Variable Development of Dryland Agriculture in Hawai'i: A Fine-Grained Chronology from the Kohala Field System, Hawai'i Island
Author(s): Thegn N. Ladefoged and Michael W. Graves
Source: *Current Anthropology*, Vol. 49, No. 5 (October 2008), pp. 771-802
Published by: The University of Chicago Press on behalf of Wenner-Gren Foundation for Anthropological Research
Stable URL: http://www.jstor.org/stable/10.1086/591424
Accessed: 16/09/2011 10:49

Variable Development of Dryland Agriculture in Hawai'i

A Fine-Grained Chronology from the Kohala Field System, Hawai'i Island

by Thegn N. Ladefoged and Michael W. Graves

Research in the leeward Kohala dryland agricultural field system on Hawai'i Island provides the opportunity to develop a fine-grained chronology for its development—both expansion and intensification—using a combination of chronometric and relative dating. Two pathways for agricultural development are identified for this field system, the first beginning as early as the fourteenth century and the second after the mid-seventeenth century. This chronology, combined with dating for residential features, religious sites, and territorial boundaries, makes it possible to link agricultural change with social and political dynamics in the late prehistoric period. This sequence is compared to four other relatively well-dated dryland field systems on the islands of Maui, Moloka'i, and Hawai'i. These systems can be assigned to either of the two pathways identified for Kohala, suggesting that dryland agricultural strategies can be sorted into (1) an earlier expansion and subsequent intensification in areas where conditions were better suited for such practices and (2) a later, more rapid expansion into and more limited intensification of areas associated with greater costs or risks. The second and later pathway for agricultural development is linked to earlier increases in populations living in more optimal locations, movement or expansion of these populations into marginal zones, regional population integration, and increasing surplus demands to fund chiefly ambitions involving territorial expansion.

Hawai'i, along with Tonga and the Society Islands, represents the apex in the development of traditional social complexity in Polynesia. This is commonly reflected in authoritarian and coercive political power, differentiation among social classes and territorially based social groups, development of a religious system that reinforced social differentiation and political power, the emergence of competition and aggression between groups, and economic and subsistence intensification. Conclusions drawn from Polynesian archaeological and historical examples are employed as models in a variety of other contexts throughout the world (see Diamond 2005 and Wright 2005 for recent popular examples). This means that studies of Polynesian social complexity must be carefully designed and implemented. In Hawai'i, archaeological interpretations of emergent and elaborated social complexity contend with various transformational pathways and a multitude of relationships linking diverse social and natural processes (Kirch 2007; Kirch et al. 2007). Some archaeologists have focused on dating the onset or establishment of and changes to monumental religious architecture (known as *heiau*) to track the expansion of chiefly based political prerogatives (Kolb 1992, 1994*a*, 1994*b*, 1997, 1999, 2006; Graves and Cachola-Abad 1996; Kirch and Sharp 2005; Mulrooney and Ladefoged 2005; Weisler et al. 2006). It is, however, clear that both the labor to build monumental architecture and the ability of chiefs to enlarge their political authority were based in part on developments in agricultural and resource intensification. Agricultural development took several forms in Hawai'i and operated under varying conditions or constraints, and it provided feedback loops to political processes involving competition and cooperation.

Thegn N. Ladefoged is Associate Professor in the Department of Anthropology of the University of Auckland (Private Bag 92019, Auckland, New Zealand [t.ladefoged@auckland.ac.nz]). **Michael W. Graves** is Professor and Chair of the Anthropology Department of the University of New Mexico, (MSC01-1040, 1 University of New Mexico, Albuquerque, NM 87131-0001, U.S.A. [mwgraves@unm.edu]). This paper was submitted 6 III 07 and accepted 23 III 08.

The two primary forms of traditional agriculture were wetland and dryland. Taro (*Colocasia esculenta*) was grown in flooded pondfields (*lo'i*) and was the main staple in wet windward areas. A number of archaeological studies (Kirch 1971; Kirch and Kelly 1975; Earle 1978; Allen 1991; Kirch and Sahlins 1992; Kirch and McCoy 2007; McElroy 2007) have been conducted in wetland systems, revealing their relatively early

 0011-3204/2008/4905-0001$10.00. DOI: 10.1086/591424

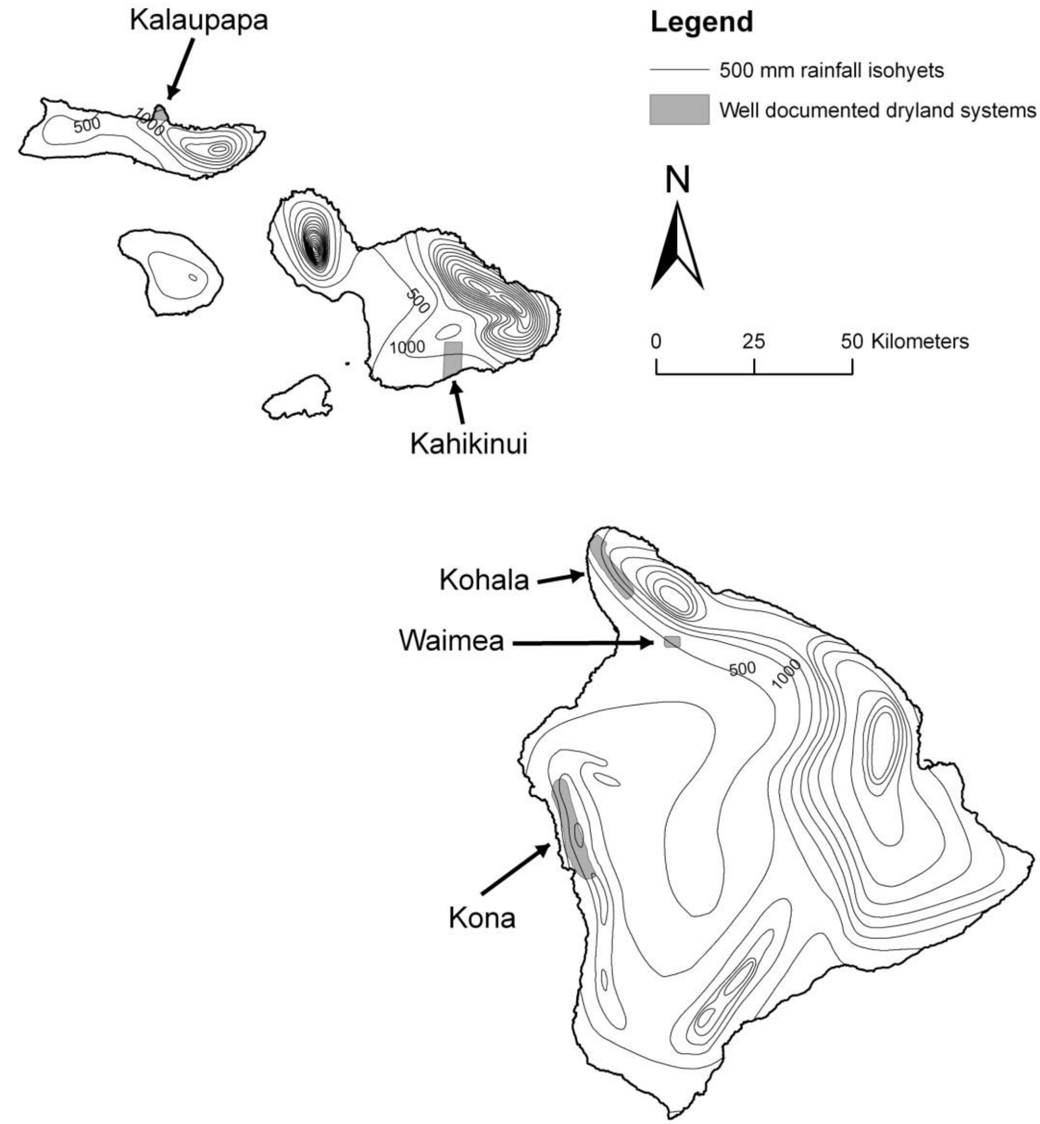

Figure 1. Well-documented dryland agricultural systems in Hawai'i.

date of construction and establishing their limited geographic scale on the older, more dissected islands of O'ahu and Kaua'i and in wetter regimes on islands such as Hawai'i, Maui, and Moloka'i.

Sweet potato and dryland taro were grown in intensified dryland systems in areas characterized as more arid, less dissected, and with younger geologic substrates (Kirch 1994; Vitousek et al. 2004). Five major dryland agricultural systems have been studied on three islands (fig. 1): the Kohala, Kona, and Waimea systems on Hawai'i Island, the Kahikinui system on Maui, and the Kalaupapa system on Moloka'i. A number of other dryland systems are now known from aerial photographs in the southern Ka'ū district on Hawai'i Island, and coastal Kaupō and upland Kula districts on Maui. The large individual size of these systems (upward of 60–80 km^2 in some cases) produces challenges for archaeologists who wish to study their dynamics and functioning. In this paper, we identify the methodological and substantive issues that accompany research on agriculturally based archaeological features distributed over sizeable leeward areas.

One of the most daunting issues in studies of prehistoric agriculture is the dating of various events. Dryland agricultural development involved two distinct processes: expansion into new areas and the intensification of previously established areas to boost outputs (Leach 1999; Ladefoged et al. 2003; Kirch 2006). Leach (1999) correctly distinguishes the process of intensification from the level of agricultural intensity. Expansion-related development occurred at various levels of labor intensity. At one end of the spectrum, it involved limited slash-and-burn horticultural activities without the construc-

Figure 2. A portion of the leeward Kohala field system, looking to the south, with agricultural walls and earth embankments running perpendicular to the slope and trails parallel to the slope.

tion of infrastructural improvements. At the other end, expansion involved constructing walls, embankments, and other infrastructure to define a series of fixed field plots in previously unoccupied areas. In contrast to expansion-related agricultural development is the process of intensification, where the outputs of fixed areas of previously established land are increased over time through various mechanisms. These included increased cropping cycles through labor expenditure on mulching, weeding, or other gardening activities and the construction of architectural components (such as rock walls, earth embankments, terraces, enclosures, and trails) to create landesque capital improvements. To document dryland agricultural development, it is necessary to distinguish agricultural expansion of new areas at various levels of intensity from diachronic intensification through energy expenditure within a fixed plot of land.

Deriving fine-grained chronologies for Hawai‘ian dryland agricultural developments has been problematic. Large numbers of chronometric estimates distributed across locations reflecting agricultural dynamics are required. Studies of the five major dryland agricultural systems have produced broad chronologies based on radiocarbon determinations for the Kohala, Kona, Waimea, and Kalaupapa systems and a tighter chronology based on both radiocarbon and thorium-230 dates in Kahikinui (see below). These dates can tell us about the onset of agricultural expansion into new areas and the duration of agricultural usage. But in all of these cases it is difficult to link dates to specific events associated with agricultural intensification and to distinguish it from some forms of expansion that involved intensified dryland farming. In an effort to better understand prehistoric Hawai‘ian dryland agricultural practices, we propose a fine-grained chronology for change based on relative and absolute dating techniques in the southern portion of the large dryland system of leeward Kohala. Our strategy allows us to link spatially distinct chronometric dates via relative dating of agricultural infrastructure (i.e., field border walls and trails that define fields), religious structures, and territorial boundaries.

Our recent research in Kohala focused on a large-scale, integrative study of the leeward Kohala field system (LKFS), one of the largest dryland field systems in the islands (fig. 2). This work illustrates the reliability and feasibility of tracking both expansion and intensification of dryland agriculture and other social processes, using both relative and chronometric dating methods. Our results expand the spatial scale of analysis and document the timing and rate of change in agricultural development in the southern portion of the LKFS, and we link these to changes in social and religious organization in this leeward part of the island. Our research emphasizes the differences—in timing, in sequencing, in organization—of agricultural and sociopolitical dynamics among Hawai‘i, Maui, and Moloka‘i islands while at the same time demonstrating the similar end points for these islands in the late eighteenth century.

The Kohala data allow us to discuss processual and comparative issues that link dryland agriculture in the Hawai‘ian archipelago. Two general developmental pathways for agriculture are identified, one based on optimality and/or effort and a second focused on areas of greater risk. The first pathway involves earlier and extended periods of intensification, whereas the second involves more rapid expansion and development of highly intensified systems. Within the second pathway, there is variation in the degree to which infrastructural improvements were constructed. We link each of these pathways to the pattern of sociopolitical change, focused particularly on Maui and Hawaiʻi Island. We suggest that the latter agricultural pathway is associated with a period of more intense intergroup and interisland aggression, conditioned in part by greater risk and the concomitant opportunity for territorial integration.

In the following, we discuss the development of five Hawaiʻian dryland agricultural systems. There has been substantial research in these areas, but the inability to integrate relative and absolute dating techniques has resulted in chronologies that lack precision. We then turn the focus to the LKFS, where we developed relative and absolute chronologies based on several data sets and the results of 33 new radiocarbon determinations. Incorporating these new data enable us for the first time to document fine-grained environmental and social processes in the area. We conclude the paper by noting the similarities and differences between the LKFS and the other four well-documented dryland agricultural systems, and we suggest that there is more variation in the development of these areas than previously recognized.

The Timing of Hawaiʻian Dryland Agricultural Development

Archaeological features associated with dryland agricultural systems have been studied on the younger, less weathered, and larger islands of Hawaiʻi Island and Maui for more than 30 years (see the early works of Soehren and Newman 1968; Pearson 1969; Newman 1970; Rosendahl 1972, 1994; Tuggle and Griffin 1973; Pearsall and Trimble 1984; Schilt 1984; Clark 1987). Over 20 years ago, Kirch (1985, 305) synthesized much of the earlier literature and proposed that the period from AD 1100 to 1650 was when "rapid agricultural expansion (occurred in leeward areas), as dryland forests and scrub were cleared and various kinds of field systems were laid out." In particular, Kirch (1985) suggested that the Kona and Kohala systems were established by ca. AD 1400.

More recent work in the dryland field systems has, however, begun to revise these initial chronological estimates and define differential developments in various leeward areas. Productive variability in leeward Hawaiʻi was influenced to a large extent by annual rainfall, elevation, and the age and fertility of geologic substrates. In addition, the relative distance to the coast influenced the suitability of an area for growing, harvesting, and distributing crops. Certain leeward areas were more marginal than other leeward areas for a variety of reasons, including the characteristics that they received either too little or too much rainfall, contained soils that were too old (i.e., weathered) or too young (and thus relatively unproductive), or were located at higher elevations with cooler temperatures, and/or greater distances from the coast.

Of the five dryland systems that have been well documented, the Waimea Agricultural System in South Kohala is the farthest inland. It was initially investigated by Clark, Kirch, and colleagues in the 1970s and 80s (Clark and Kirch 1983; Clark 1987). They identified irrigated and dryland agricultural fields in this system and inferred that both were prehistoric in age. Burtchard and Tomonari-Tuggle's (2004) more recent study reevaluates this research and concludes that "limited, short-term or seasonal residence" was established in the area by the mid-1400s. They suggest that there is substantial evidence of occupation from "AD 1600 to 1700, lingering into the early postcontact period." The Waimea Agricultural System is noted for a series of earthen field ridges that are thought to have formed as a result of sediment accumulation at the base of windbreaks that were used for agricultural purposes. There are only six radiocarbon dates associated with earthen field ridges, and as Burtchard and Tomonari-Tuggle (2004, 64) note, they are difficult to interpret, but the dates suggest the possible origin of the field ridges as "early as the late AD 1400s" with continued use into the early postcontact era. In contrast to the earlier work of Clark and Kirch (1983) and Clark (1987), Burtchard and Tomonari-Tuggle (2004) conclude that the irrigated agricultural features in the area are a post-European contact development.

A considerable amount of archeological research in the Kona field system has established the broad outlines of occupation in the area (see Schilt 1984 and Kirch 1985 for reviews of the earlier work and Allen 2001, 2004, for reviews of more recent work). Allen's (2001, 2004) work in the Amy Greenwell Botanical Garden located in the heart of the field system provides the best estimates for its chronology. Excavations in the Greenwell Garden dated the first residential activities at ca. AD 1400–1650 (Allen 2004, 208). The earliest documented agricultural features are terraces or low walls that are oriented perpendicular to the slope and that date to an interval between AD 1472 and 1645. The Kona field system is best known for a series of rock walls referred to as *kuaiwi* that are widely distributed on the surface and are oriented parallel to the slope. These were major agricultural features used for planting and plot boundaries. Allen's (2004, 217) results suggest that the *kuaiwi* in the area are "securely placed at sometime after the fifteenth century AD, and most likely in the sixteenth or seventeenth century AD." Furthermore, she notes, "After 1600 AD, there are no further capital improvements indicated at Greenwell Garden" (Allen 2004, 219). However, additional research from outside the Greenwell Garden area of the Kona field system (e.g., Kawachi 1989) suggests that further infrastructural improvements occurred during the eighteenth century into the historic era.

In the LKFS, the earlier work of Rosendahl (1972, 1994) suggested the gradual development of the central Lapakahi portion of the field system over a period from AD 1400 to 1800 (see Kirch 1985 for a brief summary). Recent contract

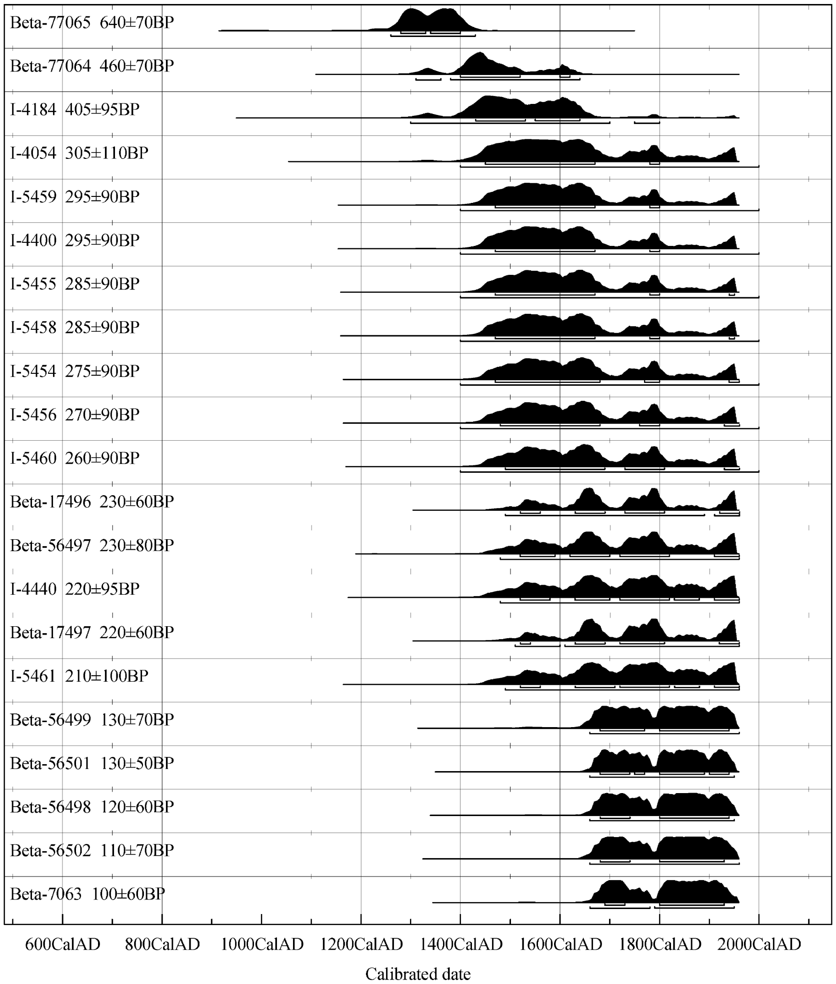

Figure 3. Calibrated radiocarbon dates from the central to northern portions of the LKFS (calibrated with OxCal 3.10; Bronk Ramsey 1995, 2001, 2005).

work has produced a range of dates, and Graves et al. (2006) point out that both the 10 radiocarbon determinations reported by Rosendahl (1972) and the 18 dates from recent contract work (Hammett and Borthwick 1986; Adams and Athens 1994; Wuzen and Goodfellow 1995) in the central to northern portions of the LKFS document residential and agricultural features from ca. AD 1450 onward (fig. 3). Our radiocarbon determinations from the southern portion of the field system are presented in detail below, but these indicate a substantially later development of the southern portion of the LKFS.

