Project Description

Hawaii's agricultural prehistory increasingly is buried beneath or has been lost to modern land development, especially that history pre-dating western contact in the late 18th century. Isolated areas, however, exist where tangible aspects of this history might be found; the remote Wailau Valley on Moloka‘i provides a prime example (Figure 1). Wailau offers a pristine archaeological record within a sizeable (936 ha) valley that has not been previously studied. Wailau is unique for its varied and well preserved archaeological sites, as well as for the former presence of two traditional Hawaiian communities, or ahupua‘a, within a single valley. It is this setting that provides an optimal opportunity to explore the temporal and spatial relationships among agricultural development, community organization, and ecology within a tropical insular environment of Polynesia.

![Figure 1. Map of the Hawaiian Islands with inset of Moloka‘i Island.](image)

This project advances the study of the expansion and intensification of traditional agricultural systems in Hawai‘i. It will focus on a windward valley on a geologically older island, its extensive irrigated agricultural systems, and will yield new information about the environmental and cultural contexts of prehistoric agricultural development. In Hawai‘i and Polynesia archaeological evidence for agricultural change has at various times implicated environmental differences, population pressure, the introduction of new domesticates, the expanding role and authority of chiefs exacting tribute, or some combination thereof. In Hawai‘i our understanding of agricultural development is limited by at least two issues: 1) the relative lack of good temporal or stratigraphic evidence to document agricultural intensification in relation to environmental and other cultural variables; and 2) a recent tendency to focus on dryland agricultural systems on the younger islands of Hawai‘i and Maui.

The primary objective of this project is to evaluate two general evolutionary ecological models describing agricultural change. These models assign varying priority to effort, risk, and production output. The first and most widely accepted model assumes that locations for farming are chosen in relation to optimizing production. The second model stipulates that agricultural development is a function of effort and risk, with the earliest fields located where the least
amount of travel is required and work is needed to construct and maintain agricultural features. This project attempts to describe and measure these variables in archaeological terms, with effort reflected by the size of individual irrigation/agricultural systems, the character of the landscape on which terraces were constructed, and distance from the coast. Risk refers to the likelihood of crop failure or lower than expected production at different locales. Output will be estimated in terms of the relative abundance and/or predictability of production across discrete agricultural systems of known size and age.

This research systematically advances our knowledge of traditional agriculture by developing general models, drawing on a body of geological and ecological data, and applying them to the spatial and temporal archaeological investigation of agricultural systems distributed throughout a windward valley in Hawai‘i, one where multiple social units once lived. Wailau on Moloka‘i is an ideal location for realizing these goals.

Agricultural Development

Archaeologists have long sought to understand the processes by which agriculture came to dominate food production systems worldwide (Brookfield 1972; Leonard 1989; Rindos 1980). In Hawai‘i and Polynesia interest in agricultural change has focused mostly on intensification, implicating a number of variables both cultural and natural (cf. Barrau 1961; Earle 1978; Green 1980; Yen 1971). Yet, intensification is just one process in agricultural development. Additional processes include innovation (in plants, practices, and technology) and expansion in addition to both technological and landesque forms of intensification (Boserup 1965; Kirch 1994; Morrison 1994). Researchers have identified a number of variables and parameters that may affect these processes including aspects of climate, the natural and geophysical environment, population change and spatial distribution, and cultural features such as the organization of labor, incorporation into more complex economic systems, and the role of complex, authoritarian social institutions (e.g., Allen 2004; Kirch 1994; Ladefoged and Graves 2000). With their access to long-term historical records, archaeologists are also well poised to answer questions about the impact of particular agricultural systems and/or their trajectories of change on the successful abilities of human groups to feed themselves, one of our measures of evolutionary adaptation.

