WATER AND POWER: AGRICULTURAL INTENSIFICATION IN WINDWARD NORTH KOHALA, HAWAI‘I ISLAND

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Christopher Ian Avery

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By

Christopher Ian Avery

APPROVED FOR THE DEPARTMENT OF ANTHROPOLOGY

Dr. Marco Meniketti, Department of Anthropology, Date

Dr. Charles Darrah, Department of Anthropology, Date

Dr. Roberto Gonzalez, Department of Anthropology, Date

APPROVED FOR THE UNIVERSITY

Associate Dean, Office of Graduate Studies and Research, Date

ABSTRACT

WATER AND POWER: AGRICULTURAL INTENSIFICATION IN WINDWARD NORTH KOHALA, HAWAIʻI ISLAND

By Christopher Ian Avery

This thesis examines the processes of agricultural intensification in the eastern gulch region of windward North Kohala district, Hawaiʻi Island. The intensification of agricultural production was essential for Hawaiʻi's transition from a collection of loose tribelets into an archaic state. To meet the growing demands of social paramounts, ancient farmers in North Kohala innovated novel technologies to improve their capacity to produce surpluses. In windward North Kohala, the chief innovation was intricate irrigation systems that transferred water from the region's gulch beds to the adjacent elevated tablelands, discovered by the Hawaiʻi Archaeological Research Project in 2008 (McCoy and Graves 2008). This technology, along with developments in leeward Kohala, appears to have emerged just prior to the period of contact, during a period of agricultural expansion and intensification, between1400 A.D. and 1650 A.D.

Political ecology provides a framework for the analysis of agricultural innovations and their impact on Hawaiian society. Geographic information systems were applied in order to build a model to describe the potential for agricultural land use in the eastern gulch region. Initial results suggest that large portions of the windward tablelands could have been dedicated to agricultural production, based on the landform and proximity to flowing water.

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Introduction:

The development of complex agricultural systems has been viewed as an integral part of the formation of complex societies throughout the world (Wolf 1972). The transition from a subsistence economy to an economy organized around the production of food surpluses has long been observed as a milestone in the processes that increase social complexity (Parsons 1971). The period of greatest agricultural intensification in Hawaii, beginning ca. 1400 A.D. and continuing through 1650 A.D., is co-incident with the greatest period of diversification and stratification of social roles in Hawaiian prehistory (Sahlins 1958; Kirch 1984, 1985, 1994; Kirch and Rallu 2007; McCoy 2006; McCoy and Graves 2010). During this period of change, social roles expanded from those primarily emphasizing food-production and subsistence practices to include a swelling elite class preoccupied with religion, warfare, politics, and still others who practiced specialized artisanal roles that supported the social practices of the elites. The chief's powerbases grew on the surplus of agricultural goods required to feed their warriors. As this social landscape changed, commoners locked in food-producing roles (the vast majority of the *maka‘ainana*, or commoner class) found themselves bearing a greater burden of tithe to these powerful chiefs.

Ancient Hawaiian farmers had to develop novel strategies to meet the additional demands placed upon them by the pressures of a surplus economy, and by the shifting social dynamics within Hawaiian society. It was because of agricultural innovations, including techniques that expanded agricultural production into the islands' marginal hinterlands, that this transition could occur (McCoy and Graves 2010).

The transition from a subsistence economy to a surplus economy also afforded the greatest opportunity for sustained population growth in Hawai'i's cultural history (Kirch and Rallu 2007). The population boom that began to skyrocket at the start of the 1400's A.D. would have been catastrophic and unsustainable without a transformation in the way early cultivators engaged their landscape. Despite the Big Island's great size—exceeding the area of the other major islands of the archipelago combined—only a small portion of the island is ideally suited for agriculture, including a handful of sheltered valleys and winnowed gulches with sufficient water flow and protection from the powerful trade winds that routinely batter the island. In the district of North Kohala, the deep gulches and drainages that course down the windward slope of Mount Kohala afforded ample opportunity for farmers to establish irrigated, terraced pond fields for the cultivation of taro (*Colocasia esuculenta*). However, these agricultural systems were limited by the topography of the local landform which often has an extreme grade in excess of 20%, and by the narrow profile of the gulches themselves, which average between only 50m and 100m across throughout the region.