McCoy's recent work on the Kalaupapa peninsula of Moloka'i has documented the development of the Kalaupapa dryland field system (Kirch 2002; McCoy 2002, 2003, 2004, 2005*a*, 2005*b*, 2006, 2008; McCoy and Hartshorn 2007). McCoy's extensive work and analysis of 27 radiocarbon dates suggests that "there are clear signs of the development of a large-scale agricultural field system that occupied the entire Kalaupapa Peninsula" after AD 1450–1550 (McCoy 2008, 22, 23). Significantly, none of the residential features on the peninsula date to before AD 1650, and it is not until after this time that "settlement expanded onto the peninsula itself" (McCoy 2008, 23).

In Kahikinui on Maui, recent research (Dixon et al. 1997, 1999; Kirch 1997, 2004; Kolb and Radewagen 1997; Kolb and Snead 1997; Kirch et al. 2004, 2005; Coil and Kirch 2005; Kirch and Sharp 2005) has documented the earliest evidence of swidden cultivation and residential features in the area as early as AD 1420, with continued development until ca. AD 1640. After AD 1640 there were significant developments with more permanent residential occupation, a relatively sudden surge in the construction of religious features, and the expansion and intensification of agricultural activities. Much less of the area, however, was ever converted to fixed field agricultural features, as has been found in most other leeward systems.

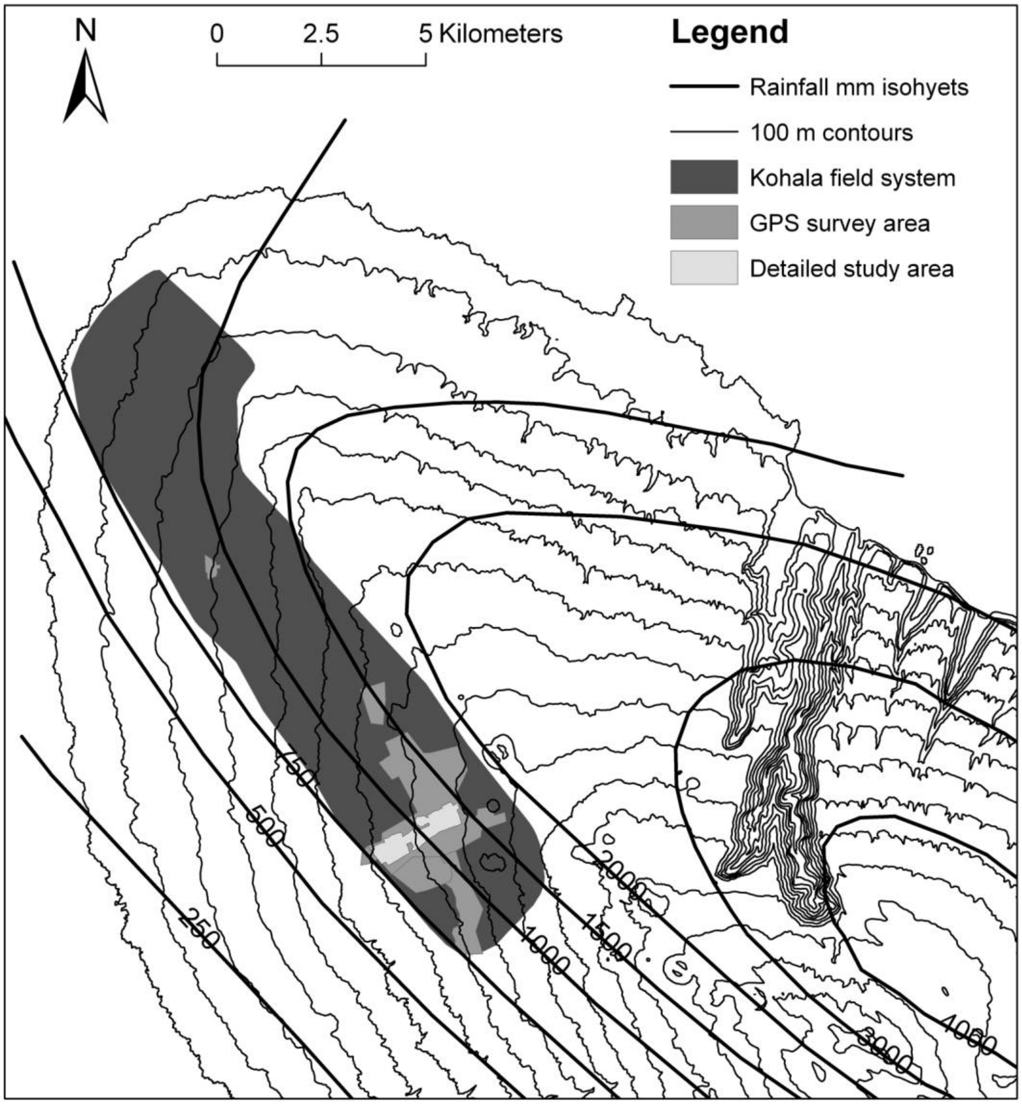

Figure 4. The distribution of the leeward Kohala field system in relation to elevation and rainfall isohyets.

In sum, there are age estimates for the development of the five major dryland agricultural systems that have been intensively investigated. These suggest that some leeward areas were initially occupied during the fifteenth century and developed for agriculture earlier than other areas, whereas other systems were not permanently occupied until the mid-seventeenth century. While these estimates are useful, none of these studies have derived fine-grained estimates (by combining both relative and absolute dating techniques) and applied them to residential, religious, and agricultural features. New data from Kohala allows us to do this, and it is thus possible to consider changes in sociopolitical, religious, and demographic processes in far more detail than ever before.

Leeward Kohala Field System

The leeward Kohala field system, located on the western side of northern Hawaiʻi Island, was one of the most intensive and productive precontact dryland agricultural systems in the Hawaiʻian archipelago (fig. 4). This ca. 3 × 20-km field system covers an area of ca. 60 km^2 and is in a zone that receives between ca. 750 and 1900 mm of rain annually. The spatial distribution and productivity of the agricultural field system is primarily limited by rainfall, elevation, and soil nutrient levels in conjunction with the effects of extremely strong tradewinds (for details, see Ladefoged et al. 1996, 2003, 2008; Ladefoged and Graves 2000, 2005, 2006, 2007; Vitousek et al.

2004; Lee et al. 2006). The field system consists of a series of agricultural walls and embankments and a network of trails and contains a high density of residential, religious, animal husbandry, and additional smaller agricultural features. Overlaying these precontact features is a range of early historic ranching enclosures and homesteads. The walls and trails throughout the field system are orientated in a grid pattern of plots that were used to grow a variety of crops, with sweet potato (*Ipomea batatas*) probably dominating this regime. In general, the agricultural walls are orientated perpendicular to the slope and would have reduced evapotranspiration and provided physical protection for the crops from the strong northeast winds. Trails are oriented parallel to the slope and would have provided access between coastal settlements and the upland agricultural areas and in some instances would have defined social boundaries (see Cordy and Kascho 1980; Ladefoged and Graves 2006). Our attempts to investigate the development of intensive agriculture (Ladefoged et al. 1996, 2003, 2005; Ladefoged and Graves 2000; Vitousek et al. 2004; Meyer et al. 2007) within the context of far-reaching prehistoric sociopolitical, religious, and demographic change (Ladefoged and Graves 2005, 2006, 2007; Mulrooney and Ladefoged 2005; Ladefoged et al. 2008) have been complicated by the large numbers of features and the palimpsest nature of the archaeological landscape. In the past we have defined relative chronologies for a number of archaeological materials and linked these to cultural processes, and when these are combined with the results of recent radiocarbon determinations, we are now in the position to link these various chronologies and decipher this palimpsest landscape.

Relative Chronologies of Development in the LKFS

Relative dating has been successfully used in leeward Kohala to add a temporal dimension to the interpretation of the archaeological record of agricultural development and human occupation. Agricultural development has been ordered by deriving a chronology based on the spatial relationship of walls and trails and the relative nutrient levels of sediments underlying agricultural walls. A chronology for changing territories has been defined on spatial relationships between boundaries, and a relative chronology for religious activities has been proposed on the basis of a seriation of temple architectural traits. Paleodemography has been modeled by associating residential features with patterns of agricultural development. These studies are briefly reviewed before integrating the findings with the results of the 33 new radiocarbon determinations.

We monitored the relative development of agriculture in the LKFS in several ways. Rosendahl (1972, 1994; and see Kirch 1984, 1985) was the first to note that the spatial relationship of walls and trails reflected the creation and subsequent division of agricultural plots, and he suggested that subdivision of land could be detected through the construction of additional abutting or offsetting walls and trails. Ladefoged and Graves (2000) employed this idea to generalize that the subdivision of plots produced a situation where earlier walls should be longer in length than later walls. Using aerial photograph geographic information system data to estimate wall length, we defined three periods of agricultural development in the field system, with the southern portion characterized by the shortest walls, which we concluded were constructed primarily during the latest phase of precontact agricultural development. We suggested that this southern area was developed as demands for increased surplus production grew and with the establishment of new levels of competition between complex chiefdoms in Hawai'i. McCoy (2000) and Ladefoged et al. (2003) refined this relative chronology using fine-grained global positioning system survey data from the southern and central portions of the field system to differentiate the processes of agricultural expansion and intensification. The methodology of Ladefoged et al. (2003) relied upon a detailed examination of the relationship of walls and trails to order architectural elements based on the principles that walls will predate the trails that intersect (i.e., cross) them and that walls will postdate or date to the same time interval as trails they abut. Using these principles, Ladefoged et al. (2003) stated a set of criteria for deriving the relative order of agricultural development and identified multiple phases of expansion and intensification within three locations of the LKFS.

One of the limitations of our relative chronology of agricultural development is that though it is logically rigorous, it cannot by itself provide a test of the accuracy or the temporal direction of the order produced. Independent evidence is required to accomplish this. One previous attempt to develop such data is Meyer et al. (2007), who measured the nutrient levels (using resin-P and the ratio of P to Nb) in sediments under agricultural walls. They reasoned that sediments under older walls should have higher nutrient levels than sediments under younger walls since farming probably depleted the nutrients of the soils, with subsequent wall construction capping or sealing the existing nutrients within a plot under the wall. Their results support the agricultural development ordering technique and the proposition that agricultural harvesting depleted nutrient levels in the soils as agricultural intensification increased.

Relative chronologies were also used to model changing territorial boundaries (Ladefoged and Graves 2006) and increased religious activities in the uplands of the southern LKFS (Mulrooney 2004; Mulrooney and Ladefoged 2005). Ladefoged and Graves (2006) documented the subdivision of larger territories into smaller social units by analyzing the spatial relationship of boundary markers such as trails and the *ahupua'a* (or community) boundaries depicted on maps first recorded in the mid-nineteenth century. We established that a series of nine larger territories were subdivided over a period of probably several hundred years into 35 smaller-sized community territories that were present by the early 1800s.

Recent modeling of life expectancy and surplus production in these territorial units suggests that the optimal configuration for life expectancy in the area was achieved when it was divided into 14 territories (Ladefoged et al. 2008; also see Lee et al. 2006). At European contact, the area containing the LKFS was divided into 32 territories, which lowered average life expectancy and increased levels of spatial variability in surplus production. This territorial configuration, however, maximized average yearly surplus and reduced its temporal variability, providing elite managers the opportunity to monitor production and control the redistribution of resources.

The dynamic territoriality in the area was combined with a seriation of architectural design traits (based on work by Graves and Cachola-Abad 1996) for temples (*heiau*) in the LKFS uplands. By doing this, Mulrooney and Ladefoged (2005; also see Mulrooney 2004) documented a four-phase development of religious activities, concluding that the delineation of smaller territories containing newly constructed temples probably reflects increased managerial control and religious activity associated with the production of agricultural surpluses.

Paleodemographic trends were also modeled through the association of residential features with changing agricultural plots (Ladefoged and Graves 2007). Because of the methodological challenges of linking specific residential features to agricultural activities, these results should be considered preliminary and should be interpreted with caution. The data does suggest, however, that population growth in the southern LKFS slowed over time, whereas agricultural production continued to increase throughout the span of prehistoric development. This in turn suggests that the amount of agricultural surplus relative to the needs of farmers increased during the later phases of occupation.

Radiocarbon Dates from the Southern LKFS

While these relative chronologies are useful in estimating the relative order of temporal change, the timing (in calendrical years) of events and processes must be grounded by absolute dating methods. The results of 33 accelerator mass spectrometry (AMS) radiocarbon determinations from agricultural, residential, and religious contexts in the southern portion of the LKFS provide this foundation (table 1). Most of these determinations were made on short-lived species, although in a few cases, identifications were ambiguous, making it possible that long-lived species were dated. Of the 33 dates, 25 are associated with agricultural features (fig. 5; also see table 1 samples with “T” in the provenance heading). Nineteen of the 25 agricultural dates are on charcoal recovered from trenches that were mechanically excavated perpendicularly through earthen and rock walls associated with fixed fields. The profiles of the trenches were cut back by hand and stratigraphy was recorded. Charcoal was recovered from the sides of these trenches, underneath the walls in soils that show clear signs of clearing or cultivation, such as digging stick holes, churned sediments, and charcoal lenses or flecking. We hypothesize that these samples date agricultural or clearance activities in field plots used before the construction of the overlying walls and that the dated charcoal was the result of intentional burning of native vegetation or fallow fields. Some of this charcoal was subsequently mixed into the cultivation layer. The charcoal samples presented here date activities that occurred before the construction of the agricultural walls. Four of the 25 dates come from underneath rock and earthen trails that cross the field system. We suspect that this charcoal was the result of gardening activities that predate the construction of the trails. Finally, two of the 25 specimens are direct dates on probable charred fragments of sweet potato (see Ladefoged et al. 2005).

Although it is probable that people utilized the southern Kohala uplands on a near-continuous basis after this area was converted to agriculture, the 25 dates associated with gardening activities can be divided into three groups (see fig. 5). The first group includes three dates (Kohala radiocarbon samples [KRC] 10, 16, 24) that have 2-sigma calibrations extending from ca. AD 1270 to AD 1420. Notably, dates KRC 10 and 16 are on charcoal that was identified only as dicot wood, and therefore, these determinations could reflect the dating of old wood. However, KRC 24 is from a piece of probable sweet potato and provides good evidence of cultivation in the area as early as AD 1290 (see Ladefoged et al. 2005). KRC 11 is another piece of charcoal that could be identified only to the level of dicot wood and that has a 2-sigma calibration of AD 1310 to 1460, an interval overlapping the first and second group of dates. The 2-sigma calibrations of the second group of 10 dates (KRC 1–3, 7, 9, 12, 17–19, 23) have high probabilities in the AD 1420 to AD 1670 range. One date, KRC 6, bridges the second and third group of dates, and has a 2-sigma calibration range of AD 1510 to AD 1960, although there is a higher probability that the charcoal dates to before AD 1810. Ten dates associated with agriculture (KRC 4, 5, 8, 13–15, 20–22, 33) have 2-sigma calibrations that span from as early as AD 1630 into the historic period. None of these later samples were associated with features that produced Euro-American artifacts, suggesting none of these field borders were constructed later than the early 1800s. In sum, the approximate calibrated age ranges for dates associated with agricultural contexts include a group 1 estimate of AD 1270 to AD 1420, a group 2 estimate of AD 1420 to AD 1650, and a group 3 estimate of AD 1630 to the early 1800s.

In addition to the 25 radiocarbon dates associated with agricultural contexts, there are seven AMS radiocarbon dates associated with residential features in the area (table 1; fig. 6). All of these dates are on charcoal from four slab-lined and three scoop hearths. Three of the slab-lined hearths (associated with KRC 25–27) were visible on the surface; one (associated with KRC 28) was encountered in the subsurface excavations, as were all three scoop hearths (associated with KRC 30–32). All but one of the hearths were located within the perimeter of the foundations that define these features. We sampled the interior ash and charcoal for each hearth, thus dating its probable last usage. Of the seven features, four are enclosures, one is a low-walled three-sided enclosure with an abutting terrace, one is a platform with a hearth immediately adjacent to it, and one is a rock overhang associated with a residential terrace. The 2-sigma calibrations of all the dates extend from the mid-seventeenth century into the historic period and match fairly closely the group 3 latest agricultural dates. The two surface slab-lined hearths and the scoop hearth adjacent to the platform are among the most recent of these dates whose calibrated ranges could extend into the early nineteenth century; all of the other subsurface slab-lined or scoop hearths date somewhat earlier, and their calibrated ranges do not significantly extend into the nineteenth century.

There is one radiocarbon determination (KRC 26) from a feature that has been interpreted as a *heiau* or temple (*heiau* H1, referred to in Mulrooney and Ladefoged 2005; see fig. 5). The radiocarbon determination is on charcoal recovered from a 1 × 1-m test unit excavated adjacent to the back wall of the structure. The date has a 2-sigma calibration extending from AD 1660 into the historic era.

