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# Restoration of ‘Āina Malo’o on Hawai‘i Island: Expanding Biocultural Relationships

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**Abstract:** Before European contact, Native Hawaiian agriculture was highly adapted to place and expressed a myriad of forms. Although the iconic lo‘i systems (flooded irrigated terraces) are often portrayed as traditional Hawaiian agriculture, other forms of agriculture were, in sum, arguably more important. While pockets of traditional agricultural practices have persevered over the 240 years since European arrival, the revival of indigenous methods and crops has substantially increased since the 1970s. While engagement in lo‘i restoration and maintenance has been a core vehicle for communication and education regarding Hawaiian culture, it does not represent the full spectrum of Hawaiian agriculture and, on the younger islands of Hawai‘i and Maui in particular, does not accurately represent participants’ ancestral engagement with ‘āina malo’o (dry land, as opposed to flooded lands). These “dryland” forms of agriculture produced more food than lo‘i, especially on the younger islands, were used to produce a broader range of resource crops such as for fiber, timber, and medicine, were more widespread across the islands, and formed the economic base for the powerful Hawai‘i Island chiefs who eventually conquered the archipelago. The recent engagement in the restoration of these forms of agriculture on Hawai‘i Island, compared to the more longstanding efforts to revive lo‘i-based cultivation, is challenging due to highly eroded knowledge systems. However, their restoration highlights the high level of place-based adaptation, demonstrates the scale and political landscape of pre-European Hawai‘i, and provides essential elements in supporting the restoration of Hawaiian culture.

**Keywords:** traditional agriculture; indigenous agriculture; biocultural; restoration; Hawai‘i

## 1. Introduction

Biocultural restoration relies upon understanding specific cultures and practices within an ecological context [1,2]. Increasingly, several fields are asserting the importance of using an approach that recognizes the intertwined nature of people and place to develop adaptive management strategies [3,4]. Doing so requires a holistic understanding of both the sociocultural and ecological systems, and in particular, the relationships and feedbacks that are encompassed within socioecological systems. It has been suggested that islands in general are well suited to the study of coupled natural

and human systems and Hawai'i in particular has been hailed as a model system for the exploration of these complex human-environment dynamics [5]. This is because unique attributes of both the natural and social environments present ideal combinations of complexity and tractability. For instance, Hawai'i encompasses an extraordinary range of variation in climate and substrate age in a small area, but the resulting diversity in soils and ecosystems is highly organized and predictable in its distribution [6]. Similarly, Hawai'i reached a high state of political complexity and state governance prior to the arrival of Europeans, yet represents a very short timeline of human occupation and a relatively closed social system at the archipelago level [5]. Consequently, unique opportunities for understanding the development and diversity of biocultural relationships exists in Hawai'i.

Of particular interest to both research and restoration have been Hawaiian agricultural systems. Before European contact, Native Hawaiian agriculture was highly adapted to place and expressed a myriad of forms [7]. The development of unique resource management practices evolved to local environments maximized efficient productivity [8–14]. This led to highly specific, place-adapted indigenous knowledge that powered the political evolution of the ancient Hawaiian state. In the past few decades there has been an increasing recognition of the high value of this knowledge in contemporary resource management and land stewardship, and growing efforts to preserve and revitalize such knowledge. Restoration of these place-adapted systems has proven challenging due to significant loss of traditional ecological knowledge.

In reviewing efforts to revitalize traditional agricultural techniques, we see several commonalities between organizations that are undertaking these efforts; in particular, the application of highly interdisciplinary, non-linear approaches that rely on strong relationships between players across different disciplines and epistemologies. We suggest that oversimplification of the diverse, place-based requirements and practices associated with traditional Hawaiian agriculture has impeded in-depth understanding of traditional Hawaiian agriculture, and consequently, has also impeded the restoration of these systems. Furthermore, we suggest that examining these agricultural efforts within a landscape-level socioecological context is essential to understanding their function and roles in both the past and the present. While exploring these theoretical underpinnings, we also discuss practical components of conducting biocultural restoration.

#### *Understanding Environmental and Social Adaptation in Hawaiian Agriculture*

In illustrating the adaptive nature of socioecological systems, this paper presents a novel treatment of the evolution and function of one core biocultural coupling—agriculture. As concepts of biocultural management grow, it is important to exemplify how form and function of socioecological couplings are a product of both the environmental and the social landscape. Even common and essential elements, in this case of agriculture, manifested differently within the larger socioecological landscape in the past, and similarly manifest differently within the contemporary efforts to restore these systems.

In this paper, we first present a review of the evolution of agricultural form in Hawai'i based on local environments, and illustrate the knowledge specificity and system functionality that existed in the past. We then consider recent efforts to expand the form of agricultural restoration from that which has dominated the last 30 years of effort by describing several organizations and their efforts. These organizations were selected as, to the authors' expert knowledge, the leading efforts on Hawai'i Island to expand the form of traditional agriculture restoration. We explore common elements of the efforts, how they differ from previous efforts, and how these differences are manifested within contemporary social and political movements.

Importantly, we utilize indigenous methodology that directly engages those intimately involved in the efforts. This includes participants from both western and indigenous science perspectives. All participants are highly experienced experts that, in a traditional ethnographic study, would be treated as human subjects within a study rather than given the opportunity to tell their own story directly. It is important to note that all the authors have been intimately involved with the restoration of these systems in different capacities and speak from immersed experience in the process; 11 of the

15 participants and six of the nine authors are native Hawaiians. All involved are highly experienced in traditional agriculture in a myriad of forms.

## 2. Evolution and Restoration of Traditional Hawaiian Agricultural Forms

The unique and highly diverse biophysical landscape of Hawai'i compared to the southern Polynesian islands supported the development of new agricultural practices that were not found elsewhere in the Pacific. Hawai'i is the only Polynesian group north of the equator, the only islands with mountain peaks over 4000 m, and the only islands with constant and current volcanic activity, resulting in a denser and more diverse array of soils and ecosystems. The most salient division in land types, recognized even by ancient agriculturalists, were 'āina wai (inundated, wet lands) and 'āina malo'o (non-flooded, dry lands).

'Āina wai and 'āina malo'o supported distinctly different forms of agriculture. In particular, 'āina wai primarily supported lo'i—flooded, irrigated agriculture akin to rice paddies but focused on kalo (taro, *Colocasia esculenta*) (Throughout this paper we use the Hawaiian crop names to emphasize that, although they are common tropical species found over broad ranges, the landraces with which the Hawaiian culture coevolved are unique Hawaiian cultivars. The names and encoded knowledge that accompany this specific group of cultivars sets it apart from the species as a whole; cultural restoration arguably could not occur, and certainly could not occur to the full extent, with just any taro species, but only the specific cultivars that are appropriately referred to as kalo.) Hawaiians deliberately created and altered 'āina wai specifically for lo'i cultivation through the building of terraces, excavating of lands, and construction of dams and canals. In contrast to the relatively tight coupling of 'āina wai to lo'i cultivation, 'āina malo'o supported a broad range of agricultural strategies that included home gardens (kihāpai), agroforestry (mahi 'ulu lā'au), intensive dryland farming (mahi 'ai), and a range of other strategies (see Lincoln and Vitousek 2017 for an overview). Additionally, there were "hybrid" systems that developed from diverting water from wet areas to irrigate dry lands intermittently, or dry lands that were intermittently wet on their own through seasonal rivers and springs.