The evidence for agricultural intensification on the Big Island comes to a head at the start of the 15th Century A.D., when archaeological analyses of agricultural sites begin to reflect an increase in labor inputs through infrastructural development (Ladefoged and Graves 2007). Contemporaneous with the intensification of existing agricultural resources, new agricultural technologies emerged that enabled ancient farmers to utilize new areas of land to increase the growing capacity in marginal territories. In the eastern gulch region of North Kohala, this period of innovation resulted in the creation of intricate irrigation systems that carried water from the active streams and *lo'i* (flooded terraces for the cultivation of taro) in the gulch beds, along a sequence of *'auwai* (irrigation ditches) dug into the gulch siding, out to garden plots placed on the elevated tablelands between the gulches. These features, first identified by McCoy and Graves in 2008, demonstrate the innovative strategies ancient farmers were using to meet the challenges posed by social and demographic shifts affecting Hawaiian society (McCoy and Graves 2008 and 2010).

With respect to this project, the wet and dry land dichotomy affords a useful means of describing the phenomenon of agricultural systems in the North Kohala region, and for comparing and contrasting the effects of agricultural intensification upon the society of cultivators working variable conditions. Water is as essential for life as it is for agriculture; therefore the consequences of accessibility or inaccessibility of water resources are profound. Water resources manifest in two forms: fresh water, suitable for agriculture, and coastal water, suitable for harvesting aquatic resources.

The Hawaiians were the only Polynesian culture to develop intensive aquaculture, including the construction of fishponds to raise and harvest select species of fish (Kirch 1985). These large scale aquaculture projects were the province of the chiefly class, and access to the sea and its wealth was a privilege of the elite. Consequently, the traditional conception of a "vertical hierarchy" with the elites dwelling above and the commoners below is inverted here, as elites would frequently dwell closer to the coast to ensure access to aquatic resources, such as seaweed, fish and shellfish (Kirch 1985).

In the eastern gulches, where community territories were organized along the *mauka-makai* (upslope-down slope) trajectories of the gulches themselves, this has the interesting consequence of saddling chiefs and high status families with what amounts to the dregs of the gulch water resources for their own agricultural and utilitarian investments. It is this spatial arrangement that would have necessitated that a portion of the commoners' yields be offered up to the chiefs, in order to supplement their aquatic resources. Likewise, coastal access afforded high status individuals with regular access to valuable, influence-enhancing commodities ranging from marine foods to shells and *'ili'ili*, the valuable water-worn cobbles used in ritual and as pavement stones in important contexts. Access to these resources increased the influence of elites. These differences in resource accessibility arguably laid the foundation for the relationships that became magnified as Hawaiian society transitioned into increasing complexity.

The *moku* (regional district) of North Kohala has a remarkable place in the history of the Hawaiian Islands. As the birthplace and ancestral territory of King Kamehameha I, the field system of leeward North Kohala and the irrigated windward gulches were an invaluable resource in his quest to unify the islands under his rule. However, the agricultural systems that were already established during the lifetime of Kamehameha (ca. 1758-1819) had their genesis centuries earlier. Consequently, the North Kohala district has been the subject of a number of research projects; however, they are distributed unevenly across the district's sites. The majority of the previous archaeological research conducted in the region has been focused on the sprawling leeward field complex of North Kohala, including recent contributions by Ladefoged and Graves 2007; Ladefoged *et al.* 1996, 1998, 2003; Vitousek *et al* 2004; and others. Relatively few projects have been undertaken in the windward portion of North Kohala. Among the most notable projects undertaken in windward Kohala, are Tuggle and Tomonari-Tuggle 1980, Tomonari-Tuggle 1988, McCoy and Graves 2007, 2008 and 2010.

