Taylor & Francis
Taylor & Francis Group

Journal of Sustainable Forestry

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/wjsf20

Non-timber Forest Products Survey of Forest Landscape Restoration: A Case Study of Hybrid Ecosystem Restoration in Invaded Hawaiian Forest

Céline B. Jennison, Rebecca Ostertag, Donald Rayome, Susan Cordell & Yadvinder Malhi

JOURNAL OF SUSTAINABLE FORESTRY
https://doi.org/10.1080/10549811.2022.2123351

Non-timber Forest Products Survey of Forest Landscape Restoration: A Case Study of Hybrid Ecosystem Restoration in Invaded Hawaiian Forest

Céline B. Jennison[a], Rebecca Ostertag[b], Donald Rayome[c], Susan Cordell[d], and Yadvinder Malhi[a]

[a]Environmental Change Institute, School of Geography and the Environment, University of Oxford, Oxford, UK; [b]Department of Biology, University of Hawai'i at Hilo, Hilo, Hawai'i, USA; [c]Pōhakuloa Training Area US Army Pacific, Hilo, Hawai'i, USA; [d]USDA Forest Service, Institute of Pacific Islands Forestry, Hilo, Hawai'i, USA

ABSTRACT
Forest restoration of landscapes benefits both biodiversity and multiple stakeholder groups. We examined how the concept of hybrid ecosystem restoration could be employed in invaded lowland wet forest in Hawai'i to examine biological, economic, and sociocultural benefits of restoration. We quantified the market prevalence of all species found within the Liko Nā Pilina experimental plots in comparison to an invaded lowland wet forest reference site with remnant native species. Using a combination of formal market and informal interviews with cultural practitioners, we examined the use of Non-timber Forest Products (NTFPs) from these species and determined the composition of native and introduced species. We found that the restoration experiment drastically increases the number of desirable species present onsite by more than five-fold, and that the majority of the NTFP species were introduced. Many different plant parts (e.g., stems, leaves, roots, flowers, and fruit) and most species in the restoration site were present in markets as raw and processed ingredients, with a majority sold as value-added products. The incorporation of agroforestry crops and native species is a multi-use perspective that greatly improves the condition of heavily-invaded forest ecosystems, and provides critical cultural and economic benefits to local people.

KEYWORDS
Agroforestry; introduced species; multifunctional landscapes; native species; Non-timber forest products (NTFPs)

Introduction

Tropical forests have experienced extensive deforestation and degradation (Malhi et al., 2014; Putz & Redford, 2010). Reforestation efforts in the tropics often involve trade-offs between economic and ecological outcomes (Brancalion & Chazdon, 2017; Lamb, 1998; Lazos-Chavero et al., 2016). The Forest and Landscape Restoration (FLR) perspective seeks to involve multiple stakeholders to improve the functioning of degraded ecosystems in ecological, social, and economic terms, by enhancing natural regeneration, conducting plantings, and allowing for sustainable use (Brancalion & Chazdon, 2017; Sabogal et al., 2015). Different models exist for how to restore these lands in a cost-effective manner (Chazdon & Brancalion, 2019; Vieira et al., 2009). One tactic in FLR is to engage in mixed agroforestry, in a manner that supports multi-functional landscapes, by integrating food

CONTACT Rebecca Ostertag ostertag@hawaii.edu Department of Biology, 200 W. Kāwili Street, Hilo, Hawai'i, 96720, USA

crops and providing important ecosystem benefits (Laurance et al., 2014; De Souza et al., 2016). This FLR strategy can also involve non-timber forest products (NTFPs) as an important component to bolster the biodiversity and provide economic benefits (Cardinale et al., 2012; Debrot et al., 2020; He et al., 2009; Sacande & Parfondry, 2018).

The initial challenge in using the FLR approach is to identify the agents and drivers of forest degradation in order to guide restoration planning (Sabogal et al., 2015). While invasive species are not a threat in all tropical forests, they are a major disruptor in some, especially in islands (Denslow & DeWalt, 2008). Invaded forests show altered delivery of many ecosystem service types including provisioning services (Mascaro, 2011), depending on invader characteristics and their interactions with native forest species. In an effort to understand how invasive species affect forests, a growing number of studies (e.g., Pokorny et al., 2005) have evaluated species' functional traits. Functional trait theory suggests that species characteristics (i.e., their functional traits) reflect their resource use and allocation and can be linked to ecosystem properties and services (Lavorel & Hutchings, 2013). Thus, in areas of high invasion potential such as islands, aspects of functional trait theory can guide restoration planning in FLR to better understand forest vulnerability to invasion and to build invasion resistance.

An example where functional trait theory was used explicitly in restoration planning is the *Liko Nā Pilina* hybrid ecosystem restoration experiment (Ostertag et al., 2015). The experiment is located in lowland wet forest, a Hawaiian ecosystem in need of restoration due to invasion and habitat loss (Ostertag et al., 2009; Zimmerman et al., 2008), and where previous restoration attempts have failed (Cordell et al., 2016). The experimental design consists of four different mixtures of native and non-native species based on functional traits, with an emphasis on cultural relevance, and the mixtures are evaluated for carbon storage, native regeneration, and biotic resistance to invasion (Ostertag et al., 2015). The ultimate goal is to determine if this hybrid ecosystem model could be an effective FLR approach, as a middle ground that balances trade-offs in terms of biodiversity, economic viability, and long-term self-maintenance (Chazdon & Brancalion, 2019; Higgs, 2017). However, the success of hybrid ecosystem restoration has yet to be comprehensively evaluated (Higgs, 2017; Hobbs et al., 2009), particularly from a socio-cultural perspective.

To assess the efficacy of hybrid restoration in balancing ecosystem restoration and providing economic benefits, we compare the market prevalence of select NTFPs in the *Liko Nā Pilina* experimental plots (mixtures of native and introduced species) to a Lowland Wet Forest reference site that has native species but is also heavily invaded. NTFPs can be quantified and evaluated in several different ways (Godoy et al., 1993). Market studies are useful indices of current forest product use and how they contribute to local livelihoods. However, the sociocultural value of these products (Lamb, 1998) might not be fully captured in a market study, as NTFPs also contribute to livelihoods in other ways such as subsistence, barter, and ceremonial use. Furthermore, market uses for NTFPs can include plant matter sold in a raw form or after processing into crafts, foodstuffs, and related value-added products (Emery, 2001). Based on the combination of formal market surveys and informal interviews, we address the following questions: (1) how prevalent and important are the species in the *Liko Nā Pilina* restoration experiment that are used as NTFPs as compared to the reference forest; (2) which comprises a larger proportion of NTFPs – native or introduced species? In the *Liko Nā Pilina* experiment, we broadly hypothesize that the addition of introduced species in the hybrid ecosystem provides positive economic and sociocultural benefits, with the overarching assertion that in heavily invaded ecosystems, the hybrid restoration strategy will be a win for biodiversity and for people who use forest products.