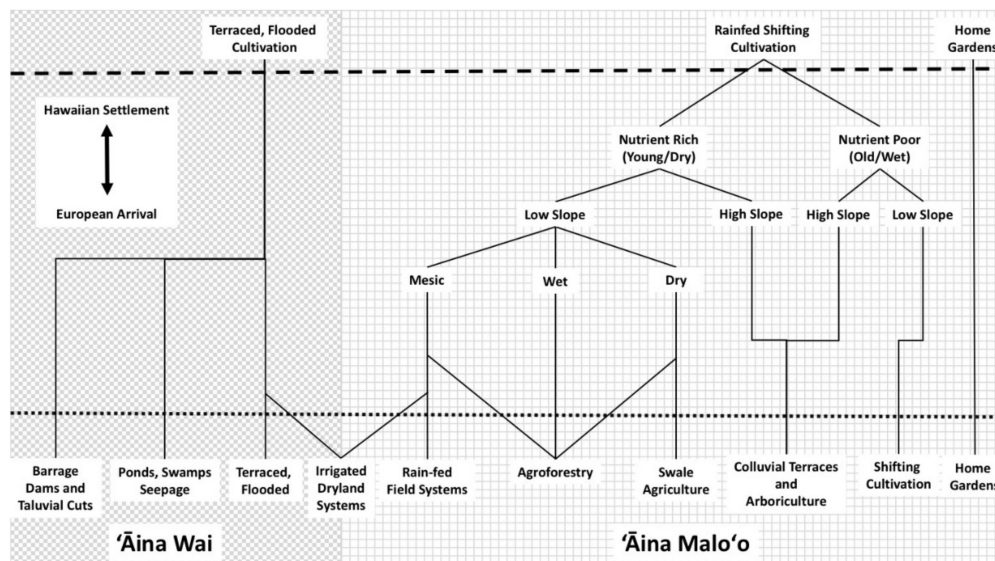
In sweeping terms, archaeologists and anthropologists consider lo'i agriculture to be high in *landesque capital* [15], requiring significant infrastructural investment to construct terraces and canals to control the flow of water. Following construction, lo'i agriculture produced a significant surplus, as the flowing water reduced labor demands for weeding, fertilization, and watering of crops while supporting high productivity [16]. This form of production was also resilient against natural perturbations, such as drought, and social disturbances, such as war. In contrast, agriculture practiced on dry lands is presented as having less infrastructural development and higher labor costs, resulting in lower surplus production and, therefore, higher vulnerability to social disturbances [17]. Such systems, being dominantly rainfed, are also inherently more variable in their production, both spatially and temporally; therefore agriculture on 'āina malo'o has been considered more vulnerable to natural disturbances as well [12]. However, these generalizations are built upon sparse investigations into traditional agricultural systems, and none of them on operational systems in Hawai'i. As described, the forms of agriculture on 'āina malo'o are too diverse for easy generalization. Recent research by the authors identifies such systems that have minimal infrastructural investment and minimal labor requirements [10], extremely high infrastructural investment and moderate labor requirements [18], and moderate infrastructural development with high labor requirements [13].

Although the iconic lo'i systems are dominantly portrayed as traditional Hawaiian agriculture, agriculture on 'āina malo'o was, arguably, more important (especially on the younger islands): they produced more food than lo'i, at least on the younger islands; they were used to produce a broader range of crops with resource crops for fiber, timber, and medicine grown almost exclusively in dryland conditions; they were more widespread across the archipelago, occurring everywhere Hawaiians inhabited; and they formed the economic base for the powerful Hawai'i Island chiefs who eventually conquered the archipelago [17,19–21]. Documentation and modeling of rainfed agriculture in the

state conservatively indicates that, in terms of land area, agriculture on ‘āina malo’o exceeded lo’i agriculture at least five times [19,20].

### 2.1. Traditional Agriculture on ‘Āina Malo’o

While lo’i agriculture is primarily based on kalo and is relatively consistent in its form, agriculture on ‘āina malo’o was much more diverse, utilizing a range of cropping systems including small heavily-managed gardens near house sites, large-scale intensive multi-crop systems, mixed agroforestry, swidden or shifting agriculture, and arboriculture (Figure 1) [7,10,16,19–55]. The diverse forms of cropping systems reflected the differing ecosystems and topography that ‘āina malo’o occupied. The drivers of agricultural form appear to dominantly be the soil depth and fertility, the slope of the land, and rainfall, although other local variations likely played a role as well [7,19,20,54].



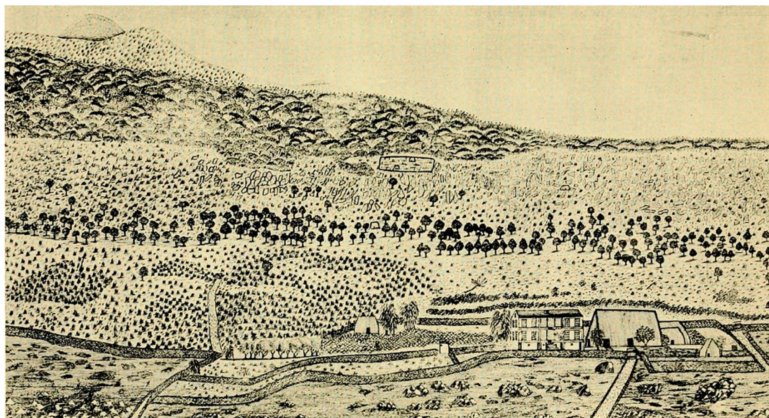
**Figure 1.** A rough typology for agricultural production systems in pre-contact Hawai’i; the general categories are not exhaustive and represent a spectrum of practices. The dashed horizontal line is intended to demarcate systems that the Polynesian discoverers of Hawai’i had in mind when they arrived; the lower dotted line indicates the range of techniques employed at the time of European arrival. There is no implication that cropping systems are invariant over time along a given line; to the contrary, we know that systems of lo’i expanded over time, rain-fed field systems underwent infilling and intensification, and shifting cultivation systems began to manage the fallow as well as the cropping phase intensively; other systems no doubt developed as well.

A considerable portion of the area devoted to rainfed cultivation occurred in vast, intensively developed “systems,” such as the Leeward Kohala Field System (Figure 2). These intensive systems were confined to areas with high natural soil fertility [9,56] and adequate rainfall, mostly on the young islands of Hawai’i and Maui [19]. These field systems are defined by common elements of agricultural infrastructure, including long linear embankments and built stone mounds, although considerable diversity in form and application of the infrastructure is evident. Embankments were planted with taller crops such as kō (sugarcane, *Saccharum officinarum*), mai’a (plantain/banana, *Musa spp.*), and kī (ti, *Cordyline fruticosa*), and bordered cleared fields containing the primary staples of kalo, ‘uala (sweet potato, *Ipomoea batatas*), and ‘uhi (greater yam, *Dioscorea alata*). These continuous systems occupied vast areas on the younger islands; the largest of which was likely the Ka’ū system that may have covered over 50,000 acres [11,19]. Portions of these systems were likely farmed seasonally based on patterns of rainfall and temperature [12,13].



**Figure 2.** The infrastructural remnants of the Leeward Kohala Field System—a vast, dense network of rainfed farming plots.