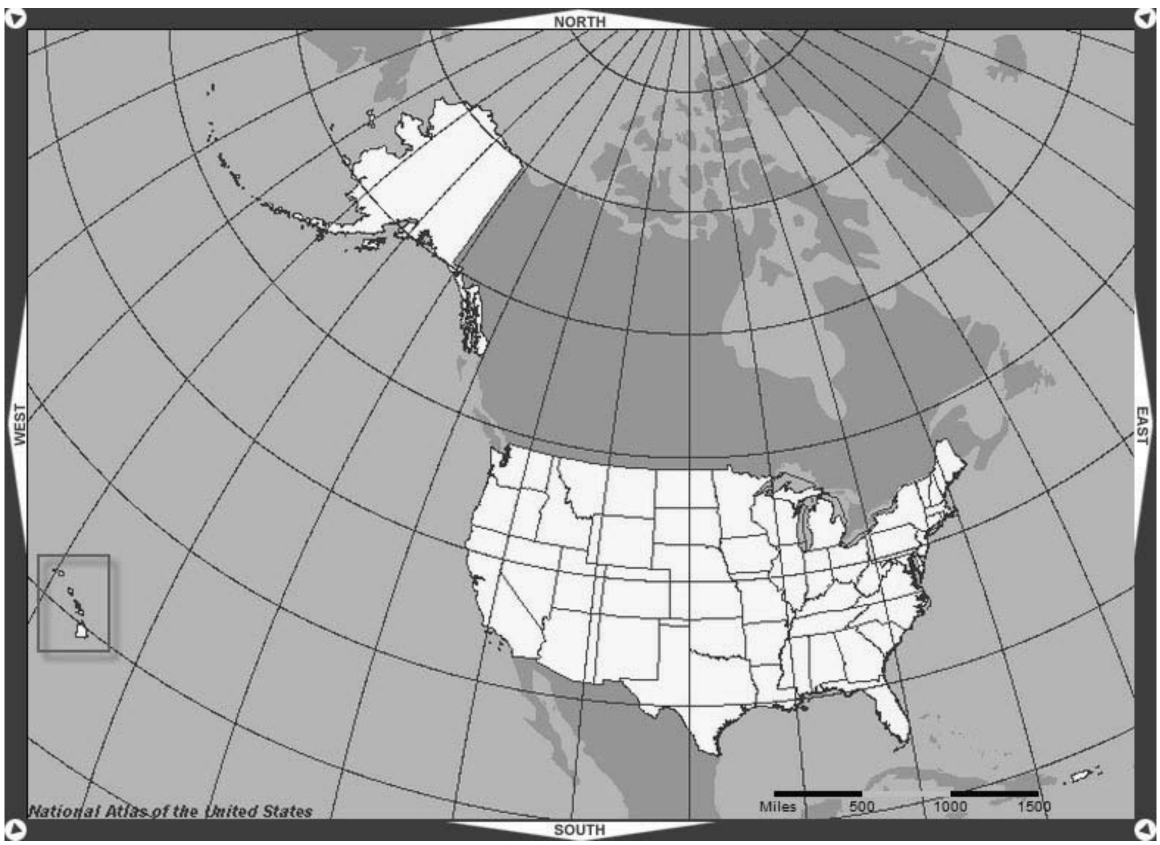

Figure 1.1: The Hawaiian Islands. Source: National Atlas of the United States.