Materials and methods

Site description and selection

The *Liko Nā Pilina* project is located on the windward side of Hawaiʻi Island in Hilo, Hawaiʻi (19°42.15 N, 155°2.40 W), within the Keaukaha Military Reservation (KMR), a base that balances military training, research, and education. The study site is characterized by low native species density and extreme vulnerability to invasion pressure (Zimmerman et al., 2008). A previous census at this site revealed that woody species density was only 1591 individuals/ha (~8% of total) for native woody species compared with 17,199 individuals/ha (~92% of total) for non-native woody species (Zimmerman et al., 2008). Yet native species persist, with the overstory (25-35 m) being dominated by ʻōhiʻa (*Metrosideros polymorpha*) and lama (*Diospyros sandwicensis*) and various smaller trees, shrubs, and ferns present in the midstory and understory (Ostertag et al., 2009; Zimmerman et al., 2008).

Liko Nā Pilina is unique in that species selected for restoration were based on functional trait combinations, rather than on native species richness (D. D. Rayome et al., 2019), which is the norm in most other biodiversity restoration experiments (Ostertag et al., 2015; D.D. Rayome et al., 2018. The functional trait approach was utilized to select both native Hawaiian and non-native non-invasive (many Polynesian introduced) species to create hybrid communities with the goals of increased carbon sequestration, invasion resistance, and natural native regeneration (Ostertag et al., 2015).

The forest in the area sits on a 750-1500 year-old ʻaʻā lava flow characterized by rocky, well-drained soils at about 30 m elevation, with 3280 mm y^{-1} rainfall (Ostertag et al., 2009) and mean annual temperature of 22.7°C (Giambelluca et al., 2014). This forest has undergone succession without major direct human disturbances, but is experiencing severe non-native species invasion pressures. Species such as *Macaranga mappa, Cecropia obtusifolia*, and *Melastoma septemnervium* dominate seedling recruits in many areas, altering forest composition and long-term integrity.

The experiment was set up as a randomized block design, with four blocks. Each block consisted of one reference (invaded forest) and the four different experimental communities. Plot size was 20 × 20 m with a 5 m perimeter buffer. Plots are about 20 m apart. Initial vegetation sampling was done in 2012 and then the plots designated to be experimental treatments were cleared of all non-native species and planted in 2013. For the purpose of this study, we are only comparing Reference plots vs. Restoration plots (all 4 treatments combined). Table 1 lists the species and their densities for species found in the Reference plots, as well as the densities of species planted in the Restoration plots.

Formal market surveys

To determine anthropogenic use for crops and other harvestable NTFPs from *Liko Nā Pilina* species, we conducted formal market surveys and informal interviews. For the formal market surveys, we visited the major open-air farmers' markets on the windward side of the

Table 1. Plants present within the Liko Nā Pilina experimental Restoration plots and in the invaded Reference forest plots. The plant list here does not include the invasive species in the Reference forest plots because that was not the focus of this market study. Status can either be Native (arrived in Hawai'i without human help); Introduced^{P}: Polynesian introduction; or Introduced (non-native but arrived after the Polynesians) (Greenwell et al., 2009). If mean density is 0, it indicates that species was not found, so that 6 species are in the Reference forest plots and 20 species were found in the Restoration forest plots. Not all the species here were found as NTFPs (as indicated by the last two columns). For *Cibotium menziesii*, NA (not applicable) is listed under the Restoration plots because almost all tree ferns planted were *Cibotium glaucum*, and in the formal market it was difficult to distinguish between the two *Cibotium* genera, so everything is listed under *Cibotium glaucum*.

Genus	Species	Family	Common name	Hawaiian name	Status	Mean Density in Reference Forest (#/m^2)	Mean Density Planted in Restoration Plots (#/m^2)	Presence in Formal Market	Presence in Informal Market
Psychotria	*hawaiiensis*	Rubiaceae		Kopiko	Native	1.22	0.00		
Metrosideros	*polymorpha*	Myrtaceae		'Ōhi'a	Native	0.61	0.00	x	x
Diospyros	*sandwicensis*	Ebenaceae		Lama	Native	0.47	0.00		
Myrsine	*lessertiana*	Primulaceae		Kōlea	Native	0.31	0.40		
Cibotium	*glaucum*	Cibotiaceae		Hāpu'u pulu	Native	0.17	0.40	x	x
Cibotium	*menziesii*	Dicksoniaceae		Hāpu'u 'i'i	Native	0.03	NA	NA	x
Psydrax	*odorata*	Rubiaceae		Alahe'e	Native	0.00	0.60		x
Pandanus	*tectorius*	Pandanaceae		Hala	Native	0.00	0.45	x	x
Pritchardia	spp.	Aracaceae		Loulu	Native	0.00	0.45	x	x
Pipturus	*albidus*	Urticaceae		Māmaki	Native	0.00	0.40	x	x
Rhus	*sandwicensis*	Anacardiaceae		Neneleau	Native	0.00	0.40		x
Cocos	*nucifera*	Arecaceae	Coconut	Niu	Exotic^{P}	0.00	0.30	x	x
Morinda	*citrifolia*	Rubiaceae		Noni	Exotic^{P}	0.00	0.20	x	x
Persea	*americana*	Lauraceae	Avocado		Exotic	0.00	0.20	x	
Thespesia	*populneoides*	Malvaceae		Milo	Native	0.00	0.20	x	x
Antidesma	*platyphyllum*	Phyllanthaceae		Hame	Native	0.00	0.15		
Mangifera	*indica*	Anacardiaceae	Mango		Exotic	0.00	0.15	x	x
Aleurites	*moluccana*	Euphorbiaceae	Candlenut	Kukui	Exotic^{P}	0.00	0.10	x	x
Artocarpus	*altilis*	Moraceae	Breadfruit	'Ulu	Exotic^{P}	0.00	0.10	x	x
Calophyllum	*inophyllum*	Calophyllaceae	Alexandrian laurel	Kamani	Exotic^{P}	0.00	0.10	x	x
Polyscias	*hawaiensis*	Araliaceae		'Ōhe mauka	Native	0.00	0.10		
Samanea	*saman*	Fabaceae	Monkeypod		Exotic	0.00	0.10	x	x
Syzygium	*malaccense*	Myrtaceae	Mountain apple	'Ōhi'a 'ai	Exotic^{P}	0.00	0.10	x	x
Terminalia	*catappa*	Combretaceae	Bengal almond	False kamani	Exotic^{P}	0.00	0.10		x

Hawai‘i island (State of Hawai‘i Agricultural Development Division, 2019) because that is the climate at the restoration site. These farmers' markets were located in Waimea, Hāwī, Hilo, Maku‘u, Kalapana Ho‘olaule‘a, and Volcano. The farmers' markets were visited once or twice to maximize total number of vendors surveyed. Each market stall was visited only once (n = 381 total). For each market visited we recorded: location, species, category of product, and type. 'Category' refers to whether the item is raw or processed to increase value. For example, a mango could be sold as a whole fruit, but could also be sold in a blended drink, which requires processing. 'Type' refers to the categorization for analysis (e.g., cosmetic, domestic item, value-added food or beverage, and dietary supplement).