Agroforestry and other forms of tree agriculture represented another significant fraction of agriculture on ‘āina malo’o (Figure 3). Tree crops, such as ‘ulu (breadfruit, *Artocarpus altilis*), kukui (candlenut, *Aleurites moloccanus*), niu (coconut, *Cocos nucifera*), hala (*Pandanus tectorius*), and ‘ōhi’a’ai (mountain apple, *Syzygium malaccense*) were employed extensively by Hawaiians, primarily in places that were too dry, too rocky, too steep, too salty, too infertile, or too small for the “system” form of agriculture discussed above (e.g., Reference [20]), although several extensive agroforestry systems were developed in fertile areas (e.g., Reference [10]). Agroforestry in ancient times included mono-cropped arboricultural stands, multi-tiered diversified agroforestry, and the alteration and tending of native forests (e.g., References [21,28,34]).



**Figure 3.** An 1836 drawing by Persis Goodale Thurston depicts the different rainfed farming zones within Kona, Hawai'i Island. The *kula* lands in the foreground represented opportunistic agriculture and home gardens in the dry lowlands, the *kalu'ulu* arboriculture appears as a distinct band of breadfruit trees across the landscape, the *'āpa'a* planting zone follows with its intensive stone infrastructure depicted, and finally the *ama'u* zone as managed native forest.

Non-flooded agriculture also includes a range of miscellaneous techniques that were smaller in scale and scope, but collectively were applied to a large area. These were highly diverse forms of practice and infrastructure at a micro-habitat scale; they included check dams (pa'amua), water holes (nā loko wai), terraces (kīpapa), intermittent water manipulation, stone and earth mounds (pu'u), swales, built soils, and other innovations that took advantages of local topography and environment. These developments ranged in intensity, scale, and productivity, but were highly place-adapted to maximize the scope of agriculture given the local opportunities and constraints. These variable developments often occurred adjacent to, or even embedded within, the intensive systems as the landscape shifted into more marginal environments in terms of water or soil fertility. However, some regions without potential for intensive systems of agriculture applied these alternative techniques extensively.

On Hawai'i Island, the vast majority of agriculture was of non-flooded forms, although a few opportunities existed for lo'i agriculture in older, windward areas. Moving clockwise around the island, we generalize its agricultural opportunities (Figure 4). Starting at the northern point of the Kohala peninsula, small valleys were developed for limited lo'i with rainfed agriculture (probably shifting cultivation) occurring between the valleys, and in a late pre-contact development, tunnels and canals were constructed to irrigate interfluvial areas [57]. On the northeastern coast a series of large valleys offered ideal locations for lo'i with agroforestry conducted on the colluvial valley slopes. Moving south into Hamakua vast areas of agroforestry were employed, and unique swidden and arboriculture systems established, along with sparse lo'i opportunities in the many small streams and rivers. Larger rivers flow into Hilo Bay, and relatively large systems of lo'i were established there. In the very young but wet regions of Puna, vast areas of multi-tiered agroforestry existed along with multiple forms of agricultural gardens such as planting pits and built soils. Surrounding the southern point of Ka'u was perhaps the largest intensive rainfed field system. The southwest coast, being very dry and young, offered limited opportunities for agriculture that took advantage of microsite development. Along the Kona coast, another large, intensive field system existed. Moving north along the west coast the landscape again becomes dry and provides only for limited development of agriculture at opportunistic sites. At the inlet just south of the Kohala peninsula, two intensive hybrid systems that intermittently irrigated dryland areas existed. Finally, along the western coast of Kohala, a final, intensive dryland field system (the Leeward Kohala Field System) existed inland. While this captures the large-scale patterns of agricultural developments around the island, it is important to note that a substantial amount of variation occurred within these generalizations.

## 2.2. *The Decline and Rise of Traditional Agriculture*

Following European colonization, with the decline of the native population, the privatization of lands, the introduction of plantation agriculture, and the control of water resources, native Hawaiian agriculture diminished substantially [58]. In particular, the rainfed agricultural systems, which were both more vulnerable and had land more conducive to plantation agriculture, declined very rapidly. While lo'i systems also declined precipitously, their physical infrastructure and continued practice were sustained at a much higher rate.

While pockets of traditional agricultural practices have persevered over the 240 years since European arrival, the revival of indigenous methods and crops has significantly increased since the "Hawaiian Renaissance" of the 1970s (e.g., see Kagawa-Viviani et al., this issue). Since then, hundreds of individual lo'i terraces in dozens of districts have been restored, both into commercial and subsistence production; often through the efforts of nonprofit organizations focused on cultural and environmental restoration and education. Conversely, restoration on 'āina malo'o remained largely non-existent. That lo'i have been prevalent in initial restoration efforts could be expected for several reasons. First, it follows the ancient temporal pattern, in which wetland areas with abundant freshwater resources were developed first by the original settlers of the island [7,59]. Furthermore, lo'i are common throughout Polynesia and therefore represent a knowledge system with more common

and recoverable knowledge from other areas. As indicated above, lo'i infrastructure and practices have been better preserved and thus represented a more accessible starting point for restoration efforts; this is coupled with the fact that labor requirements of lo'i are typically lower on a per area basis, allowing restoration to occur with a relatively small cohesive group and therefore more easily obtaining a "critical mass" to power the efforts. Finally, and not to be understated, lo'i terraces are used to grow kalo (taro, *Colocasia esculenta*) to the near exclusion of all other crops [60]. Kalo is a piko, both spiritually and physically, of the Hawaiian people; its importance as "the staff of life" gives it a central role in any efforts of biocultural restoration. Piko literally refers to the navel and umbilical cord, or a summit, and symbolically refers to a connection to the world. In Hawaiian epistemology, a person has three piko that connected one to the spiritual and physical world—the fontanel that connected one to theirhis/her ancestors, the navel that connected one to the present world, and the genitals that connected one to theirhis/her future. This worldview recognizes that humans are a product of genetic and environmental history, that they are intimately connected to everything in the present, and that their being will impact everything to come in the future. Kalo is seen as a manifestation of this connection, as it is connected to mankind through ancestryancestral cosmology, connected to mankind by reciprocal sustenance (humans farming kalo and kalo feeding humans), and connected to mankind in their relationship into the future. More practically, kalo was the preferred staple of the people and the gods, and therefore central to the diet of the people and religious and ceremonial practices.