Studies of pre-contact agricultural systems in Hawai‘i have focused onto two major issues: the scale and nature of economic organization of wetland taro farming in valleys (e.g., Earle 1978; Pearson 1962; Rosendahl 1972; Yen et al. 1972) and the timing of the introduction and expansion of dryland farming, usually along the more arid western coasts (e.g., Allen 2001; Dixon et al. 2002; Ladefoged et al. 1996; Newman 1970; Rosendahl 1972). Initial archaeological research sought to identify archaeological evidence for the nature and scale of irrigated taro production, and to relate intensified agriculture to forms of social stratification. Earle’s seminal work (1978) tested and found wanting both Wittfogel’s (1957) hydraulic model and Sahlins (1958) hypothesis, which invoked chiefs in the management and redistribution of surplus agricultural production. Instead, Earle (1978) argued that chiefs managed lands largely to their advantage, increasing production requirements to support tribute. Early research also produced several typologies of wetland agricultural features, linked to particular environmental settings (Earle 1978; Kirch 1977; Riley 1975).

Excavations have provided a range of chronometric dates for wetland complexes, possibly indicating construction as early as A.D. 440 (Allen et al. 1987), and a peak period of use or construction from A.D. 1250–1425 (Allen et al. 1987; Allen 1997; Dockall et al. 2003), but with construction continuing to the early 1800s (Kirch and Sahlins 1992; Spriggs 1997). Many of the earliest dates (e.g., Allen et al. 1987; Allen-Wheeler 1981; Yen et al. 1972) are now suspect due to problems of in-built age and/or questionable contexts (e.g., Anderson and Sinoto 2002; Dye 2000; Spriggs and Anderson 1993).

The emphasis on studying wetland taro agriculture largely waned after archaeologists shifted focus to dryland agricultural systems where sweet potato was grown. These studies
include environmental or ecological variation and often use Geographic Information Systems (GIS) analysis to examine field expansion, labor intensification, and complexity (e.g., Allen 2001; Dixon et al. 1999; Kirch et al. 2003). The work on the large Kohala Field System on Hawai‘i Island has been particularly productive. GIS analysis of agricultural features and environmental variables indicates that this system reached its limits of expansion but not its limits of intensification (Ladefoged et al. 1996). A shift in field construction to more marginal areas and a change toward more uniform-sized field plots has been documented, suggesting that political factors affected agricultural change (e.g., Ladefoged and Graves 2000; Ladefoged et al. 2003; McCoy 2001). Most recently, Vitousek et al. (2004) found that rainfall and soil nutrient levels are related, with little farming activity below 750 mm annual rainfall or above 1500-2000 mm. At higher rainfall levels critical nutrients are leached out of soils, rendering them unproductive, and the upper rainfall threshold is affected by the age of soil substrates.

Pre-contact agricultural studies in Hawai‘i, whether focused on wet or dry fields, reveal that ecological and socio-political factors played a role in the development and distribution of agricultural systems. Wetland systems are the most complex in their history of development but there is a nearly 20-year gap in their study. GIS databases, AMS radiocarbon dating, soil biogeochemistry and paleoecological analyses and modeling have been successfully integrated into recent dryland agricultural research but have yet to be employed in the analysis of irrigated agriculture.

Overall, Hawai‘i has produced a number of empirical studies of traditional agriculture, but understanding its development has been limited by several issues: 1) extrapolating or generalizing from geographically delimited localities to larger portions of the islands or archipelago (Kirch 1990b; Ladefoged and Graves 2000); 2) the focus of recent work has been on dryland agricultural systems on the younger islands of Hawai‘i and Maui (e.g., Dixon et al. 2002; Rosendahl 1994; Schilt 1984) at the expense of wetland systems on older islands such as Kaua‘i, O‘ahu and Moloka‘i; 3) a lack of acceptable evidence to document the introduction of different cropping regimes and changes from less or more intensified forms of production (Leach 1999); and 4) failure to consider the impact of soil nutrient changes that can occur with sustained agricultural use (Kirch et al. 2005; Vitousek et al. 2004). The first issue can be resolved by sampling a variety of environmental zones; the second simply involves a shift in study location to windward environments on older islands; the third can be settled by applying appropriate archaeological methods (e.g., stratigraphic evidence within fields for replacement of crops or increased effort in construction); and the fourth by documenting soil nutrient levels within agricultural plots and on unmodified landforms. These reflect the proposed objectives of this research proposal.