To identify possible sources of local items that were being sold commercially, we identified shops located in Hilo, the most populous town on the island, and two shops at the Honolulu airport where Hawai‘i Island products were sold (n = 16). In Hilo, we walked along the main thoroughfare, Kamehameha Avenue, from Ponahawai Street to Wailuku Drive. We visited all tourist shops, grocery stores, and art galleries. We recorded any *Liko Nā Pilina* species found in ingredient lists or other goods to further capture the local value of NTFPs. We also identified additional sources from the shopkeepers who had already been surveyed (Holloway, 1997). 'Made in Hawai‘i' signifies that at least 51% of the wholesale value of the item has been produced, assembled, or manufactured in Hawai‘i (State of Hawaii Department of Agriculture, Division of Marketing, 2016). However, this designation could simply include the cooking and packaging process of a baked good, implying that the raw material is not necessarily local. Our interest was only in local species and locally harvested (e.g., coconut oil that was not clearly designated as from Hawai‘i). When we encountered value-added products certified as 'Made in Hawai‘i' and the vendor could not verify ingredient origins, we contacted the company directly. If we were unable to verify ingredient origins, items were excluded from our records. If multiple species' NTFPs were found in one product, we accounted for only the marketed ingredient to avoid double-counting. Absence of species' NTFPs in markets and local shops does not necessarily imply lack of anthropogenic use today (Ambinakudige, 2011).

Informal interviews

To adopt a broader view of economic activity of these species, we also conducted informal interviews about local product use in order. Following an informal interview process and adhering to the ethics and guidelines laid out by The International Society of Ethnobiology, we used a semi-structured interview format to obtain information on current species uses (Emery, 2001). From snowball sampling (Ambinakudige, 2011), ten interview participants were identified as significant knowledge holders by someone else and as particularly well-connected with the local Hawaiian community. The participants were shown a list of the plant species and asked "do you know if and how these species are used today? If so please give examples." The purpose of these interviews was to further investigate the current use of these plants beyond commercial availability. We grouped uses into different purpose categories including landscaping, cultural, food, medicine, cosmetic, and miscellaneous. A use was deemed cultural if the species was used in activities that supported Native Hawaiian lifestyles including ceremonies, hula, crafts, building, and sports. We checked to see if these uses could be confirmed with a literature search. We compiled this information for different plant parts (e.g., leaves, fruit, roots, etc.) harvested for each plant species.

Results

The restoration plots in the *Liko Nā Pilina* experiment increased the number of desirable species present on site, as only six are considered commonly found in the invaded Reference forest in comparison to 20 present in the experimental plots (Table 1). There were a total of 18 species with recorded use as NTFPs (Table 1). Seven of the 18 NTFP species were native. Only 2 NTFP species were found in the Reference forest (both native) versus 16 species (7 native) that were found in the Restoration forest plots (Table 1). Thus, applying the *Liko Nā Pilina* restoration approach results in a 400% increase in the number of species that can be utilized as NTFPs.

In the formal market survey, 15 species (5 native, 10 introduced) were recorded, for a total of 306 products. Of these NTFPs, introduced species were more prevalent (86.3%) than native species (13.7%; Figure 1). Unprocessed NTFPs (the species leaves, roots, or fruits in its original form) accounted for 25.8% and value-added products accounted for 74.2% of sales (Figure 2). The largest percentage (55.1%) of value-added products were placed in the 'Cosmetics' category (i.e., personal care products). 'Value-added food' was

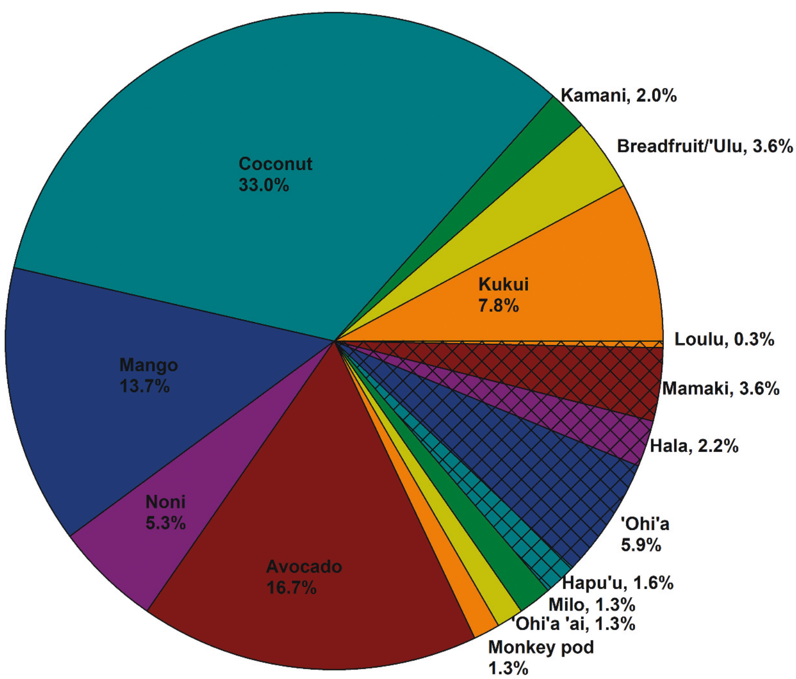

Figure 1. Native and introduced species occurrence in the formal Hawaiian market; percentages are from the total number of raw and unprocessed products seen in the farmers markets. The two tree fern species (Hāpu'u) are lumped together. The only species found in the Reference forest plots were 'Ōhi'a and Hāpu'u.