The Synthesis of Relative and Absolute Dating in the LKFS

The radiocarbon dates from underneath the agricultural walls and trails, within hearths associated with residential features, and the fill of a temple all date different behavioral activities. The charcoal from underneath the walls and trails represents a terminus ante quem date, that is, the earliest date before which these architectural features could have been constructed; the walls and trails could have been built at the same time or later than these dates indicate. The charcoal from hearths within the residential features represents a terminus post quem date, that is, the latest date we have for occupation of the feature, as hearths were often repeatedly used and cleaned out. The radiocarbon date on charcoal from the fill of the temple probably represents the construction of the feature. Because of the differences in the associations between the radiocarbon dates and the architectural features our ability to link the radiocarbon dating of three classes of architecture is limited, however, the results do provide indicative temporal associations.

Twenty-one of the radiocarbon determinations associated with agricultural activities come from the inland portions of Kahua 1 and Pahinahina *ahupua'a*, an area within the southern LKFS where we developed detailed models of agricultural development (fig. 4; area depicted as detailed study area). A series of 17 radiocarbon determinations (KRC 1–8, 12–15, and 19–23) are associated with the series of walls and trails shown in figure 7. The spatial relationships between walls and trails have been used to define five stages of agricultural development, labeled according to the building phases shown in figure 7, with phase 1 being the earliest and phase 5 the most recent. Radiocarbon samples KRC 1, 2, and 3 come from layers underneath the phase 1 walls; KRC 1 has a high probability of dating between AD 1480 and 1670, and KRC 2 and 3 have high 2-sigma probabilities of dating between approximately AD 1410 to 1630. These dates suggest that the construction of the earliest agricultural features in the area took place sometime after AD 1410 or perhaps as late as AD 1480. A number of other walls assigned to the later building phases 2–5 were constructed on top of layers that have similar 2-sigma calibrations (mid-fifteenth to mid-seventeenth-century range; KRC 7, 12, 19, 23). These radiocarbon determinations are consistent with the relative chronology and indicate that these phases of agricultural development took place possibly as early as the mid-fifteenth century AD. This age estimate, however, may be refined by considering the 2-sigma calibrations of eight other dates: KRC 4, 6, 8, 13–15, 20, and 21. KRC 20 and 21 come from under a phase 2 wall, KRC 4 comes from under a phase 3 wall, KRC 13–15 come from under phase 4 walls and a trail, and KRC 6 and 8 come from under phase 5 walls. Seven of these dates have 2-sigma calibrations that extend from AD 1660 into the historic era, and the eighth date has a 2-sigma calibration that extends from AD 1630 into the historic era. These suggest that all the walls associated with the later phases of agricultural development (that is, phases 2–5) were actually constructed after approximately AD 1660.

In sum, the relative and absolute dating of agricultural development suggests that the southern portion of the field system was initially used as early as AD 1290 but certainly by AD 1430. This earliest use could have involved horticultural activities not associated with any infrastructural improvements such as walls and trails. Two of the phase 1 agricultural walls were constructed as early as AD 1410 but possibly not until AD 1630, and a third early phase 1 agricultural wall suggests that construction did not occur until after AD 1480 and possibly as late at AD 1670. The majority of the agricultural walls were probably constructed after AD 1660, when four phases (2–5) of building development occurred.

The results of the radiocarbon determinations can also be integrated with our analysis of residential features. Three (KRC 25, 30, and 32) of the seven radiocarbon dates are from residential features in the region where a detailed relative chronology of the walls and trails has been established. The other four dates are from residential features within 50–300 m of this area. The three radiocarbon dates from residential features within the region with an established relative chronology of agricultural development have 2-sigma calibrations that range from the mid-seventeenth century into the historic era (as indeed do all the dates associated with residential features). These three features were in use in areas of the field system that, based on the relationship of walls and trails in the area, are thought to have been developed during this latest period, either just before or immediately after European contact in the late eighteenth century. It should, however, be

Table 1. Radiocarbon Dates from the Southern *Ahupua'a* of the Kohala Field System

KRC	β Number	Provenance	UTM *X* Coordinate	UTM *Y* Coordinate	Dated Material	Measured Radiocarbon Age (yr)	$^{13}C/^{12}C$ Ratio	Conventional Radiocarbon Age (yr)	OxCal 2-sigma Calibration
1	189729	T-7	205837	2228603	Unidentified dicot wood	300 ± 40	-25.8	290 ± 40	1480 AD (93.4%) 1670 AD; 1780 AD (2.0%) 1800 AD
2	189730	T-7	205808	2228592	Sida	430 ± 40	-24.2	440 ± 40	1400 AD (88.5%) 1520 AD; 1590 AD (6.9%) 1620 AD
3	189731	T-7	205792	2228585	Sida	410 ± 40	-24.5	420 ± 40	1410 AD (78.5%) 1530 AD; 1570 AD (16.9%) 1630 AD
4	189732	T-7	205775	2228580	Chamaesyce	100.3 ± 0.5 pMC	-10.4	210 ± 40	1630 AD (29.0%) 1700 AD; 1720 AD (46.8%) 1820 AD; 1830 AD (3.1%) 1880 AD; 1910 AD (16.5%) 1960 AD
5	189733	T-9	205822	2228530	Chenopodium	150 ± 30	-26.1	130 ± 30	1670 AD (37.9%) 1780 AD; 1790 AD (57.5%) 1950 AD
6	189734	T-10	206020	2228607	Chenopodium	270 ± 40	-26.2	250 ± 40	1510 AD (23.9%) 1600 AD; 1610 AD (41.5%) 1690 AD; 1730 AD (23.5%) 1810 AD; 1930 AD (6.6%) 1960 AD
7	189735	T-10	206008	2228603	Unidentified wood	400 ± 40	-24.3	410 ± 40	1420 AD (71.8%) 1530 AD; 1550 AD (23.6%) 1640 AD
8	189736	T-11	205998	2228551	Myoporum	140 ± 30	-25.2	140 ± 30	1660 AD (42.9%) 1780 AD; 1790 AD (52.5%) 1950 AD
9	189737	T-12	206375	2228638	Chenopodium	470 ± 40	-26.5	450 ± 40	1400 AD (91.6%) 1520 AD; 1590 AD (3.8%) 1620 AD
10	189738	T-12	206354	2228630	Dicot wood	640 ± 40	-23.4	670 ± 40	1260 AD (51.4%) 1330 AD; 1340 AD (44.0%) 1400 AD
11	189739	T-13	206365	2228637	Dicot wood	490 ± 40	−24.6	500 ± 40	1310 AD (9.4%) 1350 AD; 1390 AD (86.0%) 1460 AD
12	189740	T-15	205947	2228341	Probably Chamaesyce	90 ± 40	-10.4	330 ± 40	1460 AD (95.4%) 1650 AD
13	189741	T-15	205922	2228335	Chamaesyce	101.2 ± 0.4 pMC	-9.6	150 ± 30	1660 AD (78.2%) 1890 AD; 1900 AD (17.2%) 1960 AD
14	189742	T-17	205973	2228349	Sida	130 ± 30	-25.3	130 ± 30	1670 AD (37.9%) 1780 AD; 1790 AD (57.5%) 1950 AD
15	189743	T-18	205974	2228314	Chamaesyce	240 ± 40	-27	210 ± 40	1630 AD (29.0%) 1700 AD; 1720 AD (46.8%) 1820 AD; 1830 AD (3.1%) 1880 AD; 1910 AD (16.5%) 1960 AD
16	189744	T-21	206567	2228213	Dicot wood	600 ± 40	-26.5	580 ± 40	1290 AD (95.4%) 1430 AD

17	189745	T-21	206541	2228205	Chenopodium	460 ± 40	-27	430 ± 40	1410 AD (83.9%) 1530 AD; 1570 AD (11.5%) 1630 AD
18	189746	T-22	206590	2228196	Myoporum	280 ± 40	-24.8	280 ± 40	1480 AD (90.8%) 1670 AD; 1780 AD (4.6%) 1800 AD
19	208138	T-32	206003	2228635	Chamaesyce	340 ± 40	−26	320 ± 40	1460 AD (95.4%) 1650 AD
20	208139	T-32	205986	2228624	Chamaesyce	160 ± 40	−25.2	160 ± 40	1660 AD (78.2%) 1890 AD; 1900 AD (17.2%) 1960 AD
21	208140	T-35	205957	2228760	Chenopodium	150 ± 40	−25.3	150 ± 40	1660 AD (95.4%) 1960 AD
22	208141	T-36	206039	2228785	Chenopodium	200 ± 40	−24.8	200 ± 40	1640 AD (25.2%) 1700 AD; 1720 AD (48.0%) 1820 AD; 1830 AD (4.8%) 1880 AD; 1910 AD (17.4%) 1960 AD
23	208142	T-39	206070	2228755	Chamaesyce	340 ± 40	−25	340 ± 40	1460 AD (95.4%) 1650 AD
24	208143	T-50	205035	2227556	*Ipomea batatas*	580 ± 40	−24.7	580 ± 40	1290 AD (95.4%) 1430 AD
25	209736	AO-50	205598	2228252	cf. Nototrichium	150 ± 40	−26.5	130 ± 40	1660 AD (39.8%) 1780 AD; 1790 AD (55.6%) 1950 AD
26	209737	AO-76	206521	2228442	Chamaesyce	100.6 ± 0.5 pMC	−12.3	160 ± 40	1660 AD (78.2%) 1890 AD; 1900 AD (17.2%) 1960 AD
27	209738	AO-202	206274	2228173	cf. Senna	190 ± 40	−26.6	160 ± 40	1660 AD (78.2%) 1890 AD; 1900 AD (17.2%) 1960 AD
28	209739	AO-203	205767	2228729	Chamaesyce	100.2 ± 0.5 pMC	−11.8	200 ± 40	1640 AD (25.2%) 1700 AD; 1720 AD (48.0%) 1820 AD; 1830 AD (4.8%) 1880 AD; 1910 AD (17.4%) 1960 AD
29	209740	AO-209	205869	2227778	Chamaesyce	100.5 ± 0.5 pMC	−11.5	180 ± 40	1640 AD (77.6%) 1890 AD; 1910 AD (17.8%) 1960 AD
30	209741	AO-532	205213	2228093	Chenopodium	120 ± 40	−25.8	110 ± 40	1670 AD (32.9%) 1780 AD; 1790 AD (62.5%) 1940 AD
31	209742	AO-1035	205113	2227608	Chenopodium	240 ± 40	−26.9	210 ± 40	1630 AD (29.0%) 1700 AD; 1720 AD (46.8%) 1820 AD; 1830 AD (3.1%) 1880 AD; 1910 AD (16.5%) 1960 AD
32	209743	AO-3006	204728	2227719	Chenopodium	220 ± 40	−26.2	200 ± 40	1640 AD (25.2%) 1700 AD; 1720 AD (48.0%) 1820 AD; 1830 AD (4.8%) 1880 AD; 1910 AD (17.4%) 1960 AD
33	210381	T-12	206361	2228633	*Ipomea batatas*	170 ± 40	−23.8	190 ± 40	1640 AD (22.4%) 1710 AD; 1720 AD (48.3%) 1820 AD; 1830 AD (7.0%) 1880 AD; 1910 AD (17.7%) 1960 AD

Note. KRC = Kohala radiocarbon sample; UTM = universal transverse Mercator; pMC = percent modern carbon.

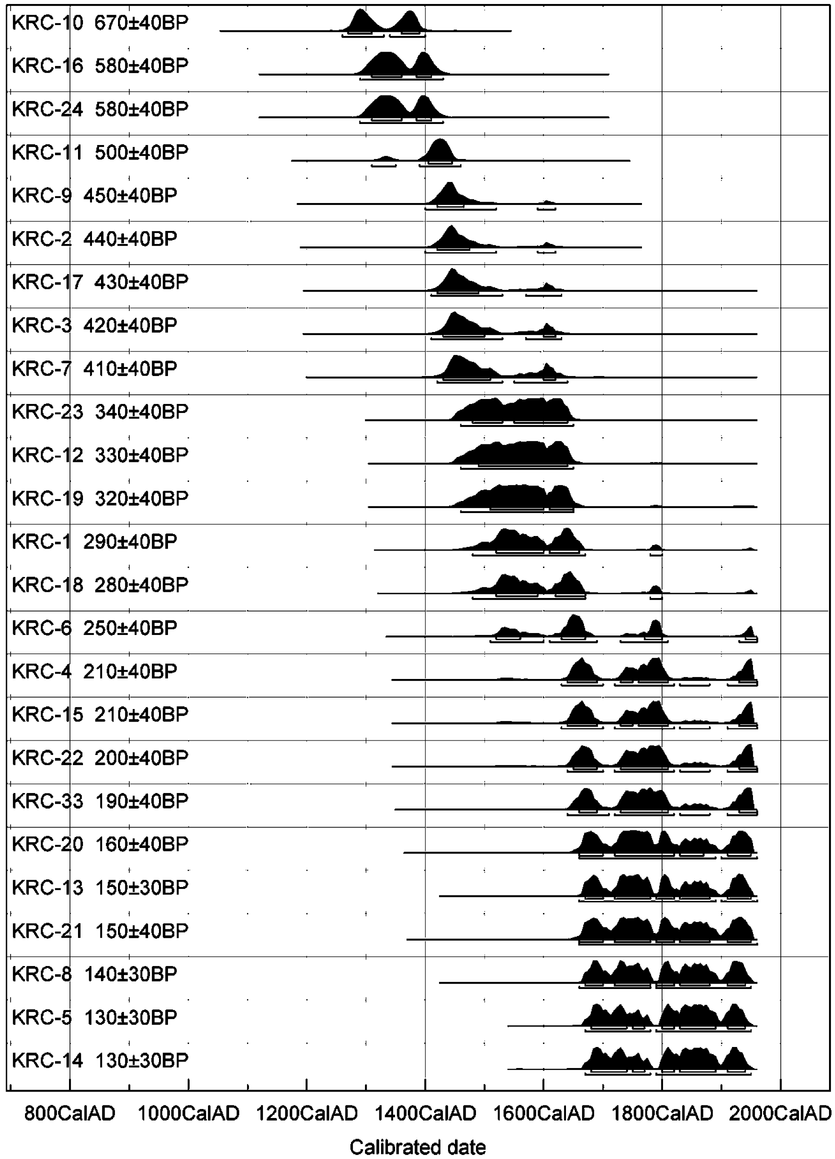

Figure 5. Calibrated radiocarbon dates associated with agricultural activities in the southern portion of the Kohala field system (calibrated with OxCal 3.10; Bronk Ramsey 1995, 2001, 2005).

noted that the relationship between the residential features and the agricultural walls is tenuous, and because the radiocarbon dates from the residential features are from hearths that might have been reused over time, we cannot say with certainty that the residential features were not used before the mid-seventeenth century.

Finally, the results of the radiocarbon determinations can be meshed with our interpretations about changing territories and religious activities. A detailed analysis of the territorial boundaries indicates that at one time the current territorial units of Pahinahina, Kahua 1, and Kahua 2 were a single territory, and Makiloa, Kalala, and a number of other land units were another territory (see Ladefoged and Graves 2006 for details). There are three radiocarbon determinations (KRC 1, 2, 3) from underneath walls that cross the Pahinahina and Kahua 1–Kahua 2 boundary. These dates have 2-sigma calibration probabilities in the AD 1410 to 1670 range. Because the walls intersect this boundary, it is assumed that they were constructed before the boundary existed. The seriation of temple attributes and the spatial analysis of boundaries suggest that *heiau* H1 was constructed when the division between Kahua 1 and Kahua 2 occurred (see Mulrooney and Ladefoged 2005). The radiocarbon determination associated with this temple has a 2-sigma calibration range of AD 1660

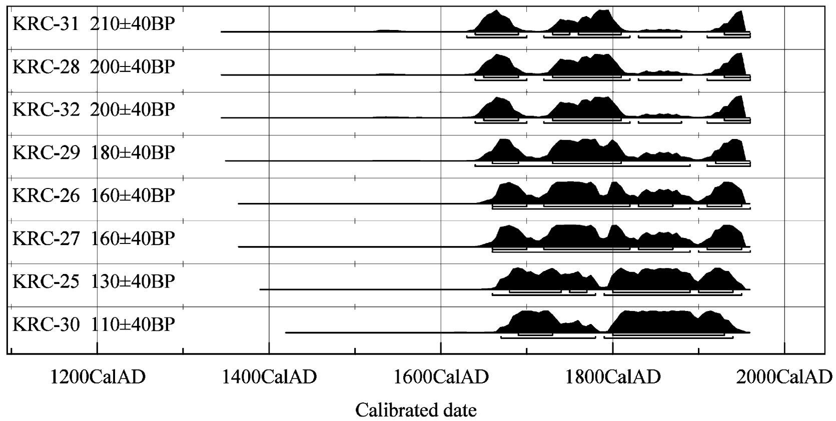

Figure 6. Calibrated radiocarbon dates associated with residential and religious features in the southern portion of the Kohala field system (calibrated with OxCal 3.10; Bronk Ramsey 1995, 2001, 2005).

into the historic era. In general then, the earliest definition of the territorial boundaries in the area (i.e., between the land unit of Pahinahina–Kahua 1–Kahua 2 and the land unit of Makiloa-Kalala and the adjacent northern land units) probably predates AD 1410 to 1670 range. The creation of the boundary between Pahinahina and Kahua 1–Kahua 2 probably postdates the interval AD 1410 to 1670 range, and the boundary between Kahua 1 and Kahua 2 postdates AD 1650.

Discussion

There was considerable variability in the development of agricultural resources in leeward Hawai'i, with some dryland areas being developed significantly earlier than other, more marginal regions. In the northern and central portions of the LKFS, radiocarbon dates from Rosendahl's (1972, 1994) and Newman's (1970) work in Lapakahi and recent research (Adams and Athens 1994; Hammett and Borthwick 1986; Wuzen and Goodfellow 1995) in Mahukona and Kakuipahu suggest human occupation and agricultural activities from ca. AD 1450 onward (fig. 3). Most of the dates are bracketed between AD 1500 and 1800, with several more dating to after AD 1700. In the central portion of Kona, Allen (2004, 209, 210, 214,) suggests residential features were initially constructed in the upland area from ca. AD 1400 to 1650, with the first evidence of agricultural terracing occurring from ca. AD 1472 to 1645, and later *kuaiwi* rock walls dating to AD 1500 to the 1600s. Allen's (2004, 219) suggestion that there were no further capital improvements in the Greenwall Garden area of the Kona field system after AD 1600 is consistent with the interpretation that the area was reaching maximum intensification, a situation that is quite different from the more marginal areas of the archipelago as a whole and perhaps the more marginal areas of the Kona field system. Both the central core of the Kona field system and the northern and central portions of the LKFS were relatively better areas of Hawai'i Island for growing dryland cultigens and/or transporting them to coastal settlements. They provided prime upland agricultural lands within easy access to coastal settlements in areas with sufficient rainfall and good, geologically young, and fertile soils. These areas are also of greater rainfall predictability for dryland farming, compared with those developed later in time. It is in these relatively optimal areas that substantial leeward populations developed from the fifteenth century onward. Later developments in these areas were influenced by sociopolitical factors, and Allen (2004, 196) notes, "Later in time (after 1650 AD) there was a shift in emphasis to productive maximizing strategies, with implications for the region (of Kona's) economic and sociopolitical stability."