**Project Setting**

Wailau is one of four valleys on the remote windward coast of Moloka‘i, which stretches from Halawa Valley on the east to Kalaupapa Peninsula on the west (see Figure 1). Heavy rainfall of 1,500 to 3,000 cm per year (Juvik and Juvik 1998) feeds two perennial streams that cut through the valley and join at the coast. Topography and soils in the area consist of rough mountainous land near the coast and in the back of the valley with limited soil development, alluvial soils along the valley bottom and lower terraces of Wailau and Kahawaii‘iki Streams, and talus slopes in some places covered by colluvial deposits along the upper terraces and reaches of the streams (Foote et al. 1972). Substrates on this eastern portion of the island are roughly 1.5 million years old (Stearns 1985).

A series of intact irrigated terraces forms an agricultural system that encompasses nearly the entire 936-hectare valley (Figure 2), and earlier agricultural terraces lie buried beneath those visible on the surface (McElroy 2004). Trails, habitation structures, ceremonial sites, and burials are part of the cultural landscape as well. The State Historic Preservation Division has
acknowledged the value of these archaeological resources, but the complex has never been thoroughly documented.

Wailau Valley is remote, remains largely pristine in terms of its archaeological resources, and has few year-round residents. Vehicular access ends outside the valley, at Halawa. Access into Wailau remains limited to a single long and dangerous foot trail or a short boat ride during the calm summer months. High sea cliffs prevent access by foot along the coastline.

Two ahupua’a, or geographically-based communities, characterize the traditional landscape of Wailau, differentiating this valley from most others in Hawai‘i. The large western portion of the valley comprised Wailau ahupua’a, while a small strip of land on the east was part of Halawa ahupua’a (Figure 3). This latter ahupua’a extends east into the large adjacent valley.

Previous Archaeology

The inaccessibility of Wailau has served as an impediment for other archaeologists, and McElroy (2004) conducted the first archaeological excavation and Global Positioning System (GPS) mapping in the valley. The only other archaeological work in Wailau took place almost a century earlier, as part of J.F.G. Stokes’ island-wide survey, in which two refuge sites, four ceremonial sites, and two trails were documented (Stokes 1909). During McElroy’s first trip to the valley, she excavated two test units in one of the irrigated agricultural terraces and dated a fragment of charred Chamaesyce sp., a short-lived native shrub. The sample yielded a calibrated radiocarbon age of 330 +/-30 years B.P.

In the summer of 2005, McElroy returned to Wailau to begin the work proposed here. She camped in the valley for two months with a crew of seven Native Hawaiian Moloka‘i residents. They surveyed approximately 12.5 ha of the valley and mapped nearly 100 agricultural terraces with GPS and plane table and alidade. The detailed maps show a plan view of the terrace walls, irrigation channels, ditches, surface artifacts, locations of test units, vegetation, and landforms such as slopes, streams, and intermittent drainages (Figure 4). These mapped terraces were part of six large wetland systems that occurred in three of the study zones in the valley (see Figure 3 and Table 1). The systems were highly variable in size and complexity; the smallest was composed of five terraces and a drainage ditch, and the largest comprised more than 50 terraces and multiple ditches. Cross-sections were drawn down the center of each system to examine changes in elevation within and between sets of terraces, and profiles were drawn for a sample of walls to compare rock size and construction style.

In addition to the survey and mapping, 20 test units (12 m²) were excavated in the six wetland systems. Excavations revealed portions of the buried walls, some extending more than a meter below the surface (Figure 5), and charcoal was collected from below the wall foundation stones in each of the six systems. Fourteen samples have been submitted for wood taxa identification to select short-lived species for AMS radiocarbon dating. These samples are ready to submit for dating. Examination of traditional and historic artifacts from surface collection and excavation is underway, and analysis of soil samples is in progress. Five additional wetland

Figure 2. A portion of an irrigated terrace system in Wailau Valley.
agricultural complexes occur in the valley, and these will be documented during the 2006 field season.