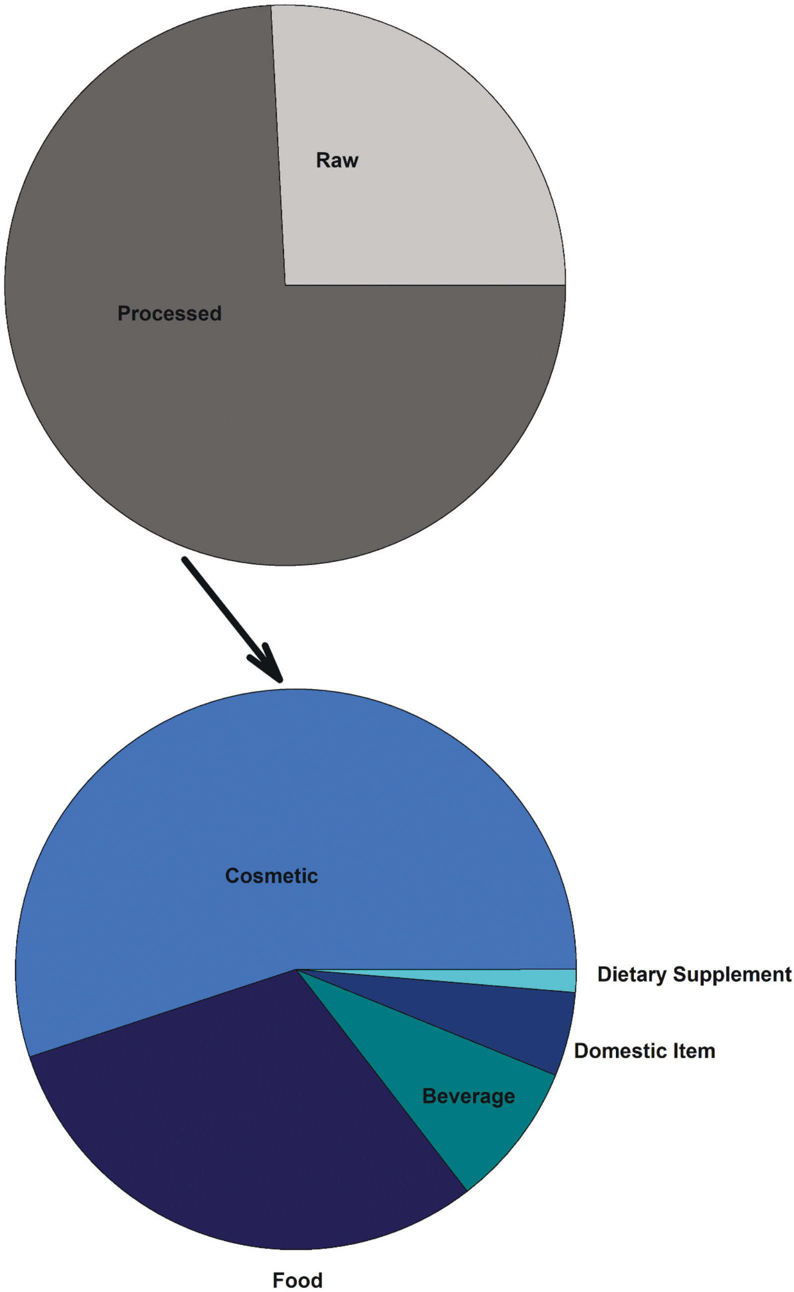

Figure 2. Percentage of the total number of products (n = 306) found in the farmers' markets and commercial shops. Unprocessed (raw) (n = 79) vs. value-added products (top) (n = 227) identified in the formal market and associated types of value-added products (bottom).

the second largest category (30.4%) which included some products that had been processed but did not have additional ingredients; commonly found examples of these were breadfruit (*Artocarpus altilis)* flour and roasted kukui (*Aleurites moluccana*) nuts. 'Domestic items' (4.8%) made with NTFPs were most often created with hala (*Pandanus tectorius*) leaves to make woven baskets, jewelry, or mats, or created with coconut (*Cocos nucifera*) leaves & husks to make bowls, jewelry, or woven hats. 'Value-added beverages' (8.4%) were either for immediate consumption (e.g., smoothies, fresh fruit juices) or drinks intended for later consumption (e.g., kombucha, flavored water, kefir). 'Dietary supplement' (1.3%) commonly consisted of plant-derived medicinal products such as noni (*Morinda citrifolia*) served as a tinctures or beverages.

The informal market survey identified all of the same species as the formal market survey, with the exception of avocado (*Persea americana*), and recorded three more additional species (Table 1). Table 2 provides detailed descriptions of the uses indicated with the informal market survey. Findings of the informal market survey showed that the majority of species have multiple plant parts that can be harvested to provide NTFPs, and furthermore that the majority of species have multiple uses specified. All of the species indicated by the informal market survey are consumed as food, utilized for medicinal purposes, and/or cultural purposes (e.g., ceremonies, clothing, lei, hula).

Discussion

The FLR approach focuses on restoration that improves ecosystem functioning through the enhancement of biodiversity, but also assumes that people will be interacting with and deriving products from the forest. The hybrid ecosystem restoration approach is one promising type of FLR that can be advantageous in areas with invasive species issues. The *Liko Nā Pilina* hybrid restoration experiment is a small-scale trial that is not scaled up to the landscape level, but shows the potential of this approach for improving ecosystem service delivery. In our market surveys, we found only three marketable species in the Reference forest versus 16 in the hybrid ecosystem (Table 1). A little more than half of the NTFP species planted for restoration purposes were introduced. Many are Polynesian introductions, which have several advantages. They are culturally relevant – as these species were originally chosen by early navigators for their utility. In addition, the species introduced by the Polynesians have been equilibrating in the environment for much longer time periods than the more recent Western introductions, and are naturalized therefore less likely to become invasive (Richardson & Pyšek, 2012). The restoration treatments also included native species not found in the Reference forest, that may have been previously in the ecosystem but that have been outcompeted by the highly invasive species. Thus, the hybrid ecosystem concept is flexible enough to incorporate agroforestry, natural regeneration, and the planting of native trees, which can magnify the biological, economic, and sociocultural benefits.

Because of the young *Liko Nā Pilina* experimental age, the species composition may still change over time, but it is interesting to identify other related social and ecological benefits of this type of restoration (Campanha et al., 2004; Cardoso et al., 2001; Soto-Pinto et al., 2000). Indeed, some low intensity agroforestry management that retains native canopy cover can conserve a high diversity of plants, mammals, birds, and insects (Bhagwat et al., 2008; Ticktin & Shackleton, 2011). Thus, while tree crops from agroforestry systems might

Table 2. NTFPs identified in the informal market survey; native and introduced species, part of the plant used, detailed description of uses identified, and whether or not uses told to us by interviewees were confirmed with a literature search. Almost all the species in the table were only found in the Restoration forest plots; an asterisk denotes the three species found in the Reference forest plots.

Hawaiian/Common (Scientific name)	Part of plant used	Uses identified in the informal market survey	Confirmed in the literature yes (Y) or no (N)
A. Native Species			
Alahe'e (*Psydrax odorata*)	Tree	**Landscaping**. Used in the landscaping industry	Y
		Cultural/Ceremonial. Tree considered sacred, leaves used for lei	Y
	Leaf	**Medicine**. Helps treat eczema	N
		Cultural. Used to poison fish for fishing purposes	N
Hāpu'u pulu & Hāpu'u 'i'i *(Cibotium glaucum* & Cibotium menziesii)**	Tree fern	**Cultural/Ceremonial**. These tree ferns have many spiritual connotations and are therefore not widely used for other purposes	N
	Shoot	**Food**. Shoot consumed	Y
		Medicine/First aid. Used to soothe burns	N
	Root	**Medicine**. Used to soothe burns	Y
Hala (*Pandanus tectorius*)	Fruit	**Food**. Consumed as a candy (rare practice today in Hawai'i)	Y
		Cultural/Ceremonial. Fruit lei given for an occasion where a time has passed: for instance, when someone passes away or for graduation	Y
		Medicine. Fruit juice used as a tonic, an adaptogen and a liver cleanser	Y
	Root	**Medicine**. Used to treat diabetes, and as an aphrodisiac and a diaphoretic (grated fresh)	Y
	Leaf	**Utensil/Food preparation**. Used for plating food	Y
		Cultural/Ceremonial. Used to weave traditional canoe sails, few of which still exist today. Leaves used for lei	Y
		Cultural/Weaving. Cultural practitioners use hala extensively for weaving objects (clothes & garments) or rope similar to those found in our formal market survey	Y
		Medicine. Young leaves are used to stop nausea	N
Loulu *(Pritchardia spp.)*	Frond	**Cultural/Weaving**. Used to thatch traditional houses and to weave hats	Y
	Fruit	**Food**. Berry consumed, fruit tastes like coconut and is not sold commercially	N
Māmaki (*Pipturus albidus)*	Fruit	**Food**. Consumed raw	Y
		Medicine. Used to ease childbirth	Y
	Bark	**Cultural**. Used to make traditional clothing and kapa	Y
		Medicine. Used to soothe tooth aches	N
	Leaf	**Medicine**. Tea made to treat constipation, also used as a cleanser, treats high blood pressure. Different varieties are used differently for men and women (red leaves are used as a source of magnesium for women, green as a source of zinc for men)	Y
Milo *(Thespesia populnea)*	Sap	**Cultural**. Used to dye clothes	Y
	Flower	**Medicine**. Flowers eaten by women to ease childbirth	Y
'Ōhi'a (*Metrosideros polymorpha)**	Flower	**Food**. Edible flowers	Y
		Cultural/Ceremonial. Significant cultural importance	Y
Neneleau *(Rhusan sandwicensis)*	Leaf	**Medicine**. Leaf used to stop diarrhea	Y
	Fruit	**Medicine**. Used to treat kidney stones (rare practice today)	Y
Alahe'e (*Psydrax odorata*)	Tree	**Landscaping**. Used in the landscaping industry	Y
		Cultural/Ceremonial. Tree considered sacred, leaves used for lei	Y
	Leaf	**Medicine**. Helps treat eczema	N
		Cultural. Used to poison fish for fishing purposes	N

(*Continued*)

Table 2. (Continued).