It should be noted that Kona and the northern and central portions of the LKFS are not the only areas where dryland agriculture may have first been established in the archipelago. Predictive modeling (Ladefoged et al. n.d.) suggests that these are just two areas that have been well studied, but other regions with suitable environmental settings (i.e., sufficient rainfall, suitable temperatures at elevations below ca. 900 m, relatively young and fertile geologic substrates, and close proximity to coast) and sociopolitical contexts probably contain intensively developed field systems that await future archaeological examination.

In contrast to these centers of early dryland agricultural development are the more marginal dryland systems of Waimea (Hawai'i Island), Kahikinui (Maui), Kalaupapa (Moloka'i), and the southern portion of the LKFS. In the LKFS, the vast majority of our data comes from the southern sections of the field system. Developments in this area are quite different than those in the north. On the basis of the relative chronology of agricultural development within the whole LKFS, we (Ladefoged and Graves 2000) suggested that the southern portion was probably one of the last areas to be fully developed with fixed fields. In part this is due to the

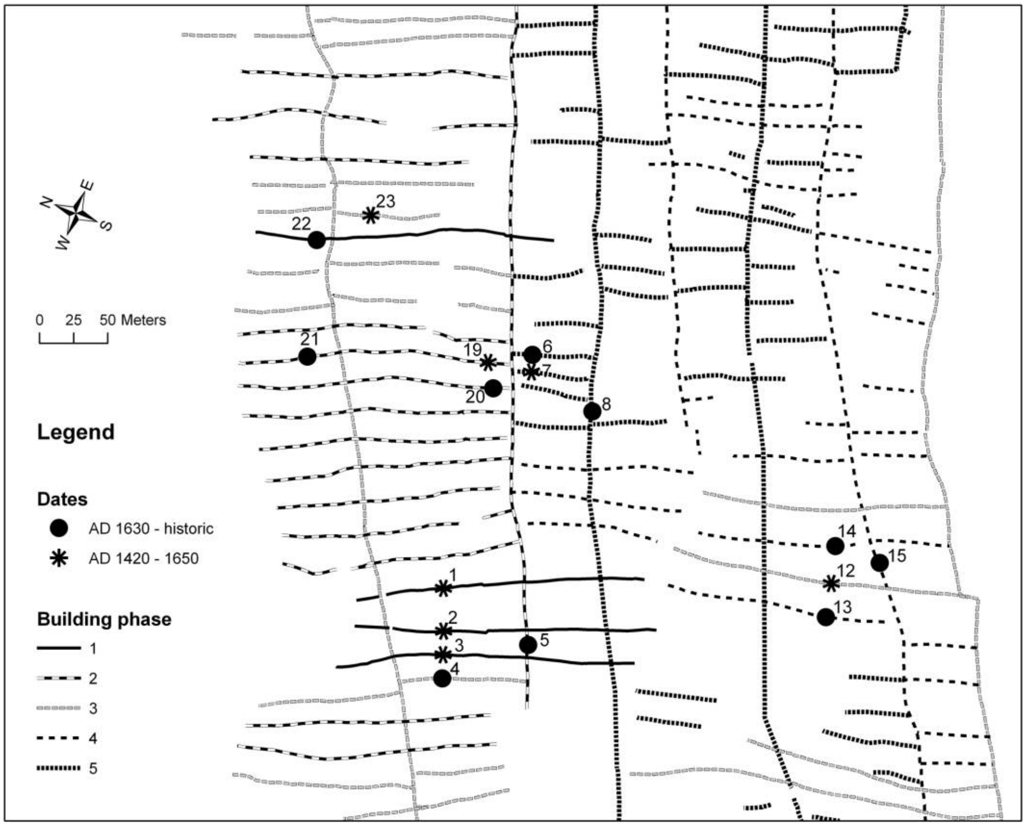

Figure 7. Agricultural walls and trails in a portion of the detailed study area, assigned to building phases, with numbered labels referring to associated Kohala radiocarbon samples.

southern portions of the LKFS being much farther inland (ca. 6.5 km) than the north, where the field system extends down to the coast.

The evidence we have presented suggests that people were gardening in the southern portion of the uplands of leeward Kohala as early as AD 1290 to 1410. This activity was probably associated with winter or rainy season slash-and-burn horticulture. The first phase of landesque capital improvements, that is, the construction of walls and trails, probably occurred sometime within the range of AD 1410 to 1630. The relative chronology of territorial units would suggest that some territory boundaries, bracketing larger geographic areas, were in place before the construction of the initial set of agricultural walls, but it is unclear how much earlier. Most wall and trail construction in this portion of the LKFS associated with both agricultural expansion and intensification probably occurred after AD 1650. The relative chronology of agricultural development identified at least four phases of construction after this time. There is no evidence of residential occupation before AD 1640, although our sample size is very small. It is tempting to suggest that ca. AD 1650 marks the point when people shifted from seasonal to permanent occupation of the area, but there is limited evidence to confirm this hypothesis.

The rapid agricultural developments after AD 1650 are marked by depletion of soil nutrients, probably the result of decreased fallow periods and the removal and consumption of these food products out of the upland agricultural zone and possibly outside of the associated coastal settlements. Within a more variable rainfall regime and as the productive potential of the soils decreased, individuals intensified agricultural effort by constructing increasing numbers of field border walls to demarcate territories and to protect crops from damaging winds. The demographic data are only tentative, but they do indicate that this increased intensification was not matched by an equivalent increase in population growth, suggesting that the ratio of agricultural surplus to domestic consumption increased during the later phases of the precontact era and food was used for other purposes (i.e., to support pig husbandry) or was consumed elsewhere. It is during this period of rapid development that smaller territorial units are defined and temples are constructed in these units to mark their boundaries and centers. The construction of monumental architecture and the definition of smaller land units would have facilitated managerial activities and probably reflected increased levels of social hierarchy.

Other marginal dryland regions of Hawai‘i Island were also developed relatively late in time. The late developments in Waimea appear to be the result of its inland location, some 10 km from the coast. This area is characterized by an adequate rainfall regime and fertile but easily depleted soils (see Erkelens 1993). Traditional dryland farming in this area would have incurred substantial costs in transporting crops from the field system to the coast. Evidence suggests that the area was occupied on a permanent basis only from ca. AD 1600 onward (Burtchard and Tomonari-Tuggle 2004) but remained in use through the historic period as sections were converted to irrigation from the Kawaihae Uka stream.

Kahikinui on Maui was also a relatively marginal area but for different reasons. While the productive area is within 5 km of the coast and the soils are relatively fertile (Kirch et al. 2004, 2005), rainfall is apparently close to the lower limits for sweet potato production. Kirch and his colleagues (Kirch 2004; Kirch et al. 2004, 2005; Coil and Kirch 2005) suggest that people first settled the area and were engaged in horticultural activities by the fifteenth century AD, but the area was not intensively used until the late sixteenth to early seventeenth centuries. Kirch and Sharp (2005) correlate this occupation to the construction of temples in the area during a relatively short 30–60-year period (AD 1565–1638) that marked territorial expansion under the reign of the chief Kamalalawalu. Kolb (2006) has recently questioned the dating of Maui temples, suggesting that some were constructed significantly earlier than the mid-sixteenth century. Kolb (2006, 663) concedes, however, that the *use* of the temples around AD 1600 based on the thorium-230 coral dates was "linked to rapid settlement expansion in Kahikinui at this time." This period marks the first time that large populations lived in the area, constructed a series of temples, and engaged in intensive agricultural activities. While there is little archaeological evidence of infrastructural improvements, agricultural activities focused on the intensive use of pockets of nutrient-rich soils (Kirch et al. 2004, 2005). This settlement and intensification were thus primarily spurred by sociopolitical demands originating from outside of Kahikinui and the relocation of populations into the area, as opposed to slow population growth within Kahikinui.

Developments in Kalaupapa, on the island of Moloka'i, followed a somewhat similar trajectory to those in Kahikinui. People had settled the northern wet valleys near the Kaluapapa peninsula by ca. AD 1100–1200 (McCoy 2007, 2008; McElroy 2007; also see Kirch and McCoy 2007), but the peninsula itself was devoid of permanent occupation until much later. While the peninsula has good dryland agricultural potential, its relative isolation, both in terms of its location on the island of Moloka'i itself and the wider political battles that were raging on the larger islands of Maui and Hawai'i Island, led to the late settlement of the area. The development involved the rapid construction of a series of agricultural rock walls that created a highly intensified system of agricultural production. This settlement was probably the result of the local movement of people from the nearby wet valleys out onto the peninsula. Thus, in Kalaupapa as in Kahihinui, populations were relocating into the more marginal areas as opposed to the steady growth of populations within those areas.

Agricultural production in many leeward areas was highly intensified by the late prehistoric period. In part, this was due to population increases over the preceding centuries. Probably more significant, however, was the desire to produce surpluses to fund far-reaching sociopolitical activities, such as warfare and constructing monumental architecture. Kirch (1994) has noted that leeward communities reached the inflection point of intensification production curves sooner than windward communities, and chiefs from this area often engaged in conquest warfare to gain access to resource surpluses. Within leeward areas, however, there were two main pathways for obtaining surpluses. The first involved the development and intensification of tracts of land over extended periods of time. This was done in better-situated leeward areas, such as the core of the Kona field system and the northern portions of the LKFS. In contrast, the second strategy involved rapidly developing more marginal areas by redeploying populations from core areas into more peripheral leeward areas. This seems to have been the case in Kahikinui, Kalaupapa, Waimea, and the southern LKFS. Within some of these more marginal areas, energy was invested in constructing agricultural infrastructure such as rock walls and earth embankments, whereas in other areas, energy was expended on alternative activities, presumably mulching and other gardening practices directed toward increasing the crop cycle. The decision to construct infrastructural improvements was made in part in response to local environmental and topographic conditions, such as strong trade winds. The walls and earthen embankments provided physical protection for the crops and altered evaporation regimes. They also, however, provided a means for assigning agricultural plots and monitoring and managing production within set areas of land. In intensified leeward areas without walls and earthen embankments, such as Kahikinui, this might have been achieved through monitoring production within swales defined by ridgelines and constructing an unusually high number of temples in the area (Kirch 2004).

The relatively rapid development of the more marginal leeward areas during the mid-seventeenth century might have been influenced by environmental factors (however, see Allen 2006 and Nunn 2000, 2007 for two completely different positions on the specifics of climatic change in the Pacific), but more significantly, it was a response to higher population levels elsewhere and sociopolitical demands for surplus. The more marginal leeward areas were previously unoccupied or supported very low population levels. They thus presented one of the few opportunities for new avenues of production. While opportunities for new surpluses were great in these areas, the risks were also high. They were farther away from permanent settlements, received limited rainfall, and were probably subject to more extreme and frequent droughts than the core leeward areas. Occupation of these areas was sustainable only if populations had direct links to more optimal zones. It was not until the social networks that came with the complex chiefdoms of the later prehistoric era were in place that these more marginal areas were viable. As Ladefoged and Graves (2000) note, the social links of these chiefdoms facilitated the redistribution of resources and the temporary relocation of populations out of areas affected by periodic environmental extremes. The core Hawai'i Island dryland areas of Kona and northern Kohala, and perhaps others such as Ka'u, were probably the centers of highly competitive and integrative systems that supported large populations generating substantial surpluses.

Conclusion

Archaeologists in Hawai'i have traditionally relied solely on radiocarbon determinations to define broad timelines for agricultural developments and sociopolitical transformations. The use of relative ordering and innovative absolute dating techniques, such as using thorium-230 in Kahikinui, provides opportunities to achieve much tighter chronological control. In the southern LKFS, radiocarbon dating defined a temporal framework for developments and relative ordering techniques distinguished fine-grained temporal associations. These fine-grained relative chronologies suggest variation in leeward agricultural developments. In some areas, such as central Kona and the northern *ahupua'a* of Kohala, there was a longer, extended history of occupation and agricultural intensification. In more marginal areas, such as Kahikinui, Kalaupapa, Waimea, and the southern *ahupua'a* of Kohala, there was rapid settlement and the development of highly intensified systems. The exploitation of these new locations provided new, yet risky, areas for generating surpluses that supported efforts to integrate larger geographic areas. Documenting the variation in these leeward developmental pathways thus provides a better understanding of the timing and trajectories of sociopolitical transformations within these areas, and the aspirations of chiefs for resources from other environmental zones.

Acknowledgments

The research was funded by NSF Biocomplexity Grant BCS-0119819, NSF Agents of Change Grant HSD-0624238, the Wenner-Gren Foundation for Anthropological Research, and grants from the University of Auckland and the University of Hawai'i. We thank our colleagues on the NSF grants (Oliver Chadwick, James Coil, Julie Field, Tony Hartshorn, Sara Hotchkiss, Patrick Kirch, Charlotte Lee, Mark McCoy, Shripad Tuljapurkar, and Peter Vitousek) for their insights. Sarina Pearson, Julie Stein, Simon Holdaway, LuAnn Wandsnider, Chris Lockwood, Stephanie Jolivette, Melinda Allen, and Mara Mulrooney have greatly enhanced our research. We thank James Coil for identifying all of the charcoal samples. Permission to conduct fieldwork was provided by the State of Hawai'i, Division of Land and Natural Resources, and by Kahua, Ponoholo, and Parker ranches. This research was inspired by Peter Ladefoged, who over the years often remarked that we should just get some radiocarbon dates and sort things out.

William S. Ayres
Anthropology Department, University of Oregon, Eugene, Oregon 97403, U.S.A. (wsayres@oregon.uoregon.edu).

Ladefoged and Graves have conducted an extended study of late prehistoric–early historic agricultural expansion in Kohala, Hawai'i Island. Their new analysis, based on additional radiocarbon readings, more clearly differentiates two "pathways" of transformation for Kohala dryland cultivation. The first is an expansion and subsequent intensification (meaning more investment per land unit) in prime dryland agricultural land, and the second is a later phase of rapid extensification into marginal areas, with associated higher costs and risks. This second pathway is significant because it reflects what I would refer to as "social" production, that is, increasing surplus demands of chiefs controlling regional entities. Comparisons with four other relatively well-dated Hawai'ian dryland field systems help assess how each system may reflect differential responses to population growth, chiefly resource expansion, or a combination of the two.

While it is important to recognize these distinct processes, it is questionable whether it is useful or accurate to call these separate "pathways," in part because the authors conclude that the second one represents a continuation of the first and they link it to prior population increases. Thus, the relationship between "earlier" population growth and subsequent expansion processes of the second pathway is not entirely clear. At the same time, it is critical to establish, if it can be substantiated, that the late-period expansion of dryland fields was not just a response to simple population growth. The authors note that demographic data are "only tentative." This is a critical point because such agricultural growth is a significant pattern recognizable in many Pacific Islands, usually with differing cultigen-field system correlates, with and without substantial chiefly escalation. While improvement and expansion of wetland root crop cultivation is often linked to political ascendancy among Hawai'ian chiefs, this kind of intensification was not possible in many areas of the island chain (or in many other Polynesian islands), and so dryland alternatives were included within a broader response to needs for increased production in this region of Hawai'i.

The ability to track field system expansion through documenting wall and trail elaboration is a remarkable aspect of the Hawai'ian field systems, perhaps especially in Kohala because of the preservation of stone and earthen walls and trails. As the authors indicated, it is necessary to distinguish agricultural expansion into new areas at various levels of intensity from diachronic intensification through energy expenditure within a fixed plot of land. This remains an issue in the Kohala analysis; however, the authors are to be commended for their efforts to reconcile contradictions between complex sequences based on field wall construction or remodeling and radiocarbon readings (see fig. 6). Not unexpectedly, working with the limitations of 2-sigma radiocarbon age sampling to make the essential fine chronological distinctions within such a short time frame—roughly 300 years—is difficult. Still, if the overall sequence of phases reflects building episodes primarily in the seventeenth century, this supports their argument.

Elsewhere in Polynesia, the results of similar dryland intensification and extensification processes have been observed, but they are not at such a large scale or as well documented as those in Hawai'i. On Rapa Nui, in particular (see Stevenson et al. 1999), the focus on sweet potato, and probably taro and yam, cultivation in an elevation zone of 150–250 m may be similar in zonal relationships to the Kohala field system on Hawai'i. However, in the Rapa Nui case, there are fewer indications that political aggrandizement was a critical factor for intensification or field expansion. Given the very limited land area of Rapa Nui (where the population density was probably twice what it was for the Hawai'ian chain), the additional factor was not required for extensified and intensified dryland production to develop.

That the sequenced changes described here reflect a requirement for expanding chiefly power as well as a response to increased population seems to be a well-founded conclusion, and the highly centralized political structures existing historically in Hawai'i, ones of state scale, serve to reinforce this interpretation. The ability to use food production intensification as another archaeological indicator of increasing political complexity, in this case a pattern of agricultural intensification and extensification, provides an important tool—along with ritual architecture, development of centers, and other means of marking status in prehistory—to trace the evolution of Hawai'ian chiefdoms. Ladefoged, Graves, and their coworkers have clarified the underpinnings of an important Polynesian subsistence transformation developed often in the face of limited (usable) land and increasing population. The Kohala data represent one of the best Polynesian cases—and perhaps the major one in terms of dryland expansion and intensification—in which to monitor these changes. Our understanding of the variable patterns of dryland production for the Hawai'ian chain has been greatly improved by the work at Kohala.

Ian Barber
Department of Anthropology, University of Otago,
Dunedin, New Zealand (ian.barber@stonebow.otago.ac.nz).

In this paper, Ladefoged and Graves tackle the universal archaeological problem of reading temporal change from the complex tapestry of a cultural landscape. The problem is heightened for agricultural lands in Polynesia, where the cumulative effects of intensive land use and the addition of mulching and/or fertilizing materials can mask or even mimic earlier cultivation. The addition and mixing of anthropic soil components also limits the fine-grained contribution of microbotanical identifications and radiocarbon charcoal dates, even where inbuilt age considerations can be eliminated for dated plants. Isolated radiocarbon samples capped by or within agricultural and associated structures may be ambiguous as well (e.g., in *heiau* associated with the leeward Kohala field system [LKFS] as noted in Mulrooney and Ladefoged 2005, 48, or from features below and cut into the kuaiwi of the Kona field system in Allen 2004, 209, 210).