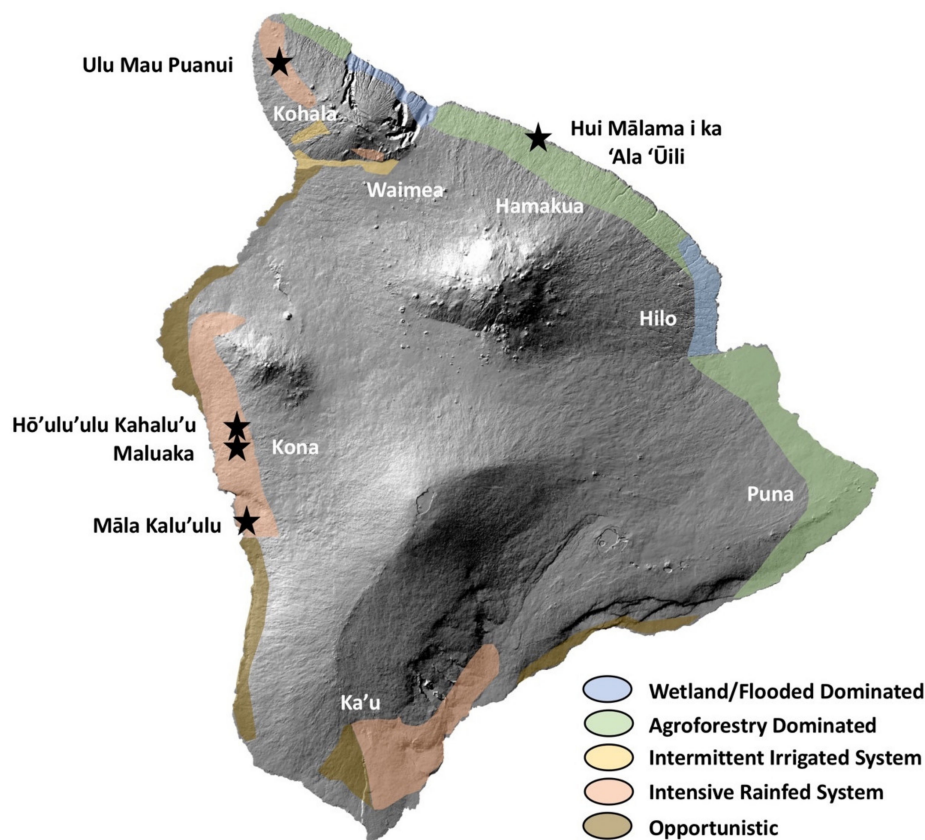
### 3. Reviving 'Āina Malo'o

While engagement in lo'i restoration and maintenance has been a core vehicle for communication and education regarding Hawaiian culture, it does not represent the full spectrum of Hawaiian agriculture and, on the younger islands of Hawai'i and Maui in particular, does not accurately represent participants' ancestral engagement with 'āina malo'o. To facilitate discussion of biocultural restoration stemming from the revived cultivation of 'āina malo'o multiple representatives from each of five identified organizations (Figure 4) contributed: Ulu Mau Puanui, Maluaka, Māla Kalu'ulu, Hui Mālama i ka 'Āla 'Ūlili, and Ho'o'ulu'ulu Kahalu'u. The contributors represent a wealth of experience regarding efforts on 'āina wai and 'āina malo'o, and are among the leading organizations conducting agricultural restoration on 'āina malo'o. We present a brief case study on three of the organizations to exemplify key aspects of the efforts. The three were selected not only because they are the most developed of the organizations, but represent the most substantially different pathways to the restoration that is occurring.

#### 3.1. Ulu Mau Puanui

While researching the leeward Kohala slopes, using one of the most striking rainfall gradients on the planet to study soils and ecosystems, Peter Vitousek and colleagues had the opportunity to collaborate with archaeologists studying the rain-fed Leeward Kohala Field System, a 6500-hectare area that was once farmed intensively by Hawaiians. The region, which is mostly used for cattle today, retains the imprint of Hawaiian agricultural practices, with the infrastructure still etched on the landscape (Figure 2). Together, ecologists and archaeologists developed an understanding of why the systems exist where they are, eventually demonstrating that the location of the field systems related to soil development and thresholds of soil properties that change with age and rainfall. The interdisciplinary team also studied the Hawaiian populations that lived in leeward Kohala and how their societies functioned and evolved [19,39,61–72]. However, for all the research that situated the development of agriculture within environmental and social context, they did not understand *how* rain-fed agricultural systems worked, namely how people grew crops and how they sustained the productivity of that land for centuries under conditions where most people worldwide practiced much less efficient slash-and-burn agriculture. Recognition of this shortcoming led to the founding of Ulu Mau Puanui, a community-based non-profit organization that established three permanent garden

plots spanning the rainfall gradient in an effort to rediscover the agricultural practices associated with the field system.



**Figure 4.** Location of the five organizations focused on restoration of traditional dryland agriculture and a depiction of the general patterns of agricultural reliance of Hawai'i Island estimates by ethnographic sources, archaeological surveys, and biogeochemical models. It is important to note that the forms of agriculture presented are only the broad categories of the dominant forms applied, and many nuanced variations within any area occurred, including areas that do not depict any agriculture. For instance, in Kona, although dominantly rainfed areas of spring-fed, flooded or irrigated cultivation occurred, along with areas of agroforestry.

Puanui is one of thirty-three *ahupua'a* in leeward Kohala that make up the Kohala Field System. (*Ahupua'a* is a traditional land division system, generally considered the smallest land division in Hawai'i that still retained strong political oversight, which, for the most part, coincides with the concentric geography of islands, in which the divisions extend from an upland interior to the ocean, encompassing a range of ecosystems and resource types [73].) While large ranching landowners now own most of the Kohala Field System, Kamehameha Schools owns the narrow *ahupua'a* of Puanui (but has leased it to Parker Ranch for grazing for many years). (The Kamehameha Schools is a private educational trust endowed by the will of Hawaiian Princess Bernice Pauahi Bishop (1831–1884) that provides preferential admittance to Native Hawaiian students. They are the largest private landholder in Hawai'i and a very substantial organization in the state. As the literal and metaphorical descendant of the Hawaiian monarchy, they are in the critical eye of the Native Hawaiian population, which insists that they be leaders and advocates for Hawaiian culture and well-being.) When approached, both Kamehameha Schools and Parker Ranch were highly supportive of an effort to bring Hawaiian crops, and the Hawaiian community, back to the Kohala Field System at Puanui. Ulu Mau Puanui's efforts focused on outreach and education to the broader community. The gardens attracted substantial local



interest, including groups from several schools that made multiple repeat visits. It quickly became clear that there is no substitute for experience and experimentation in this landscape; the system itself must have evolved that way, and as we seek to understand it, we find that experience and experiments unlock knowledge in the community as well as providing scientific information.

Ulu Mau Puanui manages the gardens of Puanui, provides access to the land for schools and community members, and encourages groups to come and work on the rain-fed agricultural system and to contribute to the process of discovery. The mission of Ulu Mau Puanui is to “engage in hands-on, land-based learning and culturally-centered science with learners, educators, families, and community in order to revitalize and better understand the Kohala Field System”. The vision is that,

when we are successful, our communities will appreciate the scope, diversity, and global significance of Hawaiian agriculture as it was practiced before European contact. We will understand that Hawaiian agriculture arose from a populous, organized and innovative society, and that the society in turn was shaped by its interactions with the land. We will build on that understanding to create an innovative and dynamic modern society that has a deep understanding and connection to its land. It is our hope that this transformation will spread across the Archipelago, and across the Pacific to produce a transformed modern agricultural system that draws from the wisdom and sustainability of the past, the knowledge and experience of local farmers and ranchers, and the best agricultural practices of the wider world that provides Hawaii with most of our food.

At Ulu Mau Puanui, a sustained interaction between scientists, respected cultural leaders, and community and student members has resulted in trust building and mutual exchange that has caused all parties to ask deeper questions and examine their own biases and assumptions in new ways. Culturally-centered science—the integration of Hawaiian ways of knowing that helps inform and inspire scientific inquiry—has been the cornerstone of activities. This has led to an inquiry-based framework that promotes creativity while practicing cultural values such as *kilo*—observation, *pili*—relationship to the land and others, *hō‘ihi*—respect, and *kuleana*—responsibility and privilege. This process has impacted the participants and the researchers alike and brought two, often disparate, perspectives much closer together. Since established, the restoration at Puanui has led to multiple publications that have directly examined elements of biocultural restoration [8,13,14,74].