Hawaiian/Common (Scientific name)	Part of plant used	Uses identified in the informal market survey	Confirmed in the literature yes (Y) or no (N)
B. Introduced Species			
Breadfruit/'Ulu (*Artocarpis altilis)*	Tree	**Cultural**. Trees are often planted for each new-born to ensure that future generations a lifelong supply of food	Y
	Leaf	**Utensil/ Food preparation/misc**. Leaves used as a plate, or sand paper (rare practice today)	Y
	Sap	**Food**. Sap is chewed on like gum	Y
		Cultural. The combination of sawdust and 'ulu sap makes for an effective binding agent (for instance, to seal traditional canoes)	Y
	Flesh	**Food**. Breadfruit flesh is widely consumed raw (when overripe) and cooked	Y
Niu/Coconut (*Cocos nucifera)*	Tree	**Tree is widely used**. Some say there are '365 uses for coconut'	Y
	Stump	**Cultural/Ceremonial**. Used to make traditional drums and for decoration	Y
	Frond	**Cultural/Ceremonial**. Used to mark an important cultural event	Y
		Cultural/Weaving. Used for making baskets, carrying foraged goods and plant material, and for thatching	Y
	Water	**Medicine**. Used to stabilize blood sugar	Y
		Food. Beverage widely consumed for its nutritional value	Y
	Flesh	**Food**. Coconut flesh is widely consumed raw, dried and cooked	Y
		Medicine. Oil is used as an antimicrobial, for weight loss and to treat Alzheimer's	Y
		Cosmetic. Oil is widely used for the skin	Y
		Animal food. Coconuts are fed to chickens	Y
	Shell	**Food preparation & consumption**. Shell can be used; as a medicine bowl, to catch soot from kukui nuts, and to hold fluids	Y
False kamani/Bengal almond (*Terminalia catappa)*	Nut	**Food**. Nut tastes like an almond	N
	Leaf	**Utensil/ Food preparation**	Y
Kamani/Alexandrian Laurel *(Calophyllum inophyllum)*	Fruit	**Cultural**. Large fruits hollowed to make crafts and calabashes	Y
		Cultural/Ceremonial. Used in making lei	Y
		Miscellaeous. Oil used to varnish wood	Y
		Medicine. Oil used to treat skin conditions (burns and skin diseases)	Y
Kukui/Candlenut (*Aleurites moluccana)*	Nut	**Medicine**. Used for digestion as a sedative, roasted nuts used as purgative. Oil made from the nuts is widely used for the skin and as a healing agent	Y
		Food. Used to make the traditional condiment 'inamona': a relish used in Hawaiian cooking made from roasted nuts and salt, sometimes mixed with seaweed	Y
		Cultural/Ceremonial. Used to oil wood and canoes. Nut lei are given to revere gods; nuts are strung on the backbone of coconut leaf.	Y
	Sap	**Medicine**. Used for herpes and children's thrush, anti-inflammatory	Y
		Cultural Used to make a red/brown dye for various items	Y
		Food. Hardened sap is chewed on like gum	Y
	Leaf	**Cultural/Ceremonial**. Leaf lei given for birthdays or graduation for enlightenment	Y
	Bark	**Cultural**. Used to make a dye for clothes	Y

(*Continued*)

Table 2. (Continued).

Mango (*Mangifera indica)*	Tree	**Landscaping**. Widely used in landscaping to mark estates	N
	Flesh	**Medicine**. Flesh used to make water to rehydrate people with the flu	Y
		Food. Mango is widely consumed	Y
	Leaf	**Medicine**. Used to treat cancer, in particular organ cancer	N
	Sap	**Medicine**. Used as an antidote for food poisoning	N
Monkey pod (*Samanea saman)*	Pod	**Food**. Pod salted and consumed raw (rare practice)	N
	Tree	**Landscaping**. Used in landscaping as it provides a lot of shade	Y
Mountain apple/'Ōhi'a 'ai *(Syzygium malaccense)*	Tree	**Cultural**. Very important tree in the Hawaiian legends	Y
	Bark	**Medicine**. Used to treat sore throat and cough	Y
	Flesh	**Food**. Fruit consumed raw	Y
	Leaf	**Medicine**. Used to treat skin rashes	N
	Seed	**Medicine**. Used as an astringent: to clean out the intestines	Y
Noni (*Morinda citrifolia)*	Leaf	**Food preparation & consumption**. Used for plating. Young leaves cooked and consumed	Y
		Medicine. Leaves used to treat swelling	Y
	Root	**Cultural**. Used to make a red dye, collected by practitioners	Y
		Medicine. Root is antibacterial	Y
	Fruit	**Medicine**. Unripe fruit used to make tinctures that boost the immune system and treat various other ailments. Used to treat cancer. Used to stabilize blood sugar. Anti-inflammatory. It is referred to as 'a miracle fruit for topical injuries'	Y
	Bark	**Medicine**. Bark used to relieve pain	Y

References for Table

Abbott, I. A. (1992). *Lā'au Hawai'i: traditional Hawaiian uses of plants*. Honolulu: Bishop Museum Press.

Elevitch, C. (2006). *Species profiles for Pacific Island agroforestry*. Holualoa: Permanent Agriculture Resources.

Etkin, N. L., & McMillen, H. L. (2003). The ethnobotany of noni (*Morinda citrifolia* L., Rubiaceae): Dwelling in the Land between Lä 'au Lapa 'au and Testimonials. In Proc of 2002 Hawaii Noni Conf.

Greenwell, A. B. H., Lincoln, N., & Van Dyke, P. (2009). *Amy Greenwell Garden ethnobotanical guide to native Hawaiian plants & Polynesian-introduced plants*. Honolulu: Bishop Museum Press.

Handy, E. S. (1972). Native planters in old Hawaii. Retrieved May 16, 2016, from http://agris.fao.org/agris-search/search.do?recordID=US201300484676

Little, Jr, E. L., & Skolmen, R. G. (1989). Common forest trees of Hawaii (native and introduced). USDA Forest Service, Honolulu, Hawaii.

Kobayashi, J. (1976). Early Hawaiian uses of medicinal plants in pregnancy and childbirth. *Journal of Tropical Pediatrics*, 22(6), 260–262.

Leonard, D. B. (2007). *Medicine at your feet: Healing plants of the Hawaiian kingdom*. I.M. Publishing.

Morton, J. F. (1987). *Fruits of warm climates*. JF Morton.