In this context, the study of the few relatively intact field systems left in Polynesia that preserve material and infrastructure evidence of change is of considerable importance. Recently Kirch (2006, 201) has proposed that the LKFS is "far and away the best documented" Polynesian landscape where cropping cycle intensification has left permanent remains. However, this field interpretation has been challenged. Leach (1999, 319–20, 332–33) is skeptical that dry networks with marked alignment variation similar to the leeward LKFS are examples of an intensification process. Instead, Leach (1999, 320) suggests, "major external boundaries and internal subdivisions may be marked off at the time of clearance."

In my view, Ladefoged and Graves make a compelling case for relative network change over time in LKFS alignment and subdivision variation. Kirch (1984, 190–92; 1994, 251–68) and subsequently Ladefoged and Graves relate this evidence to the sociopolitical developments interpreted from oral and early documentary records that link Hawai'ian chiefly elites, tribute, and ritual. The Ladefoged and Graves paper, with its emphasis on radiocarbon ages, seeks to ground this argument in an absolute chronology consistent with (and to an extent, drawing on) the relative dating methods applied previously to the LKFS. It is a valuable contribution to the archaeological understanding of temporality in extensive leeward agricultural systems.

Ladefoged and Graves report radiocarbon-dated plant samples selected for short life wherever possible below agricultural walls and rock and earth trails. These are not direct dates on the agricultural features, of course, and the authors offer reasonable hypotheses as to their meaning and association. The problem here is that charcoal can survive and recirculate for considerable time in anthropic soils. Consequently, dated charcoal generally provides a terminus post quem for cultivation events, rather than evidence of a direct age.

This problem of dating association is heightened in the interpretation of cropping cycle time depth and duration at southern LKFS. Three of four early dates are on potentially old "dicot wood." The sole identified short-lived plant date is either sweet potato or a native Ipomoea from an A/B horizon interface below a surface agricultural wall (Ladefoged et al. 2005). This is potentially a very significant result. However, further dates and botanical confirmation are required to determine whether the small fragments of this sample are pre-AD 1400 sweet potato. The authors are on firmer ground with the greater number and variety of calibrated dates from short-lived species that cluster between about AD 1400 and AD 1700 from agricultural and residential contexts. The third group of dates is subject to the pronounced wiggle of the post-AD 1600 terrestrial calibration curve, with 2-sigma calibrations that span the centuries between the late precontact and historic periods. The association of these late absolute dates with (relatively) late agricultural walls is impressive. The measurement of absolute time between these age clusters and associated network developments is less certain. Statistical analysis of the 33 southern LKFS radiocarbon determinations may help to clarify this uncertainty.

The authors suggest also that the southern LKFS pathway and structures represent "a substantially later development" than northern LKFS. However, in figure 2, the greater distributions of 13 of the 21 calibrated radiocarbon ages from the central to northern portion fall variously between the decades before, around, or after AD 1500 and AD 1800–1900, while the distributions of five other dates begin just before or around AD 1700. Only one of these 21 dates is clearly early (about AD 1300–1400). These results appear to correspond broadly with the distribution of the southern LKFS dates. It is worth noting also that Rosendahl (as cited in Ladefoged and Graves 2000, 430) suggests that "bounded fields" at Kohala were not constructed before the sixteenth century. I am interested to know whether the authors consider that it might be possible to explain the entire structural LKFS network as a rapid, perhaps punctuated, late-sequence development that followed (rather than preceded) the emergence of a leeward chiefly elite. In particular, I wonder whether the long, linking boundaries and early downslope boundaries anticipated some level of subdivision from the time of first construction.

Tim Bayliss-Smith
Department of Geography, University of Cambridge, Downing Place, Cambridge CB2 3EN, UK (tim.bayliss-smith@geog.cam.ac.uk).

The paper advances our understanding of Polynesian chiefdoms by suggesting that the material basis for their existence involved two distinct phases of development. First was a long-term intensification of production from the better land, at a time when regional integration was relatively weak. The second phase was initiated after chiefdoms became more powerful, populations more numerous and demands for surplus production more strident. It saw opportunistic expansion to marginal areas where an already intensive technology was applied to areas previously used, if at all, at low levels of agricultural intensity.

Landesque capital was generated initially for sweet potato cultivation through a gradual and incremental process, whereas in the second phase, outlying areas were reclaimed rapidly using already intensive techniques. The latter process makes little sense unless we recognize the sociopolitical connections between outlying areas and existing centers. The paper presents radiocarbon dates that flesh out the chronology of these changes in Hawai'i. Southern Kohala emerges as an area of dramatic transformation in the late period after about 1600, following the growth of chiefdoms in the more favored northern area beginning ca. AD 1290–1410.

The meticulous mapping and dating of walls and trails by using charcoal in underlying soils provide the main basis for this reconstruction. Relative chronologies for these features were inferred by the authors from their network topology, an approach pioneered by Fleming (1988) for boundary walls around Neolithic fields in Dartmoor, southwest England. For ditch networks mapped in the New Guinea highlands, similar approaches to relative chronology have been used (e.g., Ballard 2001), sometimes augmented with archaeological evidence for recutting that can be detected in channel cross sections (e.g., Bayliss-Smith and Golson 1999; Bayliss-Smith et al. 2005). However, opportunities to combine relative chronology with absolute dating are seldom available, and the Ladefoged and Graves paper achieves a breakthrough in this respect.

The inferences made about the social processes that underlie the agricultural changes in Kohala are, inevitably, rather more speculative. To reconstruct Hawai'ian chiefdoms, we need more data than walls, trails, and charcoal can provide. We also need to think beyond the evolutionary models of agriculture that tend to dominate our mental maps of the past if we are not to be imprisoned by the existing paradigm. All too often, archaeologists choose the types of data ("observations") that will enable them to test their current understandings ("theories"). As Charles Darwin remarked nearly 150 years ago, "without the making of theories there would be no observation," an insight as relevant to the origins of intensive agriculture as to the origin of species (Bayliss-Smith 2007).

The "theories" that underlie this paper on the Kohala field system are not made explicit in this article but are basically ideas from political economy adapted to prehistoric agriculture by Brookfield (1972, 1984), Farrington (1985), and others. A version of the theory of landesque capital formation, first sketched by Blaikie and Brookfield (1987) and later applied to Polynesia by Kirch (1994), is particularly important to the explanations that the paper develops. Ladefoged and Graves see the archaeological evidence of "rock walls, earth embankments, terraces, enclosures, and trails" as constituting improvements, alongside the more invisible practices that they invoke, investments to enhance the cropping cycle through "labour expenditure on mulching, weeding and other gardening activities."

These forms of intensification are all consistent with a theory of landesque capital that emphasizes increased productivity, whether under pressure of population or demand for surplus production exerted by a chiefly elite. Yet Blaikie and Brookfield (1987, 9) indicated that their own ethnographic data would not support such a straightforward explanation. Put simply, they argue that scale of investment in landesque capital very often exceeds what land managers might expect to get back in enhanced yield over a reasonable time period, when costs and benefits are both measured. Instead of emphasizing improved output, these authors emphasize the benefits of reduced risk of harvest failure on marginal land. In other words, drainage, irrigation, walls, and terraces might constitute a kind of insurance policy rather than a bid for surplus production. It may not be so surprising to see evidence of such investments in the period after 1600, when Little Ice Age droughts became more a more severe problem.

To strengthen their case, Ladefoged and Graves need to establish by experimental studies the scale of "improvement" that the archaeological evidence implies and the cost it represented to those engaged in the work. They might also consider other sociopolitical processes beyond surplus extraction within chiefdoms. If experiments show that building more walls is not crucially important for protecting crops against damaging winds and evapotranspiration, is it possible they are mainly expressions of property relations? Visible boundaries provide what Bourdieu (1977) termed cultural capital, and they could be evidence of the move away from cooperative labor by large extended families toward agriculture organized around more kin-restricted household groups. New theories will be needed if we are to generate new observations, and thus provide more rounded explanations for the intriguing new landscapes of Hawai'ian agriculture than this paper provides.

James M. Bayman
Department of Anthropology, 2424 Maile Way, Saunders Hall 346, University of Hawai'i at Manoa, Honolulu, Hawai'i 96822-2223, U.S.A (jbayman@hawaii.edu).

This pathbreaking analysis of Hawai'ian agricultural development in marginal dryland fields by Ladefoged and Graves establishes a new gold standard in Pacific island archaeology. The authors have succeeded admirably in their dogged effort over the past two decades to track the geographic organization and longitudinal growth of one of the largest dryland agricultural systems (i.e., leeward Kohala field system [LKFS]) in the Hawai'ian archipelago. Moreover, they have done so with an unprecedented degree of resolution and chronological precision by marshaling a suite of both relative and chronometric age estimations. In so doing, the authors offer historically minded scholars in Hawai'i (and beyond) an opportunity to evaluate rival models for identifying and explaining the social and economic underpinnings of agricultural intensification and expansion in emergent state societies.

Ladefoged and Graves's study begs a number of fascinating questions that they will surely consider in their ongoing research. Their observation that agricultural expansion and intensification in marginal settings was accompanied by an explosive construction of religious temples (*heiau*) will be enriched by their judicious consultation of the chiefly genealogies and oral traditions (*mo'olelo*) that were recorded in the early nineteenth century by indigenous Hawai'ian scholars, such as Samuel M. Kamakau, David Malo, and John Papa 'I'i. These accounts were compiled when many older Hawai'ians still remembered the traditional practices that were undertaken at religious temples across the Hawai'i landscape before the introduction of Christianity in the early 1820s. The authors are now in the enviable position of being able to integrate the archaeological record of agricultural production with their ongoing studies of temples in the LKFS area. Different kinds of religious temples in ancient Hawai'i were designed to supplicate Lono, the god of fertility and nonirrigated agriculture, and Ku, the god of war. While these and many other kinds of temples were constructed in the vicinity of the LKFS, detailed examination of their topographic locations and viewsheds and histories of construction and reconfiguration will further illuminate the ideological context and political economy of agricultural production in marginal settings. Application of thorium-230 coral dating will also enhance the authors' ability to calibrate the construction of large *luakini* "war" temples with chiefly genealogies, since their use for sacrifice was restricted to the most powerful elites (*ali'i nui*) and priests.

Careful review of chiefly genealogies and oral traditions also offers the strong possibility of implicating the names of *specific* individuals who must have instigated the rapid expansion of dryland agriculture in the LKFS and elsewhere. On Hawai'i Island, for example, oral traditions recall that a powerful chief—'Umi a Liloa—was a catalyst for the island's political unification in the late sixteenth century, when the LKFS was already underway but had not yet reached its apex of development. Oral recollections that 'Umi was something of a populist who enjoyed substantial commoner (*maka'ainana*) support underscore a central anthropological message of the Hawai'ian example: local politics loom large in the expansion and intensification of agriculture in early state societies—even in risky, marginal settings.

The authors' study offers still more insights for refining cross-cultural models of agricultural expansion and intensification in tandem with the emergence of highly stratified political systems. Study of the LKFS challenges the conventional expectation that agricultural "intensification," in the Boserupian sense of the term, is most likely to arise in resource-rich localities. The argument of Ladefoged and Graves that agricultural production in marginal settings like the LKFS was orchestrated by elites (*ali'i*) rather than by commoners (*maka'ainana*) counters the received wisdom of anthropological archaeology. In many areas of the ancient world, for example, archaeologists frequently assume that marginal agricultural localities were utilized by disenfranchised social classes.

Indeed, the fact that some of the most powerful Hawai'ian chiefs in the precontact and early postcontact periods sponsored production in agriculturally marginal areas illustrates the extraordinary agency of some individuals to overcome significant ecological and economic adversity. Although other scholars have acknowledged this pattern in early Hawai'i, Ladefoged and Graves can provide one of the most carefully documented archaeological examples of this phenomenon in Oceania.

Finally, this research program promises to further substantiate the general hypothesis that politics, rather than demographic pressure alone, largely determined expansion and intensification of agricultural production in the ancient world. That some agricultural intensification in the Hawai'ian Islands occurred *after* growth in human population had begun to wane runs counter to archaeologists' long-standing assumption that demographic pressure (and fear of a "Malthusian crash") was the ultimate cause of food production in marginal settings. Population was certainly a factor in elevating the demand for dryland agricultural products (like sweet potato) and in the organization of labor to acquire them, but in Hawai'ian society it was secondary to dynamics of individual agency, political machinations, and religious ideology.

Henri J. M. Claessen
Emeritus, Department of Anthropology, Leiden University, The Netherlands (hacla@xs4all.nl).

Ladefoged and Graves here continue their unraveling of the agricultural developments in the leeward Kohala field system (LKFS) and try to date these developments and to connect these findings with sociopolitical developments in Hawai'i. Agricultural expansion, necessitated by growing demands, can be reached either by intensification or by expansion. In the dryland agricultural regions of Hawai'i, intensification was difficult to achieve, and the best solution was expansion, which means that less fertile lands were brought under cultivation. The authors distinguish two periods of development in the exploitation of the LKFS, one earlier (beginning as early as the fourteenth century) and one later, starting after the mid-seventeenth century. The agricultural developments were necessitated, according to Ladefoged and Graves, by population increase on the one hand (cf. Kirch 1999, 328), and by "increasing surplus demands to fund chiefly ambitions involving territorial expansion" on the other. To the "chiefly ambitions" should be added changes in the religious organization, reflected in the building of more temples.

As convincing as the archeological analyses by Ladefoged and Graves are, historical and political anthropological aspects seem a bit underplayed. Some more suggestions, based on historical and/or anthropological data, might have been included. The development of the LKFS must have been a large undertaking. According to Ellis (1831, IV, 415) Kohala was one of the "permanent divisions" of Hawai'i, "governed by one or two chiefs, appointed by the king." Taking as a point of reference the complex political and religious organization of the Hawai'ian polities in the eighteenth century (Ellis 1831, IV, 411–19; Davenport 1969; Valeri 1985; Wichman 2003), it seems probable that also in the mid-seventeenth century, high-placed governmental functionaries were entrusted with the supervision of the Kohala region. In the development of the LKFS, there was no reason to take into consideration wishes or interests of the commoners; only the wishes of the sacred *ali'i nui* counted, for he was "considered the personal representative, as well as a direct descendant, of the gods on earth," and "it was natural that he owned all the land with all living things upon it" (Wichman 2003, 54; cf. Clerke 1967, 596; Davenport 1969, 4). He was assisted by the *kalai moku*, a sort of prime minister, and a host of lower-ranking *ali'i*. The *kalai moku* divided the island into districts, the *moku*, which were administered by lower-ranking *ali'i* (Ellis 1831, IV, 415–16; Sahlins 1992, 17–20). It thus seems probable that the development of the LKFS was ordered by the then–*kalai moku* and that some lower-ranking *ali'i* were entrusted with the supervision of the work. It might even be possible to identify the then-ruling *ali'i nui* by combining ethnographical and archaeological data.

The main occupation of the commoners seems to have been working for the elite. They had no rights to land; they just worked it. In return they were entitled to a part of the produce. The remainder was collected as taxes. Apart from the levies of food and goods, commoners also had to contribute labor for the chiefs, the priests, or the temples (Handy 1965, 38; Malo 1971, 63–7,143; Kolb 1994*a*). Ellis (1831, IV, 416) even suggests that there was no standing rule for the amount of rent and taxes, which were "regulated entirely by the caprices or necessities of their rulers." In view of these heavy obligations, the distance from the fields to the coast obviously played a role, as Ladefoged and Graves state, for all goods had to be transported by human carriers, whose productivity diminishes with growing distance (Drennan 1984).

This study is a valuable addition to the growing series of articles by Ladefoged and his collaborators on the analysis of the LKFS, and it provides a more complete insight into the development of the Hawai'ian economy, political economy, and sociopolitical organization in precolonial times.

Patrick V. Kirch
Department of Anthropology, University of California, 232 Kroeber Hall, Berkeley, CA 94720, U.S.A. (kirch@berkeley.edu).

In 1984 I presented a model for the intensification of dryland agricultural systems in the leeward region of Hawai'i Island that drew on theoretical concepts of the "production function." In this model, increased labor inputs initially produce high rates of surplus extraction but are followed by declining rates of yield relative to inputs up to the margin. Drawing on pioneering archaeological studies of the leeward Kohala field system (LKFS), I argued that a sequence of agricultural expansion and intensification spanning four centuries, from about AD 1400 until the moment of European contact could be discerned. This sequence progressed from an initial phase of shifting cultivation with long fallow periods through several phases of increasing formalization of a field system (marked by a reticulate grid of field boundary walls and trails) to the terminal phase, marked by short fallow periods or even continuous crop rotation. In many respects, the leeward Hawai'i sequence was seen to follow a classic progression of intensification as outlined by Ester Boserup (1965).

A decade later, in my comparative study of *The Wet and the Dry* (Kirch 1994), I pointed out that dryland and wetland (irrigated) agroecosystems were unevenly distributed over the Hawai'ian archipelago. The geologically older islands of Kaua'i and O'ahu were dominated by high-surplus-producing irrigation systems, whereas the larger but younger islands of Maui and Hawai'i had only limited areas suitable for irrigation but vast dryland field systems. In opposition to Wittfogel's classic theory of irrigation as underpinning complex sociopolitical structures, the Hawai'ian and similar Polynesian cases (Mangaia, Futuna) suggested that the most dynamic (and territorially aggressive) polities were associated with dryland agroecosystems. I argued that this was due to the greater labor demands required to intensify the dryland systems, to increased vulnerability to drought and cyclones, and ultimately, to their limits to produce surplus that could be extracted by chiefly elites. Unlike the irrigation systems, which tended to a Geertzian mode of "involution" (Geertz 1963), the dryland systems could be pushed only so far. Tellingly, the most aggressive war leaders of contact-era Hawai'i (Kamehameha of Hawai'i and Kahekili of Maui) presided over polities largely supported by intensified dryland field systems.

Since I set out these models of Polynesian agricultural intensification, our archaeological database on the precontact Hawai'ian agricultural systems has increased dramatically. However, in spite of being well studied spatially, thanks to ongoing research by Graves, Ladefoged, and their students (e.g., Ladefoged et al. 1996, 2003), the LKFS remained enigmatic in terms of the chronology of intensification. Spatial data had revealed a *relative* sequence of continued segmentation of territories and of delineation of increasingly smaller fields, but the *absolute* time over which this occurred remained unresolved. This lacuna in our understanding of the process of intensification in the LKFS has now been filled by the research reported by Ladefoged and Graves, and the implications of their results go beyond the historical particulars of the LKFS itself.

