8" (15-20cm)	Fleshy, green	N/A	Yes	Fast	Small, sprawling, succulent,.	N/A	N/A	Yellow

Table 1. Horticultural and Cultural Information for Native Plants Testing on Green Roofs in Hawai`i. Data adapted from: 1, 2, 11, 14 and discussions with native plant growers, Roxanne Adams, Dennis Kim and Priscilla Millen (November-December 2006). *Indicates an endangered species.

In order to determine whether the general public shares these same values, a pilot awareness and opinion survey was conducted at the end of 2006. The sample was comprised of 118 respondents, fift53% of whom were residents of Hawai`i surveyed from an exhibit table at a local mall in Honolulu, while 47%were visitors approached opportunistically along a beachside strip of hotels and restaurants in the tourist center (13). Participants were asked to describe their level of familiarity with the concept of green roofs, and by which, if any, means they had been exposed to the phenomenon. They were then asked for their opinion of potential local or State governmental programs to support or mandate the construction of green roofs in Hawai`i. They were then asked to give their opinion on the importance of each of a number of anticipated benefits of green roofs in Hawai`i. Participants were instructed to respond using a five-point scale. Selected results are presented in Table 2, while the full results are published elsewhere (13). The results show that the benefits green roofs can offer are understood by, and are of interest to residents and visitors of Hawai`i. The survey questions did not completely parallel the focal priorities in the Legislative Resolution, but there is enough overlap to show that benefits like the improvement of air and water quality, reduced energy use and food production are highly valued by both contingents. The public interest in an educational component for green roof installations corroborates the legislative priority, laid out in Endangered Species Acts 236 and 73, of using public plantings to educate and build appreciation of the featured organisms, natural communities and environmental issues.

Benefit	**Very important**	**Somewhat important**	**Slightly important**	**Not important**	**No opinion**
Improve air quality	81	13	1	0	3
Improve water quality	79	14	2	0	3
Reduce energy use	77	15	3	0	3
Provide outdoor recreation	47	30	12	0	3
Produce fresh vegetables	63	23	6	3	3
Demonstration site qualities					
Variety of types and plants	47	25	14	2	5
Educational program or tour	61	18	6	3	4
Located within 30 minutes of home or hotel	23	19	18	19	10

Table 2: Aggregate responses of visitors and residents to the 2006 green roof opinion and awareness survey, expressed as a percentage of the total sample. n = 118.

Native plant growers and landscape architects will have to reconcile practical issues of plant availability and maintenance with desired green roof performance, and other goals of clients. Landscape architects in both public and private sectors have been responsive to the directive laid out in Endangered Species Acts 73 or 236 in their choices of planting material (23). Use of native plants increased after passage of the Acts, even in the absence of penalties or other incentives.

In a survey of landscape architects in Hawai`i, conducted in 1999, the choice to use native plant species was explained by the following factors, in descending order of response frequency: laws, low maintenance, appropriateness for the intent of the design, and client's interest or request (23). Native plant selection criteria are similar for landscape architects

working in the private and public sectors, but in slightly different order, according to the 1999 survey. The most important criteria in the private sector were (in descending order) aesthetics, ecological compatibility, availability and maintenance requirements, whereas in the public sector they were prioritized by maintenance, aesthetics, availability and ecological compatibility (23). Tradeoffs are often required between these criteria, depending on the scale on which plantings will be viewed (3).

Opportunities and Barriers

Hawai`i residents, and visitors, seem to value the opportunity to learn about green roofs, and many are interested in incorporating them into their own homes or places of work. This value is further indicated by a high agreement among respondents that educational programs are an important potential benefit of green roofs (13). No educational programs exist for green roofs in Hawai`i to answer this public desire for information, though several attempts to popularize the use of native plants in landscaping are underway. In addition, local architects and landscape architects are increasingly interested in obtaining information on green roof technologies, due to a greater perceived need for sustainable design as well as to the growing use of green roofs on the mainland United States.