National Tropical Botanical Garden. (n.d.). Retrieved June 19, 2016, from http://plants.ntbg.org/plant_details.php?rid=3065&plantid=9637

Nelson, S. C., & Elevitch, C. R. (2006). *Noni: the complete guide for consumers and growers*. Holualua: Permanent Agriculture Resources.

Ragone, D. (2011). Farm and forestry production and marketing profile for breadfruit (*Artocarpus altilis*). *Specialty Crops for Pacific Island Agroforestry; Elevitch, CR, Ed.; Permanent Agriculture Resources (PAR): Holualoa, HI, USA*.

Savage, S. (2015). *Wild food plants of Hawai'i*. CreateSpace Independent Publishing Platform.

Whistler, W. A. (2009). *Plants of the canoe people: an ethnobotanical voyage through Polynesia*. Hanalei, HI: National Tropical Botanical Garden.

White, L. D. (1994). Canoe Plants of Ancient Hawai'i. Retrieved May, 10, 2016, from https://www.canoeplants.com/index.html

Young, R. A., Cruz, L. G., & Brown, A. C. (2005). Indigenous Hawaiian nonmedical and medical Use of the kukui tree. *Journal of Alternative & Complementary Medicine, 11(3), 397–400.*

not provide ideal yields, they can provide flexibility in response to fluctuating commodity prices, climate change, disease resistance, and other unpredictable events. Diversification of tree crops can be used as a strategy to quickly take advantage of emerging markets for new products (Idol, 2012). As specialty food, personal care, and herbal medicine companies seek out novel ingredients and products, flourishing niche markets for limited supplies of NTFPs (Shanley et al., 2002) could support these less productive, multi-use sites. Some consumers have indicated they are willing to pay a premium for NTFPs that have environmentally friendly characteristics (Kilching et al., 2009). Defining boundaries and sustainable harvest mechanisms that account for biodiversity and native species preservation is one such way (Shackleton et al., 2011; Ticktin et al., 2007; Ticktin & Shackleton, 2011) to contribute to local livelihoods and long-term environmental needs (Friday et al., 2015), and to incentivize novel ways of marketing products that offset high labor costs.

Best practices for the management of these multifunctional systems inherently depend on primary stakeholder objectives. In this study, the presence of edible and culturally important species contributes to dynamic formal and informal markets of NTFPs that are virtually non-existent in the high intensity land uses (e.g., housing, monocrop agriculture) and are being lost due to invasion pressure in Hawaiian lowland wet forests. This project, which melds together contemporary approaches to forest management with culturally important species including edible fruit trees, has proved appealing to the general public, school groups and summer programs, allowing restoration to benefit from an eager set of volunteers. Further, the level of community engagement is unusually high for science-based restoration experiments (Ostertag et al., 2015). At *Liko Nā Pilina*, important plants might provide a greater range of harvestable products than invaded areas not undergoing restoration, resulting in potentially greater benefits from the site (Lamb, 1998). Thus, a novel type of restoration such as *Liko Nā Pilina* may fulfill many goals of a multifunctional landscape and provide a rigorous way to choose species for restoration, as well as a framework that is appealing to local communities (Friday et al., 2015; Ostertag et al., 2015).

Findings from our interviews identifying the use of NTFPs through nonmarket strategies were extremely diverse and often cultural in nature. Market survey results indicated that native species are not as prevalent (Figure 2), but are widely used informally (Table 2). In Hawai'i, like in many other places, harvesting NTFPs is an important cultural activity that brings about a sense of community through rituals, ceremonies and dances. Interest has risen to preserve such Traditional Ecological Knowledge, partly due to a recognition that this knowledge can contribute to human health (Hilgenkamp & Pescaia, 2003) and sustainable resource management (Berkes et al., 2000). For instance, the fronds of native tree ferns such as hāpu'u are gathered to make *lei*, a practice that becomes more difficult with species invasions (Ticktin et al., 2007). Traditional Hawaiian natural medicine (*lā'au lapa'au*) products (Hilgenkamp & Pescaia, 2003) were also discovered in our interviews. Several species stood out as extremely important. Breadfruit for instance, found as a raw or value-added product plays an important role in Hawaiian culture; historically people planted a tree for each newborn in order to ensure the child a life-long food supply (Meilleur et al., 2015). In addition, coconut (Polynesian introduction) and hala (native *Pandanus*) are used in the creation of a multitude of fiber products such as baskets, home utensils, and mats (Feary, 2012).

In the Hawaiian archipelago, many crop trees including culturally-important species are often not grown commercially due to high labor cost, although some research has shown that the trend might be changing as people shift toward a local diet and politicians realize that local food security is threatened (Melrose et al., 2015; Southichack, 2007). Interestingly, even with high production costs, many consumers are willing to pay a premium for local goods (Melrose et al., 2015). While economic analyses are not in the scope of this paper, we found that the majority of crops and goods at the market were value-added items, signifying that there might be an opportunity for farmers to create 'boutique items' to offset high production costs (Melrose et al., 2015; Southichack, 2007). As Hawaii's population now depends on imported resources for a large percentage of life-sustaining needs, ensuring archipelago-wide resiliency in times of crisis is of paramount importance (Hawaii Department of Land and Natural Resources, 2010; Melrose et al., 2015; Southichack, 2007). On islands where invasion pressure is extreme and addressing food self-sufficiency is critical, land managers must find novel ways of restoring native biodiversity and sustainably managing landscapes for multiple uses.

The incorporation of agroforestry crops and native species is a strategy that can extend far beyond this case study in Hawaiian forest. Increased recognition of NTFPs' importance has been promoted as one possible means to combat deforestation and forest degradation (Bhagwat et al., 2008; Chamberlain et al., 2000; Ticktin & Shackleton, 2011) by increasing the economic value of an intact forest and looking at a site from a multi-use perspective. This type of restoration could be revised for many different local conditions, fulfilling multiple goals, and providing a rigorous way to select species for restoration as well as providing a restoration framework that may appeal to local stakeholders (Ostertag et al., 2015).

Acknowledgments

We thank the following people and institutions for use of both published and unpublished information as well as field support: Nicole DiManno & Henry Inman, University of Hawaii at Hilo; Amanda Uowolo, USDA Forest Service, Hilo; Travis Idol & J.B Friday, College of Tropical Agriculture and Human Resources (CTAHR), University of Hawaii at Mānoa

Disclosure statement

No potential competing interest was reported by the authors.

Funding

This work was supported by the Strategic Environmental Research and Development Program; NSF; Environmental Change Institute, University of Oxford.