The new sample of 33 accelerator mass spectrometry radiocarbon dates from the LKFS offers a precise chronology for agricultural development, given the statistical limits on radiocarbon dates within the last few hundred years. These data show that the LKFS went through an initial phase of expansion and intensification beginning as early as AD 1300 but more likely picking up in the fifteenth century. Relatively few formal field boundaries are associated with this earlier phase. A second phase then begins sometime after AD 1600, marked by the dramatic pattern of reticulate field walls and decreasing plot sizes previously shown by spatial analysis. In short, the LKFS progressed through two phases of agricultural intensification; the second phase pushed the system to its limits in terms of areal extent and also in terms of its ability to yield surpluses that could be extracted for political ends. It is noteworthy that this final phase was associated with measurable declines in soil fertility, based on the nutrient analysis of LKFS soils by Meyer et al. (2007).

The broader significance of these new chronological data are apparent when they are seen in the context of the emerging picture of transformations in Hawai'ian demography, monumental architecture, and political history. The emerging picture of Hawai'ian paleodemography indicates that population grew exponentially from the time of first settlement (probably around AD 800–1000) until about AD 1550 but then rapidly stabilized, with high density but little or no growth in the seventeenth and eighteenth centuries. This suggests that a density-dependent condition had emerged in late prehistory, corresponding to the later phase of intensification outlined by Ladefoged and Graves. Moreover, it was during this period that the islands of Hawai'i and Maui were politically consolidated, with increasing interisland wars of territorial conquest.

Oceanic islands, and Hawai'i in particular, offer "model systems" for understanding human ecodynamics, including processes critical to sequences of agricultural intensification (Vitousek 1995, 2004; Kirch 2007). The LKFS offers a window on the dynamically coupled interactions between human populations, their social and political structures, and the environmental variables (soils, nutrient availability, rainfall) upon which intensive agriculture depended. Understanding the course of agricultural intensification in the LKFS over a four-century-long trajectory offers insights that are likely to applicable to nonindustrialized agroecosystems everywhere, both in the past and in our current world.

Timothy A. Kohler
Department of Anthropology, Washington State University, Pullman, WA 99164-4910, U.S.A. (tako@wsu.edu).

As an archaeologist who has (unfortunately!) never set foot in Polynesia, I leave discussion of cultural-historical and ecological details to others and here remark on a few more general issues. As an aside, it is striking to see the general resemblance between the logics used to determine sequences of pueblo construction in the United States Southwest (including but not limited to bonding and abutting sequences in walls; e.g., Crown 1991) and those developed here for dryland field systems. Is it a coincidence that both authors have field experience in the Southwest?

Of course, houses for people and "houses" for plants are different in scale and design requirements. For example, the first excludes the very precipitation and (most of the) sunlight that plants require. But the analogy has some interesting consequences, since it reminds us that both are designed structures and thus provide information on technical competence, backward-looking social traditions, and forward-looking attempts to satisfy physical requirements and social goals. Trade-offs are imposed by living in a community with others who have sometimes-differing goals or power and by sharing the landscape with other communities.

For this same area, Ladefoged et al. (2008) ingeniously play off the modeled population size, modeled production, and the inferred history of territorial subdivision (from nine territories in the thirteenth/fourteenth centuries to as many as 35 in the mid-nineteenth century) to show that the partitioning of land into 14 territories should have provided the overall highest individual life expectancy at birth. Under the assumption that production was *not* shared among territories, the model suggests that division into more than 14 territories probably would have led to lower life expectancy because of greater vulnerability to drought. Smaller territories, however, provided more opportunities for surplus in good years, leading Ladefoged and colleagues to suggest that smaller, later territorial distributions provided opportunities for elites to redistribute resources or allow clients-in-the-making from poorer territories to access better ones. They believe these processes to have been operating after the seventeenth century.

Ladefoged and Graves's current contribution fits comfortably within this scenario, although it develops a somewhat different point: increasingly marginal areas were brought into production after about 1650. Occupation in these areas, the authors suggest, would not have been sustainable in the absence of "direct links to optimal zones." The findings of these two contributions may be combined to show that the need or desire to expand agricultural production apparently proceeded along several avenues, including subdivision of existing territories, colonization of new territories in less productive locations, and more building of walls for providing protection from wind and/or management and control of ownership.

I have only one criticism of this article and also one request for consideration of another dimension of social practice. The criticism is the authors' vague and inconsistent use of the extremely tricky concept of optimality. Claims for optimality, to be testable and meaningful, must at a minimum specify five parameters: optimal for whom (e.g., everyone? an elite sector?), with respect to what (e.g., rate maximizing or risk minimizing?), using what currency (calories?), assessed at what level of social granularity (individual? household? island?), and assessed at what time scale (month? year? phase of many decades?). I can only guess as to how one should interpret the statement that "two general developmental pathways for agriculture are identified, one based on optimality and/or effort and a second focused on areas of greater risk." This is even more confusing because at some points in the article, "optimal" is used to refer not to a pattern of human behavior but to a pattern of high expected agricultural yield. Juxtaposition of this contribution with Ladefoged et al. (2008) also raises the possibility that optimal might sometimes be supposed to refer to that distribution of territories and fields that maximized life expectancy.

It would also have been interesting to know whether the authors believe that their findings have any bearing on Kolb and Snead's (1997) somewhat more internally differentiated model for field types (and consequently labor types). For example, Kolb believes that (on Maui) it is possible to identify "festive" projects resulting in "large suprafamily agricultural fields and intracommunity boundary walls" (Kolb and Snead 1997, 616) that can be contrasted with smaller, family-level agricultural sites. Does this taxonomy apply to the walls analyzed here, and if so, how does construction at these two different levels sort out by the periodization supplied?

Perhaps of even more interest is the probably connected question of the nature of land tenure through this sequence. Is there reason to consider the community to have been, throughout the sequence, the unit of tenure, as suggested by Kolb and Snead (1997, 615)? Or could a case be made that community-level tenure was a relatively late development, superceding tenure by more local corporate groups (Hommon 1986)? Or perhaps the concept of overlapping stewardship (Gibson 2008, 46), in which lands are owned by a chieftain, is applicable, at least after 1650? Or does the untidy variability in the development of dryland farming areas documented here preclude any of these neat schemes? Whatever the case, this seems to me to be an area of inquiry in which the rich local ethnohistoric record can be fruitfully combined with the laudable high-resolution field-system chronology achieved here.

Mark D. McCoy
Department of Anthropology, San José State University,
One Washington Square, San José, CA 95192-0113, U.S.A.
(mdmccoy@email.sjsu.edu).

Ladefoged and Graves present a remarkably precise reconstruction of a range of past practices that accounts for social and environmental variables in a nondeterministic fashion and convincingly identifies a significant point in social evolution represented by a broad-based shift to more risky, surplus-oriented agricultural production. For these reasons, and others addressed below, this work holds value for the study of hierarchical, complex societies worldwide. However, in light of these results, there are several factors that deserve more attention, including the role of ritualization in shaping social landscapes, the use of oral traditions, and the classification of pre-European-contact Hawai‘ian polities as complex chiefdoms or archaic states.

First, the authors' combination of relative and absolute dating to create regional settlement, agricultural development, and ritual site construction histories stands as one of the most complete in Polynesia. In my research in Kalaupapa, Moloka'i Island—one of the marginal field systems discussed—I have found an identical pattern in terms agriculture and settlement (McCoy 2005*a*, 2007, 2008; McCoy and Hartshorn 2007) but a slightly different pattern from Kohala in the construction of ritual sites (McCoy 2006, n.d.). Based on a series of 18 AMS dates from 13 sites, the first signs of ritual within the fields date to after 1650 AD, concurrent with the deployment of settlement on to this marginal landscape. Ritual sites immediately outside the fields, however, yield dates as early as 1440 AD. This represents a shift in how certain locations were ritualized, starting with an early establishing phase and moving to a more geographically expansive landscape phase. This and other changes in ritual site construction appear to be linked with the region's larger political history (McCoy n.d.).

To their credit, Ladefoged and Graves present the first direct absolute date on a ritual site located within any of the three major field systems of Hawai'i Island. However, the role of ritual in the development of these social landscapes remains ambiguous, poorly known, or simply unknown. For example, while it is consistent with relative chronologies of architecture and territorial boundaries to say that southern leeward Kohala field system (LKFS) temples (*heiau*) were constructed as early as 1400 AD, it would be equally plausible to suppose that, like Kalaupapa, these were built later in time, concurrent with the shift in settlement documented here.

Second, by addressing social integration, the authors have once again demonstrated that island archaeology is not limited by the influence of biogeography or a traditional focus on isolation and environmental variables (Fitzpatrick et al. 2007; but see Rainbird 1999, 2007; Boomert and Bright 2007). Here, the political economy, warfare, and population growth are highlighted as keys to an observed shift to risky agricultural practices in environmentally marginal areas. Thus, the authors avoid making an unwarranted appeal to environmental determinism. This is a lesson that should be learned by others who would posit climate change as a causal factor without rigorously interrogating reasonable alternatives.

The focus here on social factors is thanks in part to the authors' careful incorporation of ethnohistoric evidence of increasingly intensive warfare. However, one cannot help but wonder if a closer linkage with oral traditions is possible. For example, in Kalaupapa, the establishment and development of the field system appears to have followed the fate of a district-scale polity and subsequent political domination from outside. Closer to Kohala, Allen (2004, 217) makes reference to the possible influence of the paramount chief 'Umi on agricultural practices in the Kona Field System. Explicitly relevant to this study area, it was Kohala's own Kamehameha the Great who unified the archipelago under a single kingdom. What role did he play in the history of the LKFS?

Third, while the authors have systematically identified a point in time when people's choices regarding production showed greater influence of nonmaterial social factors, like many of us, they have chosen to sidestep a debate of critical importance. Here I am referring to the current divide between those who would classify Hawai'ian polities encountered at the time of European contact as complex chiefdoms (Yoffee 2005) and those who would characterize late prehistoric Hawai'i as an archipelago of competing archaic states (see summary in Kirch 2005). While similar debates in archaeology have not proven especially useful in moving the field forward and in some ways hold us back, this study focuses on a moment in prehistory when classification matters (Pauketat 2007). The issue at hand is this—are we to interpret the shift in practices documented here as having been accompanied by a quantitative societal change (i.e., chiefdoms growing larger), a qualitative societal change (i.e., the establishment of state society), or some other type of societal change?

Karl S. Zimmerer
Department of Geography, Pennsylvania State University, University Park, PA 16802, U.S.A. (ksz2@psu.edu).

"Variable development" in the article's title refers to the temporal and spatial complexity of agricultural change in the leeward Kohala field system (LKFS) on leeward Hawai'i. Temporal complexity is demonstrated in the fine-grain chronology. Spatial complexity is shown in detailed mapping of agricultural areas including field plots. Ladefoged and Graves produce a portrait of the development of agricultural areas that was differentiated both temporally and spatially within the LKFS. Their findings distinguish the significant later development of the southern LKFS. Located at the geographic margins, it was developed as an intensive producer of political economic surplus.

The findings by Ladefoged and Graves of variable development at the LKFS site represent the sort of substantial advance that enables the rethinking of agricultural intensification and intensive land use, which are the focus of my comment. Though not foremost, these timeworn yet resilient ideas are used in the article to make crucial connections of LKFS's fine-grain temporal and spatial complexity to the site-specific mix of environmental factors and social agency producing agricultural development and agrarian change. Both ideas represent a powerful current. Intensification is a remarkably versatile concept underpinning a continuing collection of major accounts of agricultural and human-environmental change (Turner et al. 1993; Zaal and Oostendorp 2002; Matson and Vitousek 2006). It refers to the diachronic, directional change and interactions of measured state variables and, also, to the situating of the social-environmental interactions of agricultural change processes (Brookfield 1984; Morrison 1996; Marcus and Stanish 2006). Intensive agriculture, which serves as a descriptive matrix rather than a specific concept, provides capacious-style framing of the social-environmental (including technological) parameters of farming systems and food production (2007).

My comment explores these ideas in Ladefoged and

Graves's study of the LKFS site. I apply the perspectives of political and cultural ecology (to agricultural intensification) and agroecology (to intensive agriculture) (Blaikie and Brookfield 1987; Balée 2006; Zimmerer 2000, 2007). By framing my comment via these perspectives, I am attempting to engage constructively yet critically with their findings in the context of broad interests in agricultural development and human-environment change, not only in Hawai'i but also with specific reference to intensive agriculture and intensification in dryland farming (with emphasis on the twin points of agrospatial organization and tuber crop complexes).

The fine-grain LKFS findings detail the relative late development of intensive agriculture in its southern area. Intensification, *sensu strictu*, is supported albeit cautiously given acknowledged data constraints. But it is similarly valuable to consider the other sense of intensification. The fine-grain chronology and spatial resolution of the LKFS suggest a complex pathway to intensification that combines territoriality and incremental field-level intensification. In the LKFS this distinct combination is inferred in ruler-level territorial management (e.g., the multifield and landscape scale of walls and trails) *and* the chronological evidence of discrete field-level changes.

The LKFS intensification pathway thus seems to contrast some defining findings on dryland agricultural intensification and agrarian change. Anthropologists, geographers, and others examining territorial management and agricultural change in dryland environments have found extralocal territorial control to serve as a means of protecting access (without intensification) or alternatively have interpreted incremental field-level changes as a process of autonomous, household-level, and "bottom-up" aggregation (without higher-level territorial management; Doolittle 1984; Stone and Downum 1999). By contrast, the combination of landscape-scale territorial organization and the suggestion of field-level intensification outline the distinctness of the LKFS trajectory. Part of this distinctness would have been the rapid pace of small- and medium-scale intensification across significant areas of dryland agriculture. If so, it offers an interesting and potentially important comparison to well-documented scenarios of expansive intensification based on water control (e.g., irrigation) with generally similar social conditions yet contrasting environmental parameters.

Intensive agriculture—premised on environmental parameters and social conditions—is demonstrated through Ladefoged and Graves's fine-scale dating of the assemblage of walls, trails, field soils, and agricultural remains in conjunction with their findings on settlements and population. Their demonstration of intensive agriculture is supported also through the extensive array of related separate studies that have been completed on Hawai'i soils and geologic substrate (especially nutrients), topography and climate (especially annual rainfall and mean temperature estimates), and ethnohistory and environmental historical analyses that have been productively coordinated and integrated with archaeology. Agroecological functions of tillage figured prominently, an insight that Ladefoged and Graves make integral to their study.

But one wonders whether there is a still more distinct agroecological situating of LKFS dryland intensive agriculture than suggested. It would have involved not only the mulching, tillage, and management of soil fertility—essential ingredients to dryland intensive agriculture to be sure—but also the use and properties of the complex of tuber crops that the LKFS was designed to produce. Indeed, intensive dryland agriculture is frequently distinct where based on tuber crop complexes. For example, often it is distinctive evolutionary ecologies of these crop plants (e.g., phenology of maturation period) and adaptive management in response to moisture shortages within agricultural environments (e.g., seasonal and other scales of variation) that have enabled the expansion and/or intensification of dryland farming in marginal environments. While outside the article's immediate empirical focus, such functions would extend the suite of embedded dynamics supporting intensive dryland cultivation in Hawai'i. Such agroecological characteristics must be seen as potentially consequential given Ladefoged and Graves's extensive fine-grain findings on variable development at the LKFS site.

Reply

The development of Hawai'ian dryland agriculture was a complex process. For heuristic purposes, we divided it into two phases or "pathways." The first involved development of relatively young geologic areas close to the coast that received sufficient but not excessive rainfall. Secondary development involved expansion into more marginal areas. While we defined two phases, we recognize that development throughout leeward areas was more of a continuum, although we suspect that it was somewhat punctuated. Ayres notes that the term "pathway" might be inappropriate since the secondary development was a continuation of the first. While true that later developments in more marginal areas were linked to activities that occurred in earlier-developed windward and leeward areas, we used the term "pathway" to emphasize that distinct behavioral strategies were employed in the two contrasting leeward environments.

We monitored developments within five well-documented dryland systems and found that two of the systems (Kona and Kohala) were developed relatively early with subsequent developments of marginal regions, and three of the systems (Waimea, Kahikinui, and Kalaupapa) were developed somewhat later. For the Kohala system, Barber questions whether there were two phases of development, positing the alternative that the whole leeward Kohala field system (LKFS) was a late precontact development. He suggests that the calibrated dates from the northern and central portions of the LKFS have a similar distribution to the dates from the southern portion.

With the current data set it is impossible to be definitive, but in relation to the southern area, the dates from the northern and central areas do include a higher proportion of earlier dates to younger dates. Furthermore, a higher proportion of the earlier dates in the northern and central areas are associated with residential features than those found in the southern area, where there are currently no residential dates earlier than the mid-seventeenth century. Finally, the main development of walls and trails in the southern area is thought to have occurred after AD 1660. The data thus suggests to us that a larger proportion of the northern and central development took place before the mid-seventeenth century, whereas the majority of the development in the south took place after this time.

The use of radiocarbon dates to document changes from the fourteenth to late eighteenth century is problematic. The standard deviation ranges are large in relation to the periods to be discerned, and as noted by Kirch (2007*b*) and McFadgen et al. (1994), the wiggle of the calibration curves compels probabilities to fall into bimodal or trimodal distributions. There is also the problem noted by Barber that charcoal can survive and recirculate in agricultural deposits for an extended period, producing ambiguous associations and results. Most of our radiocarbon determinations come from underneath agricultural walls or in a few cases, trails. They date construction events associated with the field system infrastructure, not agricultural activity (which could conceivably have predated or postdated the wall in that vicinity). The radiocarbon dates are coarse compared to the relative construction sequence we have generated. Our approach was to be as conservative as possible, grouping together as contemporaneous only those walls that were dated to the earliest radiocarbon interval and which were also placed in the early construction phase of the relative chronology.

Several commentators (Bayliss-Smith, Zimmerer) expressed the desirability to know more about the function of agricultural walls and how they may or may not have enhanced production. As Bayliss-Smith notes, if the construction of walls did not enhance production, it is possible that they were just social boundaries. Informal experiments demonstrate their windbreak value, and given the recurrent high wind speeds in the uplands of Kohala, this would have protected young plants from the wind's damaging and desiccating effects. Additional information is currently unavailable, but ecologist Vitousek and colleagues have recently established experimental gardens within the LKFS to determine the agroecological characteristics of probable cultigens and the impact that the walls might have had on growing conditions. We concur with Zimmerman that this is important information, and we look forward to integrating these results to determine whether the development of adaptive management strategies and the introduction of new crops, such as sweet potato, or varieties might have provided novel opportunities for farming in large tracts of leeward Hawai'i.