### 3.2. The Maluaka Project

The Maluaka Project was born from the joining of forces between a series of service-learning anthropology classes taught by Jack Rossen during academic winter intersession and the mapping and restoration of the ten-acre parcel Maluaka parcel of the North Kona agricultural field system by Keone Kalawe and Māhealani Pai. The collaborative archaeological project involves excavation and intensive water flotation to examine field engineering and to recover plant remains. The work is conducted in collaboration with Kamehameha Schools and involves linkages with lineal descendant of that land, elementary, intermediate, and high school students, and at-risk youths, teaching all of them the complexity and genius of Hawaiian agricultural systems and combatting the negative stereotypes of ancient Hawaiians created and maintained by foreigners (e.g., stupid, lazy, etc.). The long-term goal is to revitalize the ancient agricultural terraces and platform system, utilizing Native Hawaiian knowledge and fine-grained archaeological and archaeobotanical data to understand the site in terms of spirituality, technology, layout, and plant patterns.

Over the years, a relationship was formed through sustained interaction. Community-based clearing, restoration, mapping, and utilization of the site was underway by Māhealani Pai and Keone Kalawe. Courses designed for New York college students to experience the culture and history of Hawai‘i Island, led by Jack Rossen, performed service at a wide range of venues, including Maluaka. Each year, the group would spend more and more time at Maluaka, contributing labor while learning about the system. Efforts at the site grew in scale and scope, clearing and restoring

more of the site while increasing community engagement and education. Each year the college returned, Māhealani, Keone, and their students had cleared and mapped more of the site. At one point, Māhealani wondered what type of research would be needed to understand the specific agricultural patterns of the planting platforms and pits we were uncovering; Jack Rossen mentioned that from the perspective of an archaeobotanist, it was a matter of excavating with an emphasis on water flotation recovery and microscope analysis of plant remains, along with starch, pollen, and phytolith studies. This conversation led to the devotion of courses to the Maluaka site and the creation of on-site field schools. During four summer field seasons (2015–2018), excavations in various sectors and elevations of Maluaka occurred, recovering numerous artifacts, and more importantly, discovering high levels of infrastructural development such as an extensive underground canal system, the system of firepits cut into pahoehoe lava, and three to five meter high mounds used as observation points. Unlike many areas of Kona, Maluaka has seasonal water sources in the form of groundwater and spring-fed wells.

How did the Maluaka Project develop from philosophical and intellectual perspectives? It began with the foundation of long-term relationships of friendship and trust. As visitors to the island, New York researchers and students gave volunteer labor over several years with interest and respect for Native culture and history. The Native Hawaiian counterparts gave welcome, cultural perspectives and indigenous practices. From an intellectual standpoint, both parties knew they wanted to combine Native wisdom and knowledge with Western science to understand Hawaiian agricultural systems from a more powerful perspective than could be accomplished by either approach alone. This combination means understanding how archaeology and archaeobotany can provide carefully collected systematic data, and how the long-term site mapping and contemporary usage and observations contribute to a fine-grained understanding. From the start, all understood that Hawaiian agriculture must be understood in terms of Native Hawaiian concepts of land and social organization. Everyone involved has endeavored to understand agriculture as part of broader, integrated, and aligned sacred landscapes. That means understanding the agricultural configuration and observation points (pānānā) of Maluaka in relation to sacred sites (heiau) at the coast below at Keauhou-Kahalu'u, and other major nearby sites such as the Kāneaka holua (land-sledding) slide. Most importantly, all agreed that the research must have practical applications: to understand the modern potential of the agricultural system and rebuild with our eyes toward the future food sovereignty of Hawai'i.

### 3.3. Māla Kalu'ulu

Māla Kalu'ulu Cooperative (MKC) was born out of a desire to restore the *kalu'ulu*—a nine square mile band of traditional breadfruit (*Artocarpus altilis*) agroforestry that stretched 20 miles across the Kona landscape. (The origin of the term *kalu'ulu* is uncertain but appears in early historical land claim records describing the breadfruit zone. Some elders have indicated the term should be, or is a contraction of, *ka ulu 'ulu*, literally meaning “the breadfruit grove”.) Research by Noa Lincoln into the extent and productivity of the breadfruit belt in this area suggested that it produced between 20 and 50 million pounds of breadfruit annually [10], and that the establishment of the breadfruit belt appears to be suited to the unique biogeochemical factors of the region [9]. Inspired by this research, a group of local farmers, entrepreneurs, and educators, in partnership with Noa Lincoln, formed MKC and applied for, and won, the 2015 Mahi'ai Matchup, a farming business plan competition supported by the Pauahi Foundation and Kamehameha Schools which provided a 4-acre land parcel in the heart of the ancient breadfruit belt.

During its establishment, MKC's founding members discussed at length the model of incorporation, ultimately settling on a worker cooperative venture for multiple reasons. Foremost, it was agreed that it was of the utmost importance that the restoration provides people livelihoods and opportunities. It was argued that the cooperative model reflected the traditional social system, in which *kuleana* dominated. *Kuleana* is often defined simply as “responsibility,” but in reality was a reciprocal function of rights that were based on one's responsibilities; in ancient times, a person's ability to access resources related to his or her contribution to maintaining those resources, just as

the rights of cooperative members to access benefits is based on their relative contributions, or in cooperative terms, patronage. Furthermore, in restoring traditional agriculture, MKC wanted to establish that the systems were viable and relevant in the modern world and therefore wanted to develop in a way that could ultimately be self-sufficient. Enrollment in the cooperative is open to all, and the leadership donates time to ensure the success of the program.

Since its inception, MKC has worked to transform its own and other Kona parcels away from dominance by invasive species or mono-cropped agriculture back into the traditional breadfruit-based systems that once existed. These multi-layered agroforestry systems produced environmental benefits, were biodiverse and resilient, reduced the need for chemicals and inputs, were highly productive, and were culturally relevant ways of producing food [75]. The mission of MKC is “to enhance our understanding, appreciation, and utilization of traditional Hawaiian land use practices focusing on food production, and through food production and distribution, research, and education, to enhance sustainability and self-sufficiency in the Hawaiian Islands.” Guided by Native Hawaiian values and practices, MKC aims to work with others across the State to collectively re-learn and enliven the techniques our predecessors used to subsist on the *‘āina* (land), and through proper engagement increase engagement in, and awareness of, Hawaiian cultural perspectives on environmental health and stewardship. Through this work, MKC helps to advance understanding of innovative farming principles developed by early Hawaiians and how these principles can apply to contemporary cropping systems. In addition to restoration and research of the traditional system, MKC develops an “adapted” version of the system to meet today’s market demand better; for instance, by planting a wider variety of crop sub-species for year-round production. The concomitant restoration of the traditional system and development of a modern version may help to demonstrate the viability and relevance of traditional farming practices in today’s socioeconomic environment.