References

Ambinakudige, S. (2011). National Parks, coffee and NTFPs: the livelihood capabilities of Adivasis in Kodagu, India. *Journal of Political Ecology*, *18*, 1–10. 1 https://doi.org/10.2458/v18i1.21702

Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications*, *10*, 1251–1262. 5 https://doi.org/10.1890/1051-0761(2000)010 [1251:ROTEKA]2.0.CO;2

Bhagwat, S. A., Willis, K. J., Birks, H. J. B., & Whittaker, R. J. (2008). Agroforestry: a refuge for tropical biodiversity? *Trends in Ecology & Evolution*, *23*, 261–267. 5 https://doi.org/10.1016/j.tree.2008.01.005

Brancalion, P. & Chazdon, Robin (2017). Beyond hectares: four principles to guide reforestation in the context of tropical forest and landscape restoration: Forest and landscape restoration principles. *Restoration Ecology*, *25*, 491–496. 4 https://doi.org/10.1111/rec.12519

Campanha, M. M., Santos, R. H. S., De Freitas, G. B., Martinez, H. E. P., Garcia, S. L. R., & Finger, F. L. (2004). Growth and yield of coffee plants in agroforestry and monoculture systems in Minas Gerais, Brazil. *Agroforestry Systems*, *63*, 75–82. 1 https://doi.org/10.1023/B:AGFO.0000049435.22512.2d

Cardinale, B. J., Duffy, J. E., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., Narwani, A., Mace, G M., Tilman, D., Wardle, D A., Kinzig, A P., Daily, G C., Loreau, M., Grace, J B., Larigauderie, A., Srivastava, D S., Naeem, S., (2012). Biodiversity loss and its impact on humanity. *Nature*, *486*, 59–67. 7401 https://doi.org/10.1038/nature11148

Cardoso, I. M., Guijt, I., Franco, F. S., Carvalho, A. F., & Neto, P. S. (2001). Continual learning for agroforestry system design: university, NGO and farmer partnership in Minas Gerais, Brazil. *Agricultural Systems*, *69*, 235–257. 3 https://doi.org/10.1016/S0308-521X(01)00028-2

Chamberlain, J. L., Bush, R. J., Hammett, A. L., & Araman, P. A. (2000). Managing national forests of the eastern United States for non-timber forest products. *Proceedings, XXI IUFRO World Congress 2000, Forests and Society: The Role of Research*, *1*, 407–420.

Chazdon, R. & Brancalion, P. (2019). Restoring forests as a means to many ends. *Science*, *365*(6448), 24–25–. https://doi.org/10.1126/science.aax9539

Cordell, S., Ostertag, R., Michaud, J., & Warman, L. (2016). Quandaries of a decade-long restoration experiment trying to reduce invasive species: beat them, join them, give up, or start over? *Restoration Ecology*, *24*, 139–144. 2. https://doi.org/10.1111/rec.12321

Debrot, A. O., Veldhuizen, A., van den Burg, S. W. K., Klapwijk, C J., Islam, M N., Alam, M I., Ahsan, M N., Ahmed, M U., Hasan, S R., Fadilah, R., Noor, Y R., Pribadi, R., Rejeki, S., Damastuti, E., Koopmanschap, E., Reinhard, S., Terwisscha van Scheltinga, C., Verburg, C., Poelman, M. (2020). Non-timber forest product livelihood-focused interventions in support of mangrove restoration: A call to action. *Forests*, *11* 1224

Denslow, J. S. & DeWalt, S. J. 2008. Exotic plant invasions in tropical forests: Patterns and hypotheses. In W.P. Carson, S.A. Schnitzer (Eds.), *Tropical forest community ecology* (pp. 87–112). Chicago, IL: University of Chicago.

de Souza, S. E., Vidal, E., Chagas, G. d. F., Elgar, A. T., & Brancalion, P. (2016). Ecological outcomes and livelihood benefits of community-managed agroforests and second growth forests in Southeast Brazil. *Biotropica*, *48*, 868–881–. 6 https://doi.org/10.1111/btp.12388

Emery, M. R. (2001). Non-timber forest products and livelihoods in Michigan's Upper Peninsula. In I. Davidson-Hunt, L.C. Duchesne, & J.C. Zasada (Eds.), Forest communities in the third millennium: linking research, business, and policy toward a sustainable non-timber forest product sector, proceedings of the meeting; 1999 October 1-4; *Kenora, Ontario, Canada* (23–30–). Gen. Tech. Rep. NC-217, St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station.

Feary, S. (2012). From Kauri to Kumara: Forests and people of the Pacific Islands. In B. J. Stubbs, ed. *Australia's ever-changing forests VI: proceedings of the eighth national conference on Australian forest history*. Lismore, New South Wales: Australia National University.

Friday, J. B., Cordell, S., Giardina, C. P., Inman-Narahari, F., Koch, N., Leary, J. J., Litton, C., & Trauernicht, C. (2015). Future directions for forest restoration in Hawai'i. *New Forests*, *46*(5–6), 733–746. https://doi.org/10.1007/s11056-015-9507-3

Giambelluca, T. W., Shuai, X., Barnes, M. L., Alliss, R. J., Longman, R. J., Miura, T., Chen, Q., Frazier, A. G., Mudd, R. G, Cuo, L., & Businger, A. D. (2014). Evapotranspiration of Hawai'i. Final report submitted to the U.S. In Army Corps of Engineers—Honolulu District, and the Commission on Water Resource Management. State of Hawaii. http://evapotranspiration.geography.hawaii.edu/howtocite.html

Godoy, R., Lubowski, R., & Markandya, A. (1993). A method for the economic valuation of non-timber tropical forest products. *Economic Botany*, *47*(3), 220–233. https://doi.org/10.1007/BF02862288

Greenwell, A. B. H., Lincoln, N., & Van Dyke, P. (2009). *Amy Greenwell Garden ethnobotanical guide to native Hawaiian plants & Polynesian-introduced plants*. Bishop Museum Press.

Hawaii Department of Land and Natural Resources. (2010). *Forest products and carbon sequestration*. Hawaii Statewide Assessment of Forest Conditions and Resource Strategy. Retrieved June 16, 2016, from http://dlnr.hawaii.gov/forestry/files/2013/09/SWARS-Issue-8.pdf

He, J., Zhou, Z., Weyerhaeuser, H., & Xu, J. (2009). Participatory technology development for incorporating non-timber forest products into forest restoration in Yunnan, Southwest China. *Forest Ecology and Management*, *257*(10), 2010–2016. https://doi.org/10.1016/j.foreco.2009.01.041

Higgs, E. (2017). Novel and designed ecosystems. *Restoration Ecology*, *25*(1), 8–13. https://doi.org/10.1111/rec.12410

Hilgenkamp, K., & Pescaia, C. (2003). Traditional Hawaiian healing and Western influence. *Californian Journal of Health Promotion*, *1*(SI), 34–39. https://doi.org/10.32398/cjhp.v1iSI.556

Hobbs, R. J., Higgs, E., & Harris, J. A. (2009). Novel ecosystems: Implications for conservation and restoration. *Trends in Ecology & Evolution*, *24*(11), 599–605. https://doi.org/10.1016/j.tree.2009.05.012

Holloway, I. (1997). *Basic concepts for qualitative research*. Blackwell Science.

Idol, T. (2012). *Ecosystem services from trees in coffee agroecosystems*. University of Hawaii.