The impetus for agricultural development is critical for understanding local and more regional processes. Ayres questions whether the late-period expansion was not simply the result of population growth. He notes that this might have been the case on Rapa Nui, where he proposes political aggrandizement had minimal influence on agricultural production. Yet on Rapa Nui, the construction of monumental architecture and statues would have required surplus production beyond the domestic level and certainly would have played into political aspirations. Indeed, Stevenson and colleagues (Stevenson 1997; Stevenson et al. 2007; Stevenson and Haoa 2008) suggest that surplus production was required for the construction of monumental architecture and that the agricultural upland regions were abandoned around AD 1700, when the social system underwent political restructuring. In Hawai'i, Kirch (and see Kirch 2007*b*) notes there was exponentially population growth until about AD 1550, with subsequent population stabilization into the late eighteenth century. It is during this period of stabilization that agricultural development in many leeward areas dramatically increases. The LKFS paleodemographic data are only preliminary, but because we can track both agricultural features and the number of habitation sites in the same area, we have concluded agricultural development outpaced population growth in the last phase of the chronology. We would agree with Bayman and Bayliss-Smith that this late-period development makes little sense unless we consider sociopolitical processes.

Hawai'ian chiefs were certainly influential in the development of leeward agricultural systems. However, we would not agree with Claessen that only the actions of *ali'i nui* were important and the wishes and interests of commoners (and by implication, secondary chiefs) were inconsequential. Land would have been developed and managed through a complex series of interactions, with a multitude of factions employing diverse behavioral strategies that probably varied by location and changed over time. While the relationship between chiefs and commoners could be interpreted as asymmetrical, chiefs who exploited commoners could lose political support (Cachola-Abad 2000). Zimmerer and Kohler raise several interesting points with regards to the scale of production and management of fields. Zimmerer suggests that the incremental field-level changes could have resulted from autonomous household-level aggregation. Kohler questions whether it is possible to distinguish agricultural plots associated with family groups from those associated with higher levels of bureaucracy and how these might fit into our periodization of the LKFS. On Maui, Kolb and Snead (1997, 613, 615) categorized archaeological features into "corvée projects where coordination is centrally organized and participation is enforced," "festive" constructions "organized by communities or low-level elites," and "family ects" that lacked "bureaucratic involvement." The basis for categorization was "site function, scale of construction, and relative proximity to other known sites." Kolb and Snead (1997, 616) depict a ca. 225 × 175-m agricultural enclosure with ca. 440 m of interior walls and suggest that because of its size and location, it was a "festive project." In contrast, a number of spatially discrete residential sites with small agricultural features were categorized as "family projects." The LKFS shows a different configuration, and detailed archaeological survey has recorded walls and trails forming a near-continuous network of architecture as wide as 2.4 km in a coast-inland transect; the network extends north-south for more than 5 km and, indeed, probably upwards of 12 or more kilometers. The 600 × 500-m sample area shown in figure 7 is fairly representative of the density of walls and trails found throughout the field system, and the thousands of residential and smaller agricultural features infilling these plots are not shown in the figure. The empty spaces in the figure are generally the result of historic disturbances or gulches. The ca. 30-ha. sample area contains approximately 9.68 km of agricultural walls (some of which were earthen embankments over 2 m wide and up to 50 cm high) and 4.19 km of trails. Given Kolb and Snead's criteria, the plots defined in our earliest and subsequent phases of agricultural development, and indeed the whole LKFS, must be classified as a series of "festive" or "corvée" projects. There are, however, a number of indications that the level of production and management changed over time. The early plots in the detailed study area cross a historically defined *ahupua'a* territorial boundary. These plots might have been farmed at the family or local corporate group level when territorial distinctions were not as significant as they were later in time. These plots, however, are not small but rather relatively large. Late-sequence plots, which tend to be smaller, are confined within distinct *ahupua'a* territorial boundaries. In this sense they conform to the expectation that they are "intracommunity boundary walls" identified by Kolb and Snead (1997) as "festive projects," perhaps organized by large "suprafamily" organizations as characteristic of chiefdoms. Defining these plots within territorial boundaries would have facilitated chiefs monitoring production levels more closely.

The evidence for changes in these LKFS territorial boundaries comes from the spatial configuration and naming of *ahupua'a* territorial units depicted on mid-nineteenth century maps, and the seriation and distribution of temples. As Bayman notes, there was a range of temples in ancient Hawai'i used for a variety of purposes. Our analysis of one class of temple, community-level structures probably associated with Lono and agricultural fertility, reinforces the notion that territorial boundaries were dynamic and not defined at a single point in time. While we lack extensive absolute dates for temples, it seems unlikely that all upland LKFS temples were constructed late in time. According to our analysis, the boundary between Makiloa and Pahinahina was in place and marked by an early temple before the boundary between Pahinahina and Kahua 1 was defined. The definition of the Pahinahina–Kahua 1 boundary postdates the construction of walls that cross the boundary, and these walls postdate sometime in the AD 1410–1670 range. While it is possible that all boundary divisions in the area that were marked by four different forms of temples were all constructed after AD 1650, this does not seem probable.

Many commentators (Bayman, Claessen, Kohler, and McCoy) suggested that oral traditions would be able to illuminate the sociopolitical and agricultural processes that occurred in leeward Kohala. Cachola-Abad's (2000) dissertation is currently the most comprehensive array and analysis of oral traditions throughout the islands that is focused on political relations and dynamics. She was able to create a relative sequence of 23 generations of chiefs up through Kamehameha the Great who unified the islands in the early nineteenth century. Her analyses and those we have recently completed (Graves et al. 2008) provide a more nuanced view of competitive and cooperative practices among chiefs. They also highlight the different political trends separating the younger western islands (Hawai'i and Maui) from the older eastern islands (O'ahu and Kaua'i). These traditions include relatively less about agricultural practices, except to note successful chiefs were generally attentive to the food requirements for themselves and their supporters. The oral traditions also denote the increasing importance of chiefs from leeward areas of Maui and Hawai'i Island, and this very likely occurred with the expansion of dryland agriculture to these zones. That they could compete effectively with the more established chiefs and polities in windward zones suggests they had resources and human populations of approximately the same numbers. This ushered in a period of considerable competition on Hawai'i Island punctuated by short periods of interpolity integration that did not survive beyond an individual chief's reign. In the last few generations before Kamehameha, the geographic scale of interaction and cooperation, as well as aggression, grew substantially, involving multiple chiefs from different islands.

This brief summary highlights some of the limitations of oral traditions—they speak largely of chiefs, and paramount chiefs at that. *Ali'i 'ai moku* (district chiefs), *na li'i okana* (chiefs of multiple, contiguous *ahupua'a*), *konohiki* or *ali'i 'ai ahupua'a* (chiefs of individual *ahupua'a*), the latter of which would have been most directly involved with coordinating and managing local scale agricultural production, are not well represented in the oral traditions. What oral traditions do assert is that *konohiki* managed agricultural production in tandem with *haku* (leaders of related households within an *ahupua'a*). Households were assigned lands to farm, and *konohiki* set tribute or taxation requirements for those households that farmed. Households were also expected to contribute labor toward the cultivation of the fields of chiefs (*ali'i ko'ele*). Those who did not meet their obligations could be evicted and replaced by others. It was, however, in everyone's interest to have mutually reinforced expectations of the other.

In our writing about behavioral decisions made by people, Kohler notes our multiple and vague use of the term "optimal." He is correct that we have used the term in at least three ways. Most often, we used the term "optimal" to reference the suitability of regions for growing dryland crops, primarily sweet potato. The critical parameters for growing sweet potato include soil nutrient levels (which are a function of the age of the geologic substrate, temperature, and rainfall), minimal rainfall levels, and distance to the coast (Ladefoged et al. 2004, n.d.). In this case, when alluding to "optimal" areas we were implicitly referring to farmers maximizing production levels in terms of tonnage per hectare, assessed for groups with access to regions, over a period of decades. We also used the term "optimality" when we referred to the first phase or pathway of agricultural development being located in "optimal" (as defined above) areas, thereby requiring less human effort to produce a set quantity of agricultural produce in these areas. Finally, in our previous analysis of dynamic territorial boundaries (Ladefoged et al. 2008) we used the term "optimal" to refer to the distribution of territories that maximized life expectancy, and in another instance, surplus. In the case of "optimal life expectancy," we were referring to a sequence of territorial areas in Kohala that when modeled for agricultural production produced varying estimates of life expectancy and potential surplus. Out of a number of territorial configurations, this modeling identified one that was "optimal," defined here as individuals maximizing life expectancy, using the average life expectancy at birth as the currency, assessed for individuals, over a period of hundreds of years.

Bayman makes the point that many anthropologists have concluded that marginal agricultural localities were not managed by chiefs but rather were utilized by disenfranchised social classes. The Hawai'i case of dryland agriculture may be instructive, as "marginal" is a relative concept based on the quality of the remaining land in a territory available for development. The areas we identified were probably the last available regions for intensive reliable dryland farming. We should note that there were many other even more marginal lands, particularly those low in rainfall, that could only be opportunistically cultivated (e.g., in years of heavy rainfall) and which were not targeted by chiefs for intensive agricultural investment.

One implication of our research has to do with surplus production in dryland agricultural contexts. Given the inherent year-to-year and spatial variability that we have documented for dryland systems in Hawai'i, relying on surplus in these regions to support high population densities would not have been ultimately successful. This is one reason we suspect that surplus production was redirected toward other purposes, for example, livestock (pigs and dogs) or tribute to chiefs. This scenario is consistent with the statement by Bayliss-Smith: "Instead of emphasizing improved output, these authors emphasize the benefits of reduced risk of harvest failure on marginal land. In other words, drainage, irrigation, walls, and terraces might constitute a kind of insurance policy rather than a bid for surplus production." We also argue that as more marginal environments were targeted for agricultural production, these needed to be part of a larger system of integration across diverse environments. This is clearly demonstrated in Kohala, as the district incorporates both dryland and wetland agriculture within the same political unit. It also appears that chiefs attempted to integrate even larger areas, particularly on Hawai'i Island and Maui, in order to combine the resources of the wet and dry.

It is this feature of late prehistoric societal change in Hawai'i that probably led to the increasing geographic scale of political integration to include multiple districts in wet and dry environments and ultimately across islands. We believe this shift included other structural and organizational changes among elite, such as development of multiple levels of chiefs to manage resources, people, and lands. Whether this constitutes a shift from complex chiefdoms to a state level of organization may depend upon the particular theoretical orientation of archaeologists. Certainly, Kamehameha's successful conquest constitutes a state level of organization. This was accompanied by a number of changes (increasing numbers of mates for *ali'i nui*, increasing scale of aggression and cooperation, redistribution of lands to junior chiefs) whose combined quantitative effects produced a transformation of traditional Hawai'ian sociopolitical organization.

The study of Hawai'ian dryland agriculture that began decades ago has recently increased in scope, scale, and detail. The collective results of this work put researchers on much firmer ground when it comes to understanding the articulation of leeward agricultural development with sociopolitical transformations. Ongoing research in windward areas should allow us to empirically evaluate some of the linkages between these diverse environmental settings in the near future. It will only be at that point that we will begin to gain a more holistic and nuanced appreciation of the complex processes that occurred throughout the archipelago.

References Cited

Adams, J., and J. Stephen Athens. 1994. *Archaeological inventory survey, upland portions of Kukuipahu and Awalua, North Kohala, island of Hawai'i.* Report prepared for Chalon International, Hawi, Hawai'i. Honolulu: IARII.

Allen, J. 1991. The role of agriculture in the evolution of the pre-contact Hawaiian state. *Asian Perspectives* 30:117–32.

Allen, M. S., ed. 2001. *Gardens of Lono: Archaeological investigations at the Amy B. Greenwell ethnobotanical garden, Kealakakua, Hawai'i.* Honolulu: Bishop Museum Press.

———. 2004. Bet-hedging strategies, agricultural change, and unpredictable environments: Historical development of dryland agriculture in Kona, Hawaii. *Journal of Anthropological Archaeology* 23:196–224.

———. 2006. New ideas about Late Holocene climate variability in the Central Pacific. Current Anthropology 47: 521–35

Balée, W. 2006. The research program of historical ecology. *Annual Review of Anthropology* 35:75–98. [KSZ]

Ballard, C. 2001. Wetland drainage and agricultural transfor-

mations in the New Guinea Highlands. *Asia Pacific Viewpoint* 42:287–304. [TBS]
Bayliss-Smith, Tim P. 2007. The meaning of ditches: Interpreting the archaeological record from New Guinea using insights from ethnography. In *Rethinking agriculture: Archaeological and ethnographic perspectives*, ed. Tim Denham, Jose Iriarte, and Luc Vrydaghs, 126–48. Walnut Creek, Calif.: Left Coast Press. [TBS]
Bayliss-Smith, Tim P., and Golson, J. 1999. The meaning of ditches: Deconstructing the social landscapes of New Guinea, Kuk, Phase 4. In *The prehistory of food: Appetites for change*, ed. C. Gosden and J. Hather, 191–231. London: Routledge. [TBS]
Bayliss-Smith, Tim P., J. Golson, P. Hughes, R. Blong, and W. Ambrose. 2005. Archaeological evidence for the Ipomoean Revolution at Kuk swamp, Papua New Guinea. In *The sweet potato in Oceania: A reappraisal*, Oceania Monograph 56, ed. C. Ballard, P. Brown, R. M. Bourke, and T. Harwood, 109–120. Sydney: University of Sydney, and Pittsburgh: Department of Anthropology, University of Pittsburgh. [TBS]
Blaikie, Piers, and H. C. Brookfield. 1987. *Land degradation and society*. London and New York: Methuen. [TBS, KSZ]
Boomert, A., and A. J. Bright. 2007. Island archaeology: In search of a new horizon. *Island Studies Journal* 2:3–26. [MDM]
Boserup, E. 1965. *The conditions of agricultural growth: The economics of agrarian change under population pressure*. Chicago: Aldine. [PVK]
Bourdieu, Pierre. 1977. *Outline of a theory of practice*. Cambridge: Cambridge University Press. (R. Nice, translator.) [TBS]
Bronk Ramsey, C. 1995. Radiocarbon calibration and analysis of stratigraphy: The OxCal program. *Radiocarbon* 37:425–30.
———. 2001. Development of the radiocarbon program OxCal. *Radiocarbon* 43:355–63.
———. 2005. OxCal V 3.10. http://c14.arch.ox.ac.uk/.
Brookfield, Harold C. 1972. Intensification and disintensification in Pacific agriculture: A theoretical approach. *Pacific Viewpoint* 13:30–48. [TBS]
———. 1984. Intensification revisited. *Pacific Viewpoint* 25:15–44. [TBS, KSZ]
Burtchard, G. C., and M. J. Tomonari-Tuggle. 2004. Agriculture on leeward Hawai'i Island: The Waimea agricultural system reconsidered. *Journal of Hawaiian Archaeology* 9:50–73.
Cachola-Abad, C. K. 2000. The evolution of Hawaiian sociopolitical comlexity: An analysis of Hawaiian oral traditions. Unpublished Ph.D. dissertation. University of Hawai'i, Honolulu.
Clark, J. T. 1987. Waimea-Kawaihae, a leeward Hawaii settlement system. Ph.D. dissertation, Department of Anthropology, University of Illinois, Urbana.
Clark, J. T., and P. V. Kirch, eds. 1983. *Archaeological investigations of the Mudlane-Waimea-Kawaihae road corridor, Island of Hawai'i: An inderdisciplinary study of an environmental transect*. Department of Anthropology Report 83-1. Honolulu: Bernice P. Bishop Museum.
Clerke, Charles. 1967. Log and proceedings. In *The journals of Captain James Cook: The voyage of the Resolution and Discovery, 1776–1780*, ed. J. C. Beaglehole, 591–603. Cambridge: Cambridge University Press, Hakluyt Society Extra Series 36. [HJMC]
Coil, J., and P. V. Kirch. 2005. An Ipomean landscape: Archaeology and the sweet potato in Kahikinui, Maui, Hawaiian Islands. In *The sweet potato in Oceania: A reappraisal*, Oceania Monograph no. 56, ed. C. Ballard, P. Brown, R. M. Bourke, and T. Harwood, 71–84. Sydney: University of Sydney.
Cordy, R., and M. W. Kaschko. 1980. Prehistoric archaeology in the Hawaiian Islands: Land units associated with social groups. *Journal of the Field Archaeology* 7:403–416.
Crown, Patricia L. 1991. Evaluating the construction sequence and population of Pot Creek Pueblo, northern New Mexico. *American Antiquity* 56:291–314. [TAK]
Davenport, William. 1969. The "Hawaiian cultural revolution": Some political and economic considerations. *American Anthropologist* 71:1–20. [HJMC]
Diamond, J. 2005. *Collapse: How societies choose to fail or succeed*. New York: Viking.
Dixon, B., P. J. Conte, V. Nagahara, and W. K. Hodgins. 1997. Upland forest periphery subsistence and settlement in the Ahupua'a of Kipapa, Nakaohu, and Nakaaha: A preliminary assessment. In *Na mea kahiko o Kahikinui: Studies in the archaeology of Kahikinui, Maui*, ed. P. V. Kirch, 28–44. Berkeley: Oceanic Archaeology Laboratory, University of California.
———. 1999. Risk minimization and the traditional Ahupua'a in Kahikinui, island of Maui, Hawai'i. *Asian Perspectives* 38:229.
Doolittle, W. M. 1984. Agricultural change as incremental process. *Annals of the Association of American Geographers* 74:124–37. [KSZ]
Drennan, Robert D. 1984. Long-distance transport costs in pre-Hispanic Mesoamerica. *American Anthropologist* 86:105–12. [HJMC]
Earle, T. 1978. *Economic and social organization of a complex chiefdom: The Halelea District, Kaua'i, Hawaii*. Anthropological Papers, 63. Ann Arbor: Museum of Anthropology, University of Michigan.
Ellis, William. 1831. *Polynesian researches, during a residence of nearly eight years in the Society and Sandwich Islands*. 4 vols. London: Fisher, Son and Jackson. [HJMC]
Erkelens, C. 1993. Review of historical documents and background literature, Waimea Town Center Project Area, Kamuela-Waimea, Hawaii Island. Honolulu: International Archaeological Research Institute.
Farrington, Ian, ed. 1985. *Prehistoric intensive agriculture in*

the tropics. BAR International Series 232. Oxford: British Archaeological Reports. [TBS]

Fitzpatrick, S. M., J. M. Erlandson, A. Anderson, and P. V. Kirch. 2007. Straw boats and the proverbial sea: A response to "Island archaeology: In search of a new horizon." *Island Studies Journal* 2:229–38. [MDM]

Fleming, Andrew. 1988. *The Dartmoor reaves*. London: Batsford. [TBS]

Geertz, C. 1963. *Agricultural Involution*. Chicago: Aldine. [PVK]

Gibson, D. Blair. 2008. Chiefdoms and the emergence of private property in land. *Journal of Anthropological Archaeology* 27:46–62. [TAK]

Graves, M. W. and K. Cachola-Abad. 1996. Seriation as a method of chronologically ordering architectural design traits: An example from Hawai'i. *Archaeology in Oceania* 31:19–32.