**Research Hypotheses and Expectations**

The objective of this project is to evaluate two models that could be generated for wetland agricultural development: one in which locations for farming are chosen in relation to optimizing production, and another in which farmers first selected low-risk areas that required the least amount of work to cultivate and later moved to areas that would require a greater labor investment for farming. Mapping of the wetland agricultural systems, excavation, GIS analysis, soil analysis, and radiocarbon dating will determine if either of these models apply to Wailau Valley. The environment will be sorted into three main areas: a coastal zone, lower terraces and floodplains of the two streams (and their main tributaries), and upper terraces and colluvial slopes flanking the valleys. The traditional *ahupua'a* boundary will serve to sort the area into two social units. Excavations will document the earlier occupation and agricultural use of the valley.

Both models would place the earliest fields near the coast, in back dune settings. These are located in areas requiring minimal effort, as they are close to coastal settlements, can take advantage of naturally occurring low wet spots, and do not require intricate water management. They also optimize production, as terraces can be built on the wide coastal plain. From the coast, the first model would see expansion up the main streams, where the largest areas would be next developed. Rich alluvial soils would provide a potentially productive resource for agricultural development, and large terrace complexes could be constructed along the valley bottom. When streams are tapped for irrigation this introduces more complexity as the larger the stream or the greater its primacy in a network, the more difficult it may be to build and maintain irrigation systems, and the riskier the endeavor, due to the danger of flooding. The returns, however, are equally large. The second model sees the earliest expansion out of the valley bottom, along side drainages and shorter watercourses taking advantage of colluvial slopes and small alluvial...
Figure 4. One of six irrigated agricultural systems examined in 2005. This is the complex farthest south in figure 3.
2) Technological and morphological descriptions and GPS map distributions of a sample of subsurface agricultural features in the valley;

3) Relative chronologies of the surface architecture and subsurface features based on architectural construction methods, locations, wall abutment relations, and super-positioning of architectural and other features (e.g., irrigation ditches);

4) An AMS radiocarbon chronology of the surface architecture and subsurface features based on identification of short-lived plant material from reliable cultural contexts which can be argued to represent discrete construction episodes; and

5) A series of soil samples that will be used for biogeochemical analyses of soil nutrient levels from a variety of landforms, rainfall levels, and from a number of agricultural terraces located in these environments; these analyses will be comparable to those completed for the Kohala, Kahikinui, and Kalaupapa agricultural studies (Vitousek et al. 2004; Kirch et al. 2005);

6) A GIS database containing relational temporal and spatial information derived from the fieldwork, historical maps and aerial photographs, and analyses of the survey and excavation data, soils, landforms, and botanical samples. The GIS database will also contain environmental layers depicting the distribution of soils and landforms in Wailau Valley.

Addressing the research objectives requires identification and distributional mapping of the following: a) three ecological zones represented in the valley - coastal lowland, inland lowland, and valley slopes; these zones will be further sub-divided by landforms, soils, and proximity to water sources; b) the ahupua’a boundaries, including demarcation architecture; c) surface architecture, including abutting or intersecting walls; and d) subsurface features and deposits, such as buried wall relations, super-positioning, and radiocarbon dates. This strategy maximizes the collection of data over a considerable area while imposing little impact on the surface and subsurface archaeological features. The ecological information exists on USGS topographic maps, soil maps, and aerial photos available for the valley. Additional environmental information will be recorded during survey. Historical documents, particularly land records, oral traditions, and oral informants provide information about the two ahupua’a, habitation areas and specific land uses, and residents of the valley and their histories.

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<tr>
<th>Wailau Ahupua’a</th>
<th>Halawa Ahupua’a</th>
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<td>Coastal Lowland</td>
<td>Coastal Lowland</td>
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<td>Inland Lowland</td>
<td>Inland Lowland</td>
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<tr>
<td>Valley Slopes</td>
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Table 1. Study Strata in Wailau Valley.