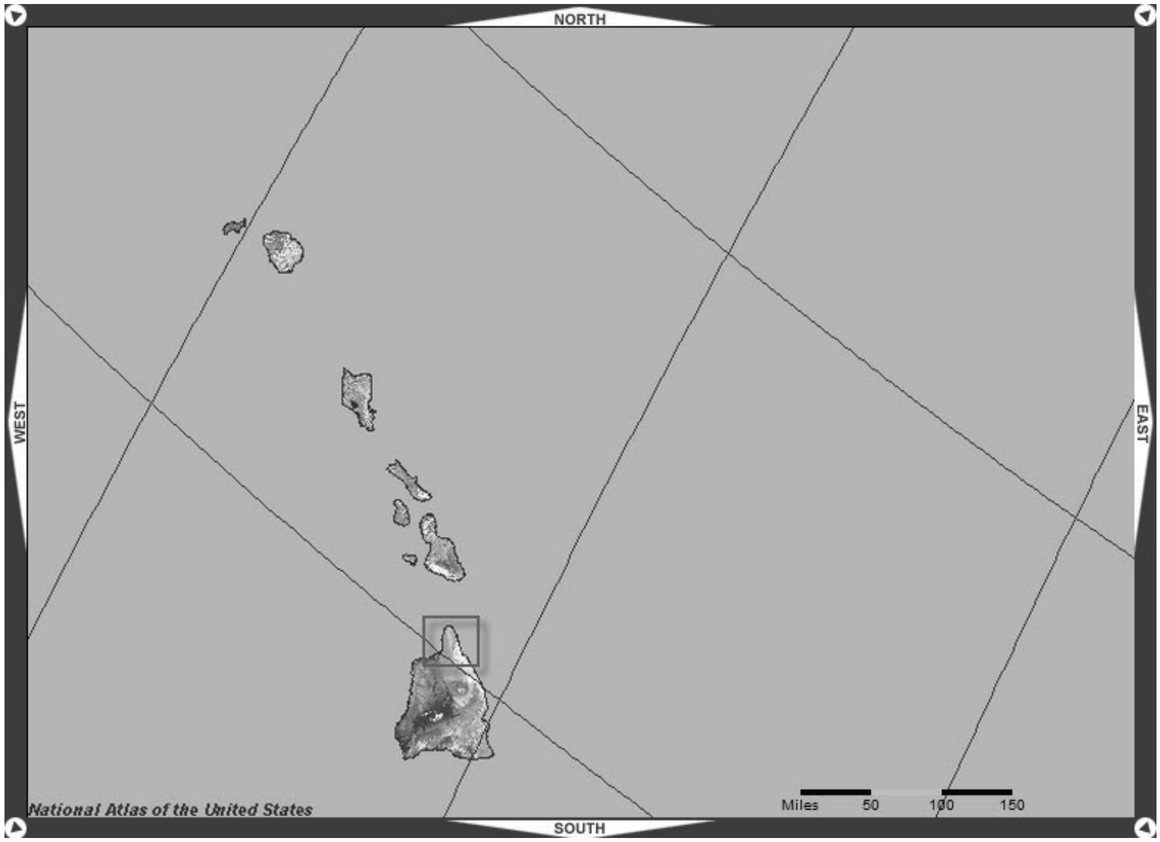

Figure 1.2: The Hawaiian Islands, Kohala Peninsula Emphasized. Source: National Atlas of the United States.

Research design

In this thesis, I examine the social and political consequences of prehistoric agricultural intensification in windward North Kohala—a phenomenon that escalated and reached a peak between 1400 and 1600 A.D., immediately preceding the period of European contact (McCoy and Graves 2010). As a key component of this analysis, I relate the processes of agricultural intensification visible in windward North Kohala to contemporaneous changes in the complexity and stratification of Hawaiian society. I then connect my discussion of these topics to broader discourses on Hawaii's transition from a collection of disparate chiefdoms to an archaic feudal state (Kirch 1984, McCoy

2006). I ground this problem theoretically by examining the archaeological and ethnohistoric evidence through the theoretical framework of political ecology. Through that framework, I make a case for the role of both agency and the environment in Hawaiian society's gradual transition from disparate chiefdoms to an archaic state.

Presented here are the results of research conducted during the summer of 2009 in Waiapuka *ahupuaʻa*, North Kohala district, on the northern tip of the island of Hawaiʻi. The goal of this field research was to identify and document further evidence of windward Kohala's unique gulch-to-tableland irrigation systems, following their initial discovery in 2008 by Drs. McCoy and Graves of the Hawaiʻi Archaeological Research Project (HARP). The field research was conducted as a field school, instructing undergraduate archaeology students in proper field methods. Finally, by drawing on the example of North Kohala's intricate gulch irrigation systems, I connect the case study of windward Kohala to the ongoing discussions surrounding the roles of agency and the environment in Hawaiian society's increasing complexity.

Based on a growing understanding of irrigation technologies and agricultural practices employed in windward North Kohala, I present the results of my application of geographic information systems (GIS) to model the potential of the windward North Kohala landscape to support irrigated tableland agriculture, based on known, historic era tableland agricultural sites. Preliminary analyses suggest that much of windward Kohala's sloping tablelands could have been extensively utilized for agricultural purposes, well beyond the scope that was recorded in the ethnohistoric record.