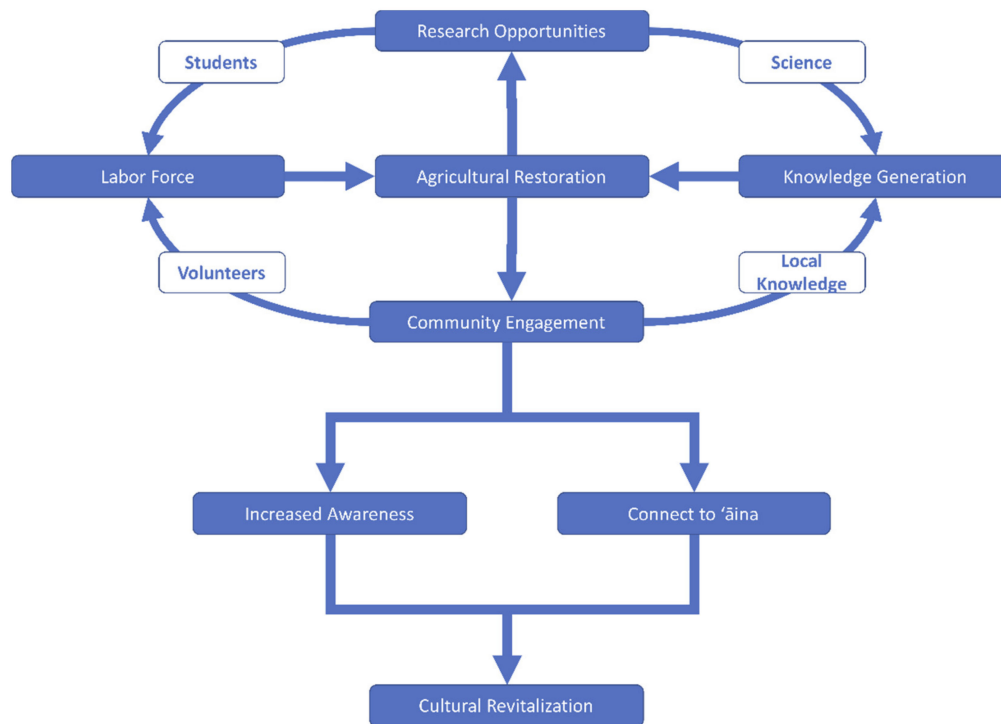
In addition to ongoing restoration of the traditional agroforestry system, MKC engages in holistic agricultural production, research, and education. The restoration plan is based on extensive ethnohistorical testimony that described in detail, from both western and native perspectives, the form and function of the *kalu’ulu*. Research interests have since emerged in how the traditional agroforestry system interacts with the young soils of south Kona, and in documenting the impacts of ecosystem services, nutrient cycles, and biodiversity. Multiple research partnerships have been established to pursue these interests. On-site research has been participatory, with researchers participating in the farming activities, co-forming research concepts, and leveraging research studies to create more opportunities for engagement and collaboration. From the beginning of this project, an emphasis was placed on community outreach, initially by sharing the ethnohistory and previous research that has been conducted about the *kalu’ulu* and growing to include sharing results from the restoration activities and related emerging research projects hosted at MKC. Since it was formed, MKC has hosted dozens of educational programs, farmer trainings, researchers and interns, and events at the farm site.

#### 4. Form and Function of Biocultural Restoration on *‘Āina Malo’o*

##### 4.1. *He loa ka ‘imina—Long is the Search*

A key challenge to restoring traditional dryland systems is the lack of working reference systems to serve as models for the restoration and research efforts. This relative lack of knowledge requires highly interdisciplinary approaches that triangulate agricultural form and function. Multiple lines of evidence are explored in each of the restoration efforts, drawing upon archaeology, archaeobotany, biogeochemistry, agronomy, ethnographic and ethnohistorical accounts, and living culture to develop models of each system. This process is far from linear, but rather is an iterative and interactive learning process, similar to descriptions of learning in adaptive co-management settings (Figure 5) [76]. Investigations of archaeology and ethnohistory influence the design of scientific field experiments and restoration; these trials further inform practices. Outreach activities at all the sites share research and experiential findings while engaging visitors in ways that enable inputs of local and traditional

knowledge. The knowledge input from the community also feeds into future activities and experiments. Through this iterative process, refinement of our understanding occurs while simultaneously powering awareness, connections, and, ultimately, cultural revitalization.



**Figure 5.** A conceptual diagram that outlines the multiple pathways used to drive agricultural restoration, and how that further leads to cultural revitalization. Each organization applies each of the pathways, although to different extents. The upper loop represents a feedback mechanism in which the agricultural restoration drives opportunities for research and engagement, which further drives opportunities for restoration. This feedback loop powers cultural revitalization through the engagement of the community.

Despite significant variations in their starting points, each organization leverages its disciplinary strengths while pursuing multiple methods. Extensive intact archaeology at Puanui [77–80] has provided for rediscovery based on archaeology and archaeobotany; however, the scantily recorded ethnohistory at Puanui resulted in an agricultural system that was well understood from a theoretical standpoint but poorly understood in practice. In contrast, Māla Kalu‘ulu has minimal physical infrastructure associated with its agroforestry and therefore minimal archaeological or archaeobotanical data. However, as one of the primary points of European contact in the 18th century, their region has exceptionally well-recorded ethnographic and historical testimony detailing many practical aspects of the agriculture. Despite considerable losses in knowledge and practice, each effort has managed to create a sharp picture of what life and agriculture were like before decline.

#### 4.2. *He ali‘i ka ‘āina—The Land is Chief*

Much of the awe which dryland systems inspire is due to their scale. At the parcel level, rainfed agricultural remains are often not conspicuous, and also lack the particular serene beauty of lo‘i with flowing water and rich mud that seems inherently more attractive on a small scale. Each organization expressed how this has led to initial challenges of attracting interest and support, and have utilized a shared strategy of connecting to a landscape level scale to overcome this issue. Puanui, the oldest of the organizations, relies directly on the visible scale of the Kohala Field System as

the best preserved and most observable example, owing to the lack of plantation agriculture that destroyed traditional infrastructure in many places, and the contemporary cattle grazing that maintains visibility of the agricultural features (Figure 2). Engagement activities at Puanui include a hike up Pu'u Kehena (a cinder cone) that offers visitors a panoramic view at the vast extent of the agricultural remains blanketing the landscape. From this exceptional vantage, many truths become apparent to the observer: the vastness of the system speaks to the ancient population, the political organization needed, the ecological gradients encompassed, and the integrated socio-political features. This powerful view was a pivotal aspect to building support for the effort and continues to be a major tool of engagement and impact. Although the extent of the traditional agricultural systems is not directly observable at the other sites, each develops aspects of scale to paint a picture of ancient agriculture within a broader landscape. Māla Kalu'ulu emphasizes how the interactions of politics, ecology, and breadfruit defined the extent of the *kalu'ulu* system and describes the ancient productivity in terms of modern populations to demonstrate the scale of the development. Maluaka connects its plot to other major landscape features within its land division to elucidate how the more monumental developments near the coast were integrally connected to and supported by the agricultural developments in the uplands.

With their scale, dryland systems carry a story of political development, innovation, and complexity that may have many parallels to continued developments for Hawaiian sovereignty and self-determination today (e.g., References [81,82]). In contrast, lo'i tend to situate agriculture within the spiritual and family realm, owing to the strong connections of kalo to these aspects of Hawaiian culture and lo'i restoration has played a central role in the revival of cultural pride and practices (e.g., Kagawa-Viviani et al., this issue). The themes of scale and community food systems in the strategy of each of these organizations tends to place non-flooded agriculture within the socio-political history of the islands, emphasizing the importance of food, and in particular, the social movements powered by the vast rainfed agricultural areas. Indeed, these areas are what separated the Hawaiian archipelago from the rest of the Pacific, allowing the development of the most complex political systems [5]. The scale of rainfed systems is also what separated the young islands of Hawai'i and Maui from the rest of the archipelago, eventually powering the conquest of the archipelago by Kamehameha, a Hawai'i Island chief who was born and grew to power in the Leeward Kohala Field System, and moved to the Kona system once he achieved paramountcy in the archipelago [17]. Pulling the parallel into the present, engagement at these sites tends to raise discussion of the importance of large-scale sustainable food systems for security and self-determination of communities today.