Both ahupua’a contain all three ecological zones, generating six areas of study (Table 1 and Figure 3). The six study areas will provide the means for generating a stratified sample of the surface and subsurface features and deposits for excavation within each of the ecological/ahupua’a classes. The total survey area will include roughly 20 ha of land; this land is divided into discrete parcels, owned by individuals or the State. Two parcels from each study area will be selected for survey and excavation. The selection criteria for
determining the placement, orientation, and dimensions of the survey blocks will include, but not be limited to: access permission, the kinds of agricultural (and other) features represented, and the terrain. McElroy has permits to work on land owned by the State of Hawai‘i, the primary landowner in the valley, and this year she received permission to work on land owned by the Francis Brown Trust, the second largest landowner in Wailau.

One field season has successfully been completed in which 12.5 ha were surveyed in four of the study zones. Six large wetland agricultural systems were examined in three of the study strata: the Inland Lowland and Valley Slopes of Wailau Ahupua‘a and the Inland Lowland of Halawa Ahupua‘a. No agricultural features occurred in the Coastal Lowland of Halawa Ahupua‘a. Unmodified landforms were mapped in this zone and soil samples taken. The six agricultural complexes were mapped, and 12 m² were excavated. Material for radiocarbon dating was obtained for all six systems. At least five additional wetland complexes remain undocumented in Wailau. One of these lies within the coastal lowland zone, an area not yet examined. A second field season, focusing on delimiting the boundaries and historical development of the five systems, and conducting an intensive survey in the two remaining study strata, is critical to the project’s completion.

The second field season will consist of survey and excavation of the five remaining agricultural systems, providing comparable data to that obtained in the first field season. The Coastal Lowland of Wailau Ahupua‘a and the Valley Slopes of Halawa Ahupua‘a will be targeted this year. Four weeks of fieldwork with a five-person crew will complete this work. Survey will involve recording, illustrating, photographing and GPS mapping surface architecture. This will provide the required information for dataset 1 (documenting surface architecture), the surface portion of dataset 3 (wall abutment and super-positioning), and the initial component of dataset 6 (GIS database). The excavation units, 2-4 per system (10-20 m² in area), will examine buried architecture and deposits. Sediments will be sieved through ½ inch mesh to recover both artifacts and diagnostic sample material (e.g., botanical remains) for post-field analyses. Excavation provides the critical data for dataset 2 (subsurface documentation), completion of datasets 3 and 4 (relative and radiocarbon chronologies), and additions to dataset 6 (GIS database). Soil samples for biogeochemical analyses will also be collected during the test excavations and by natural scientists sampling the different environmental/climatic zones of the Valley, to provide the critical data for dataset 5 (soil nutrient analysis).

Post-field analyses include radiocarbon dating, soil analysis, and GIS modeling. Wood taxa identification and AMS radiocarbon dating will be performed on 25 charcoal samples, providing an absolute age for wet and dry cultivation in different parts of the valley. Bayesian analysis offers a means of calibrating the radiocarbon results. Bayesian statistics are appropriate here because the goal of this dating program is to provide an estimate of when the stone architecture was built; the age of the dated samples is of secondary interest. Bayesian calibration can yield a posterior probability for an archaeological event that cannot be directly dated, given a model that includes its temporal relationship to one or more events that are dated (Buck et al. 1996). Soil nutrient levels will be calculated for each of the wetland systems at different depths and for non-agricultural soils. GIS modeling will include elevation, drainage networks, soil types, ahupua‘a boundaries, archaeological features, and results of the dating analyses. The value of GIS extends beyond mapping archaeological material; the relations between different types of data, both environmental and cultural, can be studied both temporally and spatially within and across ecological zones and ahupua‘a, providing a platform capable of integrating the complex datasets required for this unique study of a valley characterized by dual-ahupua‘a control and an extensive wetland agricultural complex in early Hawai‘i.