Information about native plants is increasingly available to the public, for example at the Halawa Xeriscape Garden on O`ahu, maintained by the Board of Water Supply, which offers classes and free publications on xeriscaping for gardens at residences and businesses. Workshops and lectures on native plant use for landscape architects are offered through the Leeward Community College. A website is being built for the display of plant inventories from all interested nurseries (Presentation by Priscilla Millen, June, 2006). In addition, at the 2006 Landscape Industry Council of Hawai`i's trade show and conference there was a native plant track that hosted a variety of seminars on growing, designing, and using native Hawaiian plants in the landscape.

Plant cultivation is identified as a central component of traditional Hawaiian cultures, one which can enrich a person's understanding of the natural world and of Hawaiian traditions (2). Several attempts have already been made to involve the community in the development and care of native plantings, but thus far, such attempts have been unsuccessful in the long term (Conversation with Roxanne Adams, Landscape Manager at the University of Hawai`i at Manoa, December 2006). This is a challenge that green roof projects will likely face as well, particularly in demonstration projects associated with schools and community buildings. In these cases, specialized training of grounds staff on the needs of native plants may help to decrease the tendency for projects to fail due to poor maintenance (23; conversation with Roxanne Adams, December 2006). The palette of potential green roof plants was expanded by the legalization of commercial sale of threatened and endangered native plants, from cultivation (15). Commercial harvest permits for seedlings of non-threatened native plants harvested from public lands can be obtained from the Department of Land and Natural Resources (15), which provides growers with a source of new, and more genetically distinct, propagation material. While it was hoped that the presence of native plants in public landscaping projects would serve as a gene bank for species vanishing from the wild (23), many nursery operations use clonal propagation techniques that do not produce genetic heterogeneity. If landscaping is to aid in the preservation of genetic stability, the genetic diversity in nursery stock needs to be further explored. Such diversity would decrease the homogeneity of planting material, which is a tension that needs to be addressed in the context of landscape architects' expectations (23).

The growers that were contacted all expressed an interest in the idea of green roofs, and each suggested native species they would expect to be successful in an extensive green roof environment. Four native plant nurseries, *Hui ku maoli ola,* Native Plant Source, *Pisces Pacifica*, and *La'au Hawai`i,* are operative on O`ahu, the latter of which is devoted to fern cultivation (Conversations with professor, Priscilla Millen and native plant grower, Frani Okamoto, 2007). The only one of these that is actively expanding is *Hui Ku Maoli Ola*, much of whose business is contracted. They also sell to Home Depot, which is one of the few venues for native plant sales. *Hui Ku Maoli Ola* are interested in supplying plants for green roofs, and are willing to work with modular units.

In 2001, 34% of the State's oil imports were used for jet fuel, and 24% for ground and water transportation (9). Thus, the energy saving impact of green roofs can be extended by the use of locally available materials, which is presently not extensive. Black cinder (lava rock) is harvested from the island of Hawai`i, and sold for nursery use. Organic materials tested for suitability to local nursery trade include macadamia nut hulls, compost from recycled waste, raw or composted bagasse (from the sugar industry), and imported recycled sewage sludge (10) which it might behoove residents of the state to produce locally. Coconut coir, used by several growers in Hawai`i, is a water-absorbent, durable and lightweight media component, though it does not retain nutrients as well as other organic materials (Conversations with Roxanne Adams, and native plant growers, Dennis Kim and Frani Okamoto, 2006). While coconut trees grow in Hawai`i, the coir in horticultural use in Hawai`i is imported from Sri Lanka, where facilities for compressing the material have been established. Experimentation with different mixes of locally available materials, complemented by different substrate depths, watering and fertilization regimes and pH amendment should be a high priority for green roof research in Hawai`i.

Looking to the Future

Top priorities for making green roofs an accessible technology in Hawai`i are further research on local conditions and resources, and informational outreach. Central to this would be the creation of demonstration sites in different climatic zones, and on different building types where there is public interest in green roof installations, including public buildings, businesses, residences, hotels and mixed-use buildings with a commercial component (16). On O`ahu, the location of most of the State's urban development, a distribution of demonstration sites that covers the wet/dry gradients stretching from the leeward side of the south shore (average annual rainfall 23.5 in., 596mm) along the coast to the windward side (33 in., 835mm) and from the back of Manoa Valley (153 in.,3,886mm) south to Waikiki beach (24in., 610mm) in Honolulu, is recommended (25;26;27;28; conversation with Gary Barnes, professor of meteorology at the University of Hawai`i at Manoa, 2007).