In this way, the restoration of Hawaiian agricultural systems could be seen to parallel the larger cultural movement of the islands. Starting with lo'i, early focus of the renaissance movement focused on building internal strength and cohesiveness within the Hawaiian community, reconnecting to values and practices that were lost or hidden away. The use of kalo as a spiritual and family center was a pivotal symbol to revive the basic units of the Hawaiian social fabric. Subsequently, Hawaiian activism engaged more expansive goals, revitalizing the fight for sacred spaces locally, such as the pushback against further telescope construction on Mauna Kea Volcano [83], and sovereignty in the international arena, such as appeals to the United Nations that have formally recognized Hawai'i's status as a sovereign country under military occupation by the United States [84]. These more recent activities have coincided with the greater awareness and restoration of the large-scale dryland agricultural systems that were essential to the development of the high levels of political complexity represented by the Hawaiian Kingdom [5]. This coincidence of activities may suggest a growing resurgence of Hawaiian cultural activity beyond the individual family and community units to a broader political framework.

#### 4.3. *He mā'ona moku—A Satisfaction with the Land*

At all sites an emphasis is placed on place-based adaptations of Hawaiian agriculture to environmental variation and microclimates. At Maluaka, the young lava flow creates a highly diverse topographic landscape, with many localized high and low points that direct the flow of

water and the accumulation of soils; correspondingly, very high heterogeneity of infrastructure is apparent, demonstrating extreme adaptation to microhabitats and topography at a scale that, until recently, was not well documented or even widely known. At Puanui, although the infrastructure is simple and regular, engagement at the site emphasizes the adaptation of the cropping systems to the local environment and to the huge environmental gradient encompassing the three restoration sites. Similarly, at Māla Kalu'ulu, while the agroforestry system could be described as a whole, the small-scale variation of planting based on light gaps and water distribution is substantial and dynamic. Here, planting trials have demonstrated different niches for the rhizome-based crops as a function of light availability: kalo will grow only in the drip lines at the edge of the canopy of larger trees, while 'awapuhi (shampoo ginger, *Zingiber zerumbet*) will only grow under canopied areas.

The organizations here push beyond the “keystone” biocultural relationship with kalo [60] by expanding the range of crops and cropping systems and by reviving place specific knowledge and practices. This is important to the overall resilience and diversity of culture and practice, expanding the suite of biocultural couplings to strengthen the larger socioecological system of the modern Hawaiian culture. This is particularly important on Hawai'i Island, where the history of Native Hawaiians dominantly consisted of interactions with 'āina malo'o and a broad range of staple and supplementary crops. The need to recognize and revitalize that range of interaction is a critical element to the identity and practice of Hawai'i Island culture. Following 120 years of colonial occupation and often de facto banning of Hawaiian culture (e.g., banning of 'awa (*Piper methysticum*) drinking; Kagawa-Viviani et al., this issue), the mental health and well-being of Hawaiians have declined precipitously, as it has done globally for indigenous peoples (e.g., References [85–88]). Engagement with the land and agriculture, a central component to Hawaiian culture in which social and family values are encoded, is critical in restoring identity and wellbeing to Hawaiian people [89,90]. By providing a broader range of relationship between people, plants, and places, well-being follows (e.g., References [91–93]). This is particularly relevant for the many locations and individuals where the practice of lo'i agriculture does not appropriately address their genealogical connection to the land.

While Hawaiian and other indigenous place-based adaptations in resource management is often proclaimed to be exceptional [2,94–96], the more consistent practices associated with lo'i do not capture the diversity of adaptive strategies in the way that agriculture on 'āina malo'o does. This is largely a function of necessity. Lo'i systems occur in lowland valleys with flowing water that regulates multiple aspects of the cropping system—they therefore do not have to deal with the same level of spatial and temporal variation in environment that agriculture on 'āina malo'o does. The extensive loss of the detailed knowledge and practices associated rainfed systems (e.g., References [21,35,36]) requires a revival of knowledge, which, despite significant information from investigation, can only be regained through active restoration on the land.

What we now see as the archaeological infrastructure is only the remaining physical manifestation of the diverse practices and cropping systems employed within the sites. A simple comparison of the sites themselves offers a case-study of adaptation, with vastly different forms consisting of different suites of crops, temporal patterns, and practices seen (e.g., References [8,10,12,14,18,97]). One thing that has been clear in the restoration of these systems is the diverse and innovative methods for managing water. In Kohala, research has demonstrated how the long walls running perpendicular to the wind were a vital mist-trap, enhancing and concentrating soil moisture to facilitate better growing of sweet potatoes [8,14]. In Kona, highly diverse infrastructure appears adapted to the changing water situations. Infrastructure, such as cut canals to move, store, and disperse intermittent water flows [18], mounds to take advantage of areas where water pools (J. Kahoonei, pers. com.), and a host of strategies to prevent water from evaporation in lower elevations, illustrate the adaptive hydrological strategies (e.g., Reference [97]). Conversely, the restoration also highlights how much is still unknown. For instance, the striking difference in wall orientation between agricultural areas, with Leeward Kohala alignments perpendicular to the slope and wind while Kona alignments are parallel to them, has not been adequately explained.

#### 4.4. *E ho'ohuli ka lima i lalo—Turn the Hands Down*

Community engagement at these sites is multifaceted but active. A “service learning” component is associated with education all the sites. For the host, it provides a vital source of labor while simultaneously driving a particular and important experience. Everyone works at these sites—be he or she world-class researchers or delinquent students, elder or child—and they work side-by-side. The action of collectively getting one’s hands dirty has a substantial effect on bringing people to the same level in a way that is not easily replicated, driving informal sharing through which knowledge transfer that may otherwise be difficult can occur. Here real bi-directional learning occurs between generations and ways of knowing. Subsequently, the restoration of each site is presented in mission statements as a vehicle through which to engage and grow communities of people. These restoration efforts are not solely restoration of physical infrastructure or ecosystems, but the biocultural systems of food and culture. Each mission statement includes phrases such as “space for the community to connect” and “regenerate responsibilities,” recognizing that these agricultural systems are socio-ecological landscapes that rely on the physical environment, biota, and human knowledge and practice to function correctly. Each of these organizations expressed that such relationships are difficult to teach but can be learned; educating people about a biocultural relationship through talk provides little adoption of practice but conducting activities that actively place individuals in direct contact with the environment allows the opportunity for those biocultural connections to be formed.

Although people might believe that it would be easy to restore these systems, the participants were clear about the difficulties. It is not just the physical clearing and planting of an ancient agricultural system, but it is the revival of place and history, the healing and building of relationships, and the cultivation of interaction. All of these take considerable time and commitment, influential leaders, and collaboration. It takes dedication to a cause in which importance and impact are not necessarily immediately seen. The sustained partnerships for restoration, research, and education requires working across academic and rural community partners, which is not always easy. The success of both the research and engagement hinges on positive and productive relationships. These relationships are bound by a common interest in understanding the sustainability of the respective systems in both environmental and socio-cultural terms, which must emerge from a diversity of knowledge sources.