Summary and Research Contributions

This wetland agriculture study of Wailau Valley contributes to integrative approaches using multiple reinforcing methods to explore, model, and interpret the pre-contact history of
agricultural expansion and intensification (e.g., Kirch et al. 2004; Ladefoged et al. 1996; Vitousek et al. 2004). Investigating these issues within Wailau’s unique dual-ahupua’a system makes it possible to examine the relations between agriculture, social organization and natural resources, particularly the development and self-sufficiency of traditional Hawaiian communities, a long-standing interest in Hawaiian anthropology (e.g., Allen and McAnany 1994; Cordy and Kaschko 1980; Graves and Green 1993; Graves et al. 2002; Earle 1978; Hommon 1986; Kirch 1990; Weisler and Kirch 1985).

For this study, we have developed two general models that individually or in combination may account for the temporal and spatial pattern of agricultural development: one in which locations for farming are chosen in relation to optimizing production, and another in which farmers first selected low-risk areas that required the least amount of work to cultivate and later moved to areas that would require a greater labor investment for farming. Mapping of the wetland agricultural systems, excavation, GIS analysis, soil analysis, and radiocarbon dating will determine if either of these models apply to Wailau Valley. The two models include both social and environmental factors and make optimal use of the valley’s former organization into two distinct communities, the varying distributions of arable lands (or those that could be developed for agriculture), and the various and discrete wetland agricultural systems located throughout. With this, archaeologists will be in a position to evaluate Kirch’s (1994:226-227) hypothesis that the environmental and productive features of Hawaiian polities located in the eastern and western portions of the archipelago structured their dynamic political (i.e., competitive) and economic (surplus production) histories.

Agricultural research in Hawai‘i has a long and productive history, but has been limited by a number of factors, including a tendency to generalize from restricted studies to entire islands or regions and an inability to convincingly document the introduction of different cropping regimes and changes in intensification. In addition, the potential of soil nutrient analysis has not been fully realized, and reliable chronologies have not been produced. Recent research focuses on dryland agriculture in the leeward regions of the younger islands in the archipelago, and this has successfully resolved a number of research questions having to do with the timing of agricultural colonization into more arid (leeward) areas, their expansion and relationship to climatic and physical parameters, and the relative degree and conditions under which these systems could be intensified and sustained (e.g., Ladefoged et al. 1998; Dixon et al. 1999; Ladefoged and Graves 2000; Allen 2001; McCoy 2001; Kirch et al. 2003; Ladefoged et al. 2003; Vitousek et al. 2004). New technology and methods, such as GIS, soil analysis, and wood taxa identification coupled with AMS radiocarbon dating have met with much success in these areas, and hold great promise for the study of wetland systems.

What is now needed is a renewal of archaeological studies of windward or wetland agriculture on the older islands of the Hawaiian chain. While we know the location of many of these systems, have developed typologies for their design, and can estimate their approximate sizes, we know far less about their development in relationship to environmental variables including biogeochemical properties of soils, the timing and duration over which change occurred in these systems, and the role of wetland agriculture as a stimulus to increasing social complexity and inter-group competition. The time is ripe for a return to the study of wetland agriculture in Hawai‘i, to document changes over time and space in these systems, and interpret them with respect to hypotheses integrating environmental and cultural variables.

**Broader Scientific and Social Significance of this Research**

This proposed research will add new evidence to answer questions regarding the circumstances and conditions that would promote the sustainability of wetland agriculture in a tropical setting of Polynesia. It will also identify the conditions that led to changes in the agriculture from more limited locations and likely more simple constructions at an earlier period to more extensive, more varied, and likely more intensive forms of traditional agriculture in
Hawai‘i. As Native Hawaiians seek to better understand the history of their ancestors' development of these islands and the nature of their interactions with the environment, especially in the areas of food production, research such as this will provide a basis for realistic estimates of human impact and human innovation in Hawaiian prehistory. This research also has incorporated training in the field and in the laboratory of Hawaiians and other community members who might not otherwise experience archaeological research, the interaction between models and data, and the responsibility that we have to adequately assess both the quality and limitations of our interpretations of the past.