Physical conditions associated with the structure of potential green roof sites are also a consideration. Thermal benefits may not extend past a particular building height (Kaufman *et al.* 2006), and plantings on tall buildings will be exposed to increasingly high winds, so research into the feasibility and advantages of greening buildings of different heights should be on the research agenda for Hawai`i given the prevalence of condominiums and skyscrapers in the zones of interest. The extent of green roof installations required for the realization of large-scale benefits, such as the diminution of the urban heat island effect, is not known for Hawai`i, but the results of modeling for one temperate city suggest that to observe a significant effect requires that well over half the city be covered in green roofs (Bass 2002, in 4). Realization of this benefit

would require predictive modeling, and more aggressive incentives than effects that can be appreciated by individual building users or owners, with a short payoff period.

Potential use in locations near sensitive environments is also a consideration for the demonstration and implementation of green roof projects. Demonstration of green roof potential as a storm water best management practice would be useful to institutions, like the University of Hawai`i at Manoa, that are required to ensure their storm water discharge is free from pollutants before it enters the local stream (conversation with Stacie Cheramie, storm water compliance officer, University of Hawai`i at Manoa, 2007). The land-based action plan for the protection of coral reefs (5) recommends priority funding for the development of small-scale storm water management systems on recreational infrastructure, such as public restrooms and parking lots at Honolua, a popular surf spot on the island of Maui. A green roof on such facilities would also cool the facilities, making them more comfortable for visitors.

No comprehensive resources are available for the selection and use of green roof plants for tropical settings, let alone specifically for Hawai`i, and even those for temperate environments have been developed in the past couple of years (4; 19). As a starting point, native plant growers affiliated with the Hawaiian Botanical Society in Hawai'i were contacted from August, 2006 to February, 2007, for plant and substrate suggestions, and to discern their potential interest in providing plant material for green roof installations. The concept and projected benefits of green roofs were explained, and general site parameters associated with extensive green roofs, e.g. high sun and wind exposure (7), and in the case of extensive roofs, shallow soil and minimal irrigation and maintenance, were described. Likelihood of species survival and sustained presence (having a long lifespan or ability to reseed) were the primary selection criteria presented to growers along with moderately high growth rate, availability in the horticultural trade and potential for use with green roof modules. The ability to persist without supplemental watering is a favored criterion, but will have to be weighed against other priorities, such as planting complexity and the maintenance of evapotranspiration, year-round aesthetic appeal and fire safety of planting components like drought-deciduous native grasses, which are a mainstay of naturalistic rooftop plantings in temperate climates (4). The above criteria do not exhaust the factors identified in prior work (4; 19), but are considered a basis for beginning the inquiry into functional plant and substrate configurations for green roofs in Hawai`i.

These conversations led to the development of a preliminary list of suggested native plant species available from growers on the island of O`ahu. Based on these recommendations, and horticultural information from the existing literature, a subset of these species will be tested in modular planting units on several rooftops on the campus of the University of Hawai`i at Manoa this year.

An underlying theme that emerges from consideration of Hawai`i's situation is that widespread acceptance of green roofs is hindered by lack of awareness, higher installation costs, insufficient information detailing their benefits, limited knowledge about how to build them, lack of government policies that encourage them and the lack of adequate knowledge of how to sustain native plants in a rooftop environment. The need for training in native plant care, particularly on green roofs, for maintenance staff is a point of wide agreement (23; conversation with Roxanne Adams, December 2006). The above challenges have been overcome in other countries and Hawai`i has the potential to realize added benefits from green roofs due to the long growing season and richness of botanical resources. Resources to help individuals evaluate the feasibility of building a green roof on their house or condominium, as well as their business, are also necessary and desired by the public.

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