Graves, M. W., J. K. Field, T. Vallante, and D. M. Issac. 2006. Dating the human occupation of Pololu Valley, North Kohala, Hawai'i island. Paper presented at the Society for Hawaiian Archaeology Annual Meeting, Maui.

Graves, M. W., T. N. Ladefoged, and C. K. Cachola-Abad. 2008. Evolutionary ecology of Hawaiian political complexity: Case studies from Maui and Hawai'i islands. Unpublished ms. Department of Anthropology, University of New Mexico, Albuquerque.

Hammett, H. H., and D. Borthwick. 1986. Archaeological survey and excavations at Kohala Ranch, North Kohala, Hawaii Island. Report on file with Cultural Surveys Hawaii.

Handy, E., S. Craighill. 1965. Government and society. In *Ancient Hawaiian civilization: A series of lectures delivered at the Kamehameha schools*, ed. E. S. C. Handy, K. P. Emory, E. H. Bryan, P. H. Buck, and J. Wise, 35–46. Rev. ed. Rutland, Vt./Tokyo: Tuttle. [HJMC]

Hommon, R. C. 1986. Social evolution in Hawaii. In *Island societies: Archaeological approaches to evolution and transformation*, ed. P. V. Kirch, 55–68. Cambridge: Cambridge University Press. [TAK]

Kirch, P. V. 1971. Halawa Valley: Two field seasons in retrospect. *New Zealand Archaeological Association Newsletter* 14: 47–61.

———. 1984. *The evolution of Polynesian chiefdoms.* Cambridge: Cambridge University Press.

———. 1985. *Feathered gods and fishhooks: An introduction to Hawaiian archaeology and prehistory.* Honolulu: University of Hawai'i Press.

———. 1994. *Wet and the dry: Irrigation and agricultural intensification in Polynesia.* Chicago: University of Chicago Press.

———, ed. 1997. *Na mea kahiko o Kahikinui: Studies in the archaeology of Kahikinui, Maui.* Berkeley: Oceanic Archaeology Laboratory, University of California.

———. 1999. Comment on H. M. Leach, Intensification in the Pacific. *Current Anthropology* 40:326–28. [HJMC]

———. 2002. From the "Cliffs of Keolewa" to the "Sea of Papaloa": An archaeological reconnaissance of portions of the Kalaupapa National Historical Park, Moloka'i, Hawaiian Islands. Berkeley: Archaeological Research Facility, University of California.

———. 2004. Temple sites in Kahikinui, Maui, Hawaiian Islands: Their orientations decoded. *Antiquity* 78:102–14.

———. 2005. *From chiefdom to archaic state: Social evolution in Hawaii*. Grace Elizabeth Shallit Memorial Lecture Series Publication. Provo, Utah: Department of Anthropology, Brigham Young University. [MDM]

———. 2006. Agricultural intensification: A Polynesian perspective. In *Agricultural Strategies*, ed. J. Marcus and C. Stanish, 191–220. Los Angeles: Cotsen Institute of Archaeology, University of California.

———. 2007*a*. Hawaii as a model system for human ecodynamics. *American Anthropologist* 109:8–26.

———. 2007*b*. "Like shoals of fish": Archaeology and population in pre-contact Hawai'i. In *The growth, regulation, and collapse of island societies*, ed. P. V. Kirch and J. Rallu, 52–69. Honolulu: University of Hawai'i Press.

Kirch, P. V., O. A. Chadwick, S. Tuljapurkar, T. N. Ladefoged, M. W. Graves, S. Hotchkiss, and P. Vitousek. 2007. Human ecodynamics in the Hawaiian ecosystem, from 1200–200 yr B.P. In *The model-based archaeology of socionatural systems*, ed. T. Kohler and S. van der Leeuw, 121–39. Santa Fe: Santa Fe Institute.

Kirch P. V, J. Coil, A. S. Hartshorn, M. Jeraj, P. M. Vitousek, and O. A. Chadwick. 2005. Intensive dryland farming on the leeward slopes of Haleakalā, Maui, Hawaiian Islands: Archaeological, archaeobotanical, and geochemical perspectives. *World Archaeology* 37:240–58.

Kirch, P. V., A. S. Hartshorn, O. A. Chadwick, P. M. Vitousek, D. Sherrod, J. Coil, L. Holm, and W. Sharp. 2004. Environment, agriculture, and settlement patterns in a marginal Polynesian landscape. *Proceedings of the National Academy of Sciences* 101:9936–41.

Kirch, P. V., and M. Kelly, eds. 1975. *Prehistory and ecology in a windward Hawaiian Valley: Halawa Valley, Moloka'i.* Pacific Anthropological Records, 24. Honolulu: Department of Anthropology, Bernice P. Bishop Museum.

Kirch P. V. and M. McCoy. 2007. Reconfiguring the Hawaiian cultural sequence: Results of re-dating the Hälawa Dune site (MO-A1–3), Moloka'i island. *Journal of the Polynesian Society* 116(4):385–406.

Kirch P. V. and M. Sahlins. 1992. *Anahulu: The archaeology of history in the Kingdom of Hawaii.* Vols. 1, 2. Chicago: University of Chicago Press.

Kirch P. V. and W. D. Sharp. 2005. Coral Th-230 dating of the imposition of a ritual control hierarchy in precontact Hawai'i. *Science* 307:102–4.

Kolb, M. J. 1992. Diachronic design changes in "heiau" temple architecture on the island of Maui, Hawai'i. *Asian Perspectives* 31:9–37.

———. 1994*a*. Monumentality and the rise of religious authority in precontact Hawai'i. *Current Anthropology* 35: 521–48. [HJMC]

———. 1994*b*. Ritual activity and chiefly economy at an upland religious site on Maui, Hawai'i. *Journal of Field Archaeology* 21:417–36.

———. 1997. Labor mobilization, ethnohistory, and the archaeology of community in Hawai'i. *Journal of Archaeological Method and Theory* 4:265–85.

———. 1999. Monumental grandeur and political fluorescence in pre-contact Hawai'i: Excavations at Pi'ilanihale Heiau, Maui. *Archaeology in Oceania* 34:71–82.

———. 2006. The origins of monumental architecture in ancient Hawai'i. *Current Anthropology* 47:657–65.

Kolb, M. J., and E. C. Radewagen. 1997. Na heiau o Kahikinui: The temples of Kahikinui. In *Na mea kahiko o Kahikinui: Studies in the archaeology of Kahikinui, Maui*, ed. P. V. Kirch, 61–77. Berkeley: Oceanic Archaeology Laboratory, University of California.

Kolb, M. J., and J. E. Snead. 1997. It's a small world after all: Comparative analyses of community organization in archaeology. *American Antiquity* 62:609–28.

Ladefoged, T. N., and M. W. Graves. 2000. Evolutionary theory and the historical development of dry-land agriculture in North Kohala, Hawai'i. *American Antiquity* 65: 423–48.

———. 2005. Human ecodynamics of Kohala, Hawai'i. In *The Reñaca papers: VI International Conference on Rapa Nui and the Pacific/VI Congreso internacional sobre Rapa Nui y el Pacifico,* ed. C. M. Stevenson, J. M. Ramírez Aliaga, F. J. Morin and N. Barbacci, 155–60. Los Osos, Calif.: Easter Island Foundation.

———. 2006. The formation of Hawaiian territories. In *Archaeology of Oceania*, ed. Ian Lilly, 259–83. New York: Blackwell.

———. 2007. Modeling agricultural development and demography in Kohala, Hawai'i. In *The growth, regulation, and collapse of island societies*, ed. P. V. Kirch and J. Rallu, 70–89. Honolulu: University of Hawai'i Press.

Ladefoged, T. N., M. W. Graves, and J. Coil. 2005. The introduction of sweet potato in Polynesia: Early remains in Hawai'i. *Journal of the Polynesian Society* 114:359–73.

Ladefoged, T. N., M. W. Graves, and R. P. Jennings. 1996. Dryland agricultural expansion and intensification in Kohala, Hawai'i Island. *Antiquity* 70:861–80.

Ladefoged, T. N., M. W. Graves, and M. McCoy. 2003. Archaeological evidence for agricultural development in Kohala, Island of Hawai'i. *Journal of Archaeological Science* 30: 923–40.

Ladefoged, T. N., P. V. Kirch, S. Gon., O. A. Chadwick, A. S. Hartshorn, and P. M. Vitousek. n.d. Opportunities and constraints for prehistoric intensive agriculture in the Hawaiian archipelago. *Ecosystems.*

Ladefoged, T. N., C. Lee, and M. W. Graves. 2008. Modeling life expectancy and surplus production of dynamic precontact territories in leeward Kohala, Hawai'i. *Journal of Anthropological Archaeology* 27:93–110.

Leach, H. M. 1999. Intensification in the Pacific: A critique of the archaeological criteria and their application. *Current Anthropology* 40:311–39.

Lee, C. T., S. Tuljapurkar, and P. Vitousek. 2006. Risky business: Spatial and temporal variation in preindustrial dryland agriculture. *Human Ecology* 34:739–63.

Malo, David. 1971. *Hawaiian antiquities (Moolelo Hawaii)*, ed. N. B. Emerson. Special Publication 2, 2d edition. Honolulu: Bishop Museum Press. [HJMC]

Marcus, J., and C. Stanish, eds. 2006. *Agricultural strategies.* Los Angeles: Cotsen Institute of Archaeology. [KSZ]

Matson, P. A., and P. M. Vitousek. 2006. Agricultural intensification: Will land spared from farming be land spared for nature? *Conservation Biology* 20:709–10. [KSZ]

McCoy, M. D. 2000. Agricultural intensification and land tenure in prehistoric Hawai'i. M.A. thesis. University of Auckland.

———. 2002. Report on Kalaupapa Peninsula Archaeological Project (KPAP) fieldwork. Report on file with the U.S. National Park Service and Hawaii State Historic Preservation Office, Honolulu.

———. 2003. Report on Kalaupapa Peninsula Archaeological Project (KPAP) fieldwork. Report on file with the U.S. National Park Service and Hawaii State Historic Preservation Office, Honolulu.

———. 2004. Report on Kalaupapa Peninsula Archaeological Project (KPAP) fieldwork. Report on file with the U.S. National Park Service and Hawaii State Historic Preservation Office, Honolulu.

———. 2005*a*. The chronology of the Kalaupapa field system, Moloka'i Island, Hawai'i. *Journal of the Polynesian Society* 114:339–58.

———. 2005*b*. The lands of Hina: An archaeological overview and assessment of Kalaupapa National Historical Park, Moloka'i Island. Honolulu: Technical Report 135, Pacific Cooperative Studies Unit of the University of Hawai'i and National Park Service, U.S. Department of the Interior.

———. 2006. Landscape, social memory, and society: An ethnohistoric-archaeological study of three Hawaiian communities. Unpublished Ph.D. dissertation. University of California, Berkeley.

———. 2007. A revised late Holocene culture history for Moloka'i Island, Hawai'i. *Radiocarbon* 49:1273–322.

———. 2008. Hawaiian limpet harvesting in historical perspective: A review of modern and archaeological data on *Cellana* spp. from the Kalaupapa Peninsula, Moloka'i Island. *Pacific Science* 62:21–38.

———. 2008. Life outside the temple: Reconstructing traditional Hawaiian ritual and religion through ritualized practices. In *Religion, archaeology, and the material world: A conference on the archaeology of religion*, ed. Lars Fogelin, 261–78. Carbondale: Center for Archaeological Investigations, Southern Illinois University, Occasional Paper 36 [MDM].

McCoy, M. D., and A. S. Hartshorn. 2007. Wind erosion and intensive prehistoric agriculture: A case study from the Kalaupapa field system, Moloka'i Island, Hawai'i. *Geoarchaeology* 22:511–32.

McElroy, W. K. 2007. The development of irrigated agriculture in Wailau Valley, Moloka'i Island, Hawai'i. Unpublished Ph.D. dissertation. University of Hawai'i, Honolulu.

McFadgen, B. G., F. B. Knox, and R. R. L. Cole. 1994. Radiocarbon calibration curve variations and their implications for the interpretation of New Zealand prehistory. *Radiocarbon* 36:221–36.

Meyer, M., T. N. Ladefoged, and P. M. Vitousek. 2007. Soil phosphorus and agricultural development in the leeward Kohala field system, island of Hawai'i. *Pacific Science* 61: 347–53.

Morrison, K. D. 1996. Typological schemes and agricultural change: Beyond Boserup in precolonial South India. *Current Anthropology* 37:583–608. [KSZ]

Mulrooney, M. A. 2004. Religious activity and surplus production in the Kohala dryland agricultural field system, Hawai'i. Unpublished M.A. dissertation. Department of Anthropology, University of Auckland.

Mulrooney, M. A., and T. N. Ladefoged. 2005. Hawaiian heiau and agricultural production in the Kohala dryland field system. *Journal of the Polynesian Society* 114:45–67.

Newman, T. S. 1970. *Hawaiian fishing and farming on the island of Hawaii in AD 1778*. Honolulu: Division of State Parks, Department of Land and Natural Resources.

Nunn, P. D. 2000. Environmental catastrophe in the Pacific Islands around A.D. 1300. Geoarchaeology 15:715–40.

———. 2007. Climate, environment and society in the Pacific during the last millennium. London: Elsevier.

Pauketat, T. R. 2007. *Chiefdoms and other archaeological delusion*. Walnut Creek, Calif.: Alta Mira Press. [MDM]

Pearsall, Deborah M., and Michael K. Trimble. 1984. Identifying past agricultural activity through soil phytolith analysis: A case study from the Hawaiian Islands. *Journal of Archaeological Science* 11:119–33.

Pearson, R., ed. 1969. *Archaeology on the island of Hawaii*. Asian and Pacific Archaeology Series No. 3. Honolulu: Social Science Research Institute, University of Hawai'i at Manoa.

Rainbird, P. 1999. Islands out of time: Towards a critique of island archaeology. *Journal of Mediterranean Archaeology* 12:216–34. [MDM]

———. 2007. *The archaeology of islands*. Cambridge: Cambridge University. [MDM]

Rosendahl, P. H. 1972. Aboriginal agriculture and residence patterns in upland Lapakahi, island of Hawaii. Ph.D. dissertation. University of Hawai'i.

———. 1994. Aboriginal Hawaiian structural remains and settlement patterns in the upland agricultural zone at Lapakahi, island of Hawaii. *Hawaiian Archaeology* 3:14–70.

Sahlins, Marshall D. 1992. *Anahulu: The anthropology of history in the kingdom of Hawaii*. Vol. 1. *Historical ethnography*. Chicago/London: University of Chicago Press. [HJMC]

Schilt, R. 1984. *Subsistence and conflict in Kona, Hawai'i: An archaeological study of the Kuakini highway realignment corridor*. Department of Anthropology Report 84-1. Honolulu: Bernice P. Bishop Museum.

Soehren, L. J., and T. S. Newman. 1968. *The archaeology of Kealakekua Bay*. Honolulu: Bernice P. Bishop Museum and the University of Hawai'i.

Stevenson, C., Ladefoged, T. N. and Haoa, S. 2007. An upland agricultural residence on Rapa Nui: Occupation of a hare oka (18–473G) in the Vaitea Region. *Archaeology in Oceania* 42:72–8.

Stevenson, C. M. 1997. *Maunga Tari: an upland agricultural complex*. Los Osos, Calif.: Easter Island Foundation, Occasional Papers No. 3.

Stevenson, C. M., and S. Haoa. 2008. *Prehistoric Rapa Nui: Landscape and settlement archaeology at Hanga Ho'onu*. Los Osos: Easter Island Foundation.

Stevenson, Christopher, Joan Wozniak, and Sonia Haoa. 1999. Prehistoric agricultural production on Easter Island (Rapa Nui), Chile. *Antiquity* 73:801–2. [WSA]

Stone, G. D., and C. E. Downum. 1999. Non-Boserupian ecology and agricultural risk: Ethnic politics and land control in the Arid Southwest. *American Anthropologist* 101: 113–28. [KSZ]

Tuggle, H. D., and P. B. Griffin, eds. 1973. *A summary of Lapakahi lowland research: 1969–1970, in Lapakahi, Hawai'i*. Archaeological Studies. Asian and Pacific Archaeology Series 5. Honolulu: Social Science Research Institute, University of Hawai'i.

Turner, B .L., G. Hyden, and R. W. Kates, eds. 1993. *Population growth and agricultural change in Africa*. Gainesville: University Press of Florida. [KSZ]

Valeri, Valerio. 1985. *Kingship and sacrifice; Ritual and society in ancient Hawaii*. Chicago: University of Chicago Press. [HJMC]

Vitousek, P. M. 1995. The Hawaiian Islands as a model system for ecosystem studies. *Pacific Science* 49:2–16. [PVK]

Vitousek, P. M., T. N. Ladefoged, P. V. Kirch, A. S. Hartshorn, M. W. Graves, S. C. Hotchkiss, S. Tuljapurkar, and O. A. Chadwick. 2004. Soils, agriculture, and society in precontact Hawai'i. *Science* 304:1165–9.

Weisler, M. I., K. D. Collerson, Y.-X. Feng, J.-X. Zhao, and K.-F. Yu. 2006. Thorium-230 coral chronology of a late prehistoric Hawaiian chiefdom. *Journal of Archaeological Science* 33:273–82.

Wichman, Frederick B. 2003. *Na pua ali'i o Kaua'i. Ruling chiefs of Kauai'i*. Honolulu: University of Hawai'i Press. [HJMC]

Wright, R. 2005. *A short history of progress.* New York: Carroll and Graf.

Wuzen, W., and S. T. Goodfellow. 1995. Final report, phased archaeological inventory survey, phase II—data collection, Chalon International Mahukona Mauka parcel. Hilo: Paul Rosendahl, Ph.D., Inc.

Yoffee, N. 2005. *Myths of the archaic state: Evolution of the earliest cities, states and civilizations.* Cambridge: Cambridge University Press. [MDM]

Zaal, F., and R. H. Oostendorp. 2002. Explaining a miracle: Intensification and the transition towards sustainable small-scale agriculture in dryland Machakos and Kitui Districts, Kenya. *World Development* 30:1271–87. [KSZ]

Zimmerer, K. S. 2000. Rescaling irrigation in Latin America: The cultural images and political ecology of water resources. *Ecumene* 7:150–75. [KSZ]

———. 2007. Cultural ecology (and political ecology) in the "environmental borderlands": Exploring the expanded connectivities within geography. *Progress in Human Geography* 31:227–44. [KSZ]