Kilching, P., Hansmann, R., & Seeland, K. (2009). Demand for non-timber forest products: Surveys of urban consumers and sellers in Switzerland. *Forest Policy and Economics*, *11*(4), 294–300. https://doi.org/10.1016/j.forpol.2009.05.003

Lamb, D. (1998). Large-scale ecological restoration of degraded tropical forest lands: The potential role of timber plantations. *Restoration Ecology*, *6*(3), 271–279. https://doi.org/10.1046/j.1526-100X.1998.00632.x

Laurance, W. F., Sayer, J., & Cassman, K. G. (2014). Agricultural expansion and its impacts on tropical nature. *Trends in Ecology & Evolution*, *29*(2), 107–116. https://doi.org/10.1016/j.tree.2013.12.001

Lavorel, S., & Hutchings, M. (2013). Plant functional effects on ecosystem services. *Journal of Ecology*, *101*(1), 4–8. https://doi.org/10.1111/1365-2745.12031

Lazos-Chavero, E. L., Zinda, J., Bennett-Curry, A., Balvanera, P., Bloomfields, G., Lindell, C., & Negra, C. (2016). Stakeholders and tropical reforestation: challenges, trade-offs, and strategies in dynamic environments. *Biotropica*, *48*(6), 900–916. https://doi.org/10.1111/btp.12391

Malhi, Y., Gardner, T. A., Goldsmith, G. R., Silman, M. R., & Zelazowski, P. (2014). Tropical forests in the Anthropocene. *Annual Review of Environment and Resources*, *39*(1), 125–159. https://doi.org/10.1146/annurev-environ-030713-155141

Mascaro, J. (2011). Eighty Years of Succession in a Noncommercial Plantation on Hawaii Island: Are Native Species Returning? *Pacific Science*, 65(1), 1–16. https://doi.org/10.2984/65.1.001

Meilleur, B. A., Jones, R. R., Tichenal, C. A., & Huang, A. S. (2015). *Hawaiian breadfruit: Ethnobotany, nutrition, and human ecology*. University of Hawaii Press.

Melrose, J., Perroy, R., & Cares, S. (2015). *Statewide agricultural land use baseline*. Hawaii State Department of Agriculture.

Ostertag, R., Cordell, S., Michaud, J., Cole, T. C., Schulten, J. R., Publico, K., & Enoka, J. H. (2009). Ecosystem and restoration consequences of invasive woody species removal in Hawaiian lowland wet forest. *Ecosystems*, *12*(3), 503–515. https://doi.org/10.1007/s10021-009-9239-3

Ostertag, R., Warman, L., Cordell, S., Vitousek, P. M., & Lewis, O. (2015). Using plant functional traits to restore Hawaiian rainforest. *Journal of Applied Ecology*, *52*(4), 805–809. https://doi.org/10.1111/1365-2664.12413

Pokorny, M. L., Sheley, R. L., Zabinski, C. A., Engel, R. E., Svejcar, T. J., & Borkowski, J. J. (2005). Plant functional group diversity as a mechanism for invasion resistance. *Restoration Ecology*, *13*(3), 448–459. https://doi.org/10.1111/j.1526-100X.2005.00056.x

Putz, F. E. P., & Redford, K. H. (2010). The importance of defining 'forest': Tropical forest degradation, deforestation, long-term phase shifts, and further transitions. *Biotropica*, *42*(1), 10–20. https://doi.org/10.1111/j.1744-7429.2009.00567.x

Rayome, D. D., Ostertag, R., & Cordell, S. (2018). Enhancing aboveground carbon storage and invasion resistance through restoration: Early results from a functional trait-based experiment. *Pacific Science*, *72*(1), 149–164. https://doi.org/10.2984/72.1.10

Rayome, D. D., Ostertag, R., Cordell, S., Vitousek, P., Fung, B., Pante, P., Tate, R., & Vizzone, A. (2019). *Restoring ecosystem services tool (REST) introduction and user guide*. General Technical Report 262. U.S. Department of Agriculture, Forest Service, Southwest Research Station.

Richardson, D. M., & Pyšek, P. (2012). Naturalization of introduced plants: ecological drivers of biogeographical patterns. *New Phytologist*, *196*(2), 383–396. https://doi.org/10.1111/j.1469-8137.2012.04292.x

Sabogal, C., Besacier, C., & McGuire, D. (2015). Forest and landscape restoration: concepts, approaches and challenges for implementation. *Unasylva*, *245*(66), 3–10. https://www.fao.org/3/i5212e/i5212e.pdf

Sacande, M., & Parfondry, M. (2018). *Non-timber forest products: from restoration to income generation*. FAO. 40. License: CC BY-NC-SA 3.0 IGO.

Shackleton, C., Shackleton, S., & Shanley, P. (2011). Building a holistic picture: An integrative analysis of current and future prospects for non-timber forest products in a changing world. In S. Shackleton, C. Shackleton, & P. Shanley (Eds.), *Non-timber forest products in the global context* (Vol. 7, pp. 255–280). Springer. Tropical Forestry

Shanley, P., Luz, L., & Swingland, I. R. (2002). The faint promise of a distant market: a survey of Belém's trade in non-timber forest products. *Biodiversity & Conservation*, *11*(4), 615–636. https://doi.org/10.1023/A:1015556508925

Soto-Pinto, L., Perfecto, I., Castillo-Hernandez, J., & Caballero-Nieto, J. (2000). Shade effect on coffee production at the northern Tzeltal zone of the state of Chiapas, Mexico. *Agriculture, Ecosystems & Environment*, *80*(1–2), 61–69. https://doi.org/10.1016/S0167-8809(00)00134-1

Southichack, M. (2007). *Inshipment trend and its implication on Hawaii's food security. Hawaii Department of Agriculture, Agriculture Development Division, Market Analysis and News*. State of Hawaii Agricultural Development Division. Retrieved September, 9, 2013 from http://www.kohalacenter.org/pdf/HDOA_hawaii_food_securitypdf

State of Hawaii Agricultural Development Division (2019). *Farmer's market listings*: http://hdoa.hawaii.gov/add/md/farmers-market-listings. 14 Dec 2019

State of Hawaii Department of Agriculture, Division of Marketing. (2016). *Made in Hawaii License Agreement*. https://stateofhawaii.na1.echosign.com/public/esignWidget?wid=CBFCIBAA3AAABLblqZhAa5XE1WPyLBXiqWM2VN1I0mPzuVpw6E7S_sSANdsV0mQRIqWF5uCYDGlAB1PFXr0. 14 Dec 2019

Ticktin, T., Fraiola, H., & Whitehead, A. N. (2007). Non-timber forest product harvesting in alien-dominated forests: Effects of frond-harvest and rainfall on the demography of two native Hawaiian ferns. *Biodiversity and Conservation*, *16*(6), 1633–1651. https://doi.org/10.1007/s10531-006-9030-0

Ticktin, T., & Shackleton, C. (2011). Harvesting non-timber forest products sustainably: opportunities and challenges. In S. Shackleton, C. Shackleton, & P. Shanley (Eds.), *Non-timber forest products in the global context* (Vol. 7, pp. 149–169). Tropical Forestry.

Vieira, D. L., Holl, K. D., & Peneireiro, F. M. (2009). Agro-successional restoration as a strategy to facilitate tropical forest recovery. *Restoration Ecology*, *17*(4), 451–459. https://doi.org/10.1111/j.1526-100X.2009.00570.x

Zimmerman, N., Hughes, R. F., Cordell, S., Hart, P., Chang, H. K., Perez, D., Like, R. K., & Ostertag, R. (2008). Patterns of primary succession of native and introduced plants in lowland wet forests in eastern Hawaiʻi. *Biotropica*, *40*(3), 277–284. https://doi.org/10.1111/j.1744-7429.2007.00371.x