#### 4.5. *Pupukahi i holomua—Unite in Order to Progress*

The success of each effort has relied heavily on collaboration at multiple levels. Collaboration is essential between the leaders and the landowners, with the community, with scientists, and with the broader public. With many different stakeholders in each of the efforts, there exist many different lenses on the value and purpose of the restoration. Finding a way to move everyone together in a productive way is a crucial part of the process. Discussions emphasized the critical importance of trust-building between stakeholder groups. Particularly in Hawai’i where there has been a long history of science focused on a still-living culture subjected to recent (and active) traumas, there have been many conflicts between scientists and communities. The groups have different timelines, where scientists are often driven by short time frames dictated by grants and careers, while communities have a long-term perspective on value and multi-generational outcomes. Recognizing and managing the different time-scales is an integral part of the process. There have also been issues of knowledge ownership and give-back. Often scientists “mine” local knowledge that is used to guide research, and report that local knowledge directly by themselves, thereby representing a taking of community knowledge. Simultaneously many researchers do not make the time and effort to conduct strong outreach and reporting of results to the community of interest. Historically, this has represented a one-way flow of knowledge away from locations, leading to burnt bridges and an overall distrust of many scientists by local communities.

There were several common strategies employed by the organizations to overcome relationship barriers. First and foremost is addressing the past issues by forging better relationships with

communities, acknowledging their knowledge as central, committing to long-term engagement, and conducting appropriate sharing of scientific knowledge back to the locales. Aiding in this is that each site has a “kanaka scholar,” typically a native Hawaiian or local scientist who served as a liaison between outside researchers and communities to ensure proper acknowledgment of contributions, to translate ground-based activities and observations into academic speak, and to prioritize communicating science back to the community. These individuals also help to forge stronger relationships with researchers coming from the outside. Often this is as simple as “translation,” helping people from different backgrounds and perspectives speak the same language. The quality of these relationships is directly related to perceived value on both sides; win-win activities are essential to continuing and growing relationships. At Maluaka, an active program has been developed that engages local at-risk youth in the archaeological investigations through field schools, rather than solely utilizing college archaeology majors as is often the case. This has allowed direct and indirect benefits to both the community and the archaeology. Ultimately, this is an indigenous approach that pursues multiple benefits, values, and emphasizes relationships and impact, rather than solely the science itself.

#### 4.6. *He aha ka mea nui?—What Is the Most Important Thing?*

The approach by these organizations also recognizes that these systems are not just agriculture, but are deeply integrated into a more extensive, sacred, socio-ecological system that was intact until relatively recently; they represent a vital part of a living culture and embody history, religion, livelihoods, environment, and culture as a whole. Each organization attempts to recreate this aspect of a whole. The emphasis on relationships extends beyond those between people to also include relationships among people and the places, the plants, and the history. This recognizes in multiple ways the importance of interactions between people and elements of natural and social environments. At Māla Kalu’ulu, the emphasis on rights to the land based on one’s inputs revives the ancient cornerstone of *kuleana*. At Puanui, each visit asks that participants introduce themselves to the place, and to envision their role in the future of the place, and at all sites engagement in protocol that grounds participants in the moment, in the place, at to each other is consistently practiced. The different strengths, yet common goals and outcomes, of the restoration efforts highlighted in this article are a testimony to the interconnected nature of the biocultural system as a whole. This is a distinctly native perspective that does not separate the daily activities from identity, values, and spirituality. The mix of knowledge sources that form the foundation of these restoration efforts each offer their opportunities and challenges, but engaging with all sources is a crucial element to the initial success of these operations.

Following the political shift with the illegal overthrow of the Hawaiian monarchy [98] and subsequent ongoing military occupation by the United States [84], Hawaiian people have been drastically impacted. In virtually every socio-economic statistic measured, from education to income to domestic violence to incarceration, Hawaiian people score the lowest of all groups within their ancestral home of Hawai’i [99]. While the creation of a new socioeconomic system has benefitted many non-Hawaiian immigrants to Hawai’i, Native Hawaiians have constantly struggled for rights and opportunities. By reviving Hawaiian relationships with the land, with their history, and with each other, significant gains have been made in the education, pride, and organization of the Hawaiian people [90]. In our experience, lo’i cultivation has had a critical impact on reconnecting people to the land, revitalizing ancestral responsibilities, and generating awareness of Hawaiian accomplishments and excellence prior to being displaced. This has strengthened a desire to return to traditional knowledge and epistemology to support and maintain Hawaiian communities, practices, and land stewardship. Furthermore, the expansion of restoration from lo’i systems of agriculture to systems on ‘āina malo’o appears to parallel larger shifts in the Hawaiian community that seek to increase self-sufficiency, expand land stewardship, and increase activity in the realms of policy and activism. Each organization inadvertently, perhaps unconsciously, contributes to these movements by sharing the extent of historical scale and political power associated with the vast agricultural developments on



Hawai'i Island. To see and hear of the complexity and sophistication of the Hawaiian society in the past simultaneously emphasizes to some participants what was lost.

## 5. Conclusions

Even though non-flooded agriculture was, in ancient times, much more widespread and likely more important than lo'i, today lo'i restoration outweighs restoration of agriculture on 'āina malo'o. Restoration of 'āina malo'o agriculture by several organizations on Hawai'i Island has important biocultural consequences, particularly when compared to the more widespread restoration of lo'i. The use of highly interdisciplinary work to triangulate a more complete understanding of the social and physical aspects of the systems is crucial, particularly where knowledge systems have been severely eroded. This triangulation includes scientific investigation, use of historical resources, effectively tapping into local ecological knowledge, and conducting practical, experiential learning through active practice. This approach requires strong relationships and appropriate engagement with the community and culture at all levels; it is essential to building the complex relationships that make these efforts work. Only through strong engagement and mutual respect have these efforts been made possible and successful, and their success is often facilitated by someone with a foot in both Western and indigenous worlds. Organizations must leverage their strengths in this process and situate their connections in an appropriate socio-cultural role. This may require creative framing, such as how these organizations found ways to connect to the large scale of the systems even if the specific restoration plots are small. These essential aspects support previous example and case studies within the field of biocultural restoration.

Biocultural restoration of agriculture on 'āina malo'o highlights the oversimplification in the treatment of ancient Hawaiian agriculture by the dominant narratives told largely in the fields of archaeology and anthropology and perhaps too readily adopted culturally. In particular, there is a very high level of diversity of form of traditional agriculture on 'āina malo'o, and it cannot appropriately be lumped into "rainfed agriculture" as it has previously. High levels of place-specific knowledge are being uncovered through interdisciplinary and multi-epistemological restoration teams. Understanding agriculture on 'āina malo'o broadens the scope of biocultural relationships by engaging a more significant range of crops and therefore assortment of associated practices. Finally, agriculture on 'āina malo'o grounds itself in the scale and scope of the younger islands, and in the political processes that the vast agricultural areas powered prior to European arrival. We suggest that underlying socioecological functions that underpin agricultural types differ substantially, with lo'i and kalo focusing on family and spirituality, while agriculture on 'āina malo'o with its range of crops and systems emphasizing socio-political complexity. These same biocultural themes could parallel larger movements within the revitalization of Hawaiian culture.

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