The significance of this research is to demonstrate the complexity of agricultural development in windward North Kohala, and to bring light to the processes of intensification at work in the windward gulch communities in contrast to the broadly studied leeward field systems. Furthermore, I discuss the application of spatial technologies to agricultural landscape archaeology, its role in this research, and its potentials for improving site prospecting within the region. By increasing general knowledge of the agricultural systems employed in North Kohala, I intend to generate a concise picture of the processes of agricultural intensification and optimization employed by prehistoric Hawaiians in the windward North Kohala region.

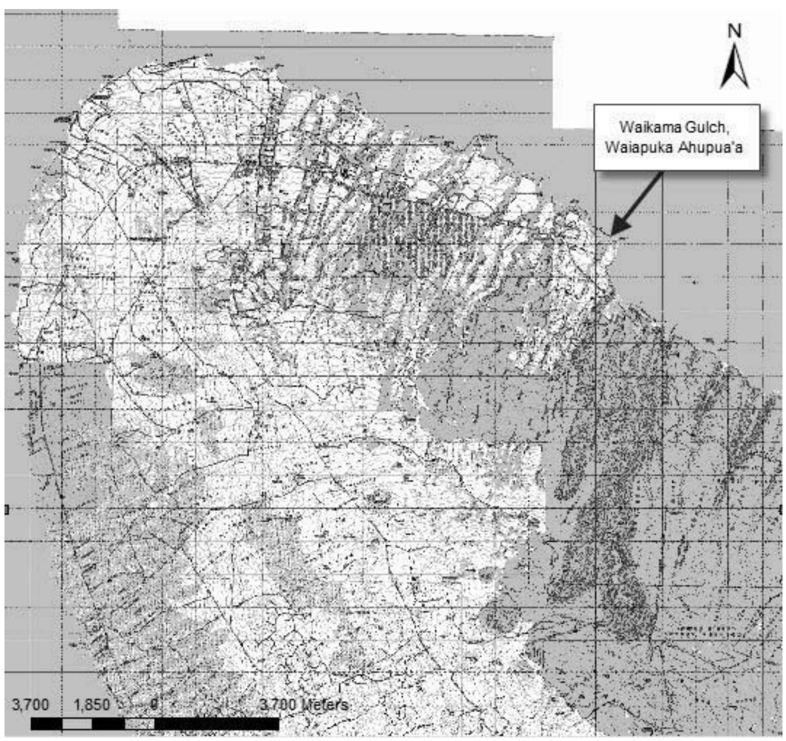

Figure 1.3: USGS contour map showing Waiapuka ahupua'a in the North Kohala district, Hawai'i Island.

Thesis presentation

Chapter 2 contains a brief sketch of the theories that influenced this research. First I connect agriculture to the formation of complex societies, through the lens of political ecology—a novel approach to ecologically-informed cultural archaeology that bridges political economy and practice theory to create an effective synthesis for examining social structures in light of the environment. I then address the wet and dry dichotomy of island environments and agriculture, and briefly review the essential elements of the hydraulic society theory, before offering contemporary views on the influence of water accessibility on power relationships and on the processes of social formation. Finally, I offer competing perspectives on landscape archaeology and spatial analyses—the principle methodological position of this research. Within this context I position myself between New World and Old World perspectives on landscapes in archaeology.

Chapter 3 addresses the natural and cultural history of the study area in the eastern gulch region of windward North Kohala, Hawai‘i Island. I briefly review the previous archaeology conducted in the region. I continue with an overview of the field research methodologies employed by the Hawaii Archaeological Research Project’s Summer Fieldschool 2009. Finally, I conclude with a description of the surveys and excavations conducted during that summer in Waikama Gulch, Waiapuka *ahupua‘a*, a territory in the eastern gulch region, where in previous years, the discovery of novel irrigation technologies started changing conceptions of agricultural land-use throughout the region.

Chapter 4 includes the spatial analysis undertaken to support the field component of this research. This chapter details the application of geographic information systems (GIS) to create a model that measures the potential for irrigated agriculture on the tablelands of the eastern gulch region of North Kohala, based on factors like the slope of the landform, and the proximity of known tableland agricultural sites to the gulch interfaces. I detail the methods used step-by-step, including the missteps and corrections made to the process. I then discuss the implications for expanded and intensified agriculture in the eastern gulch region based on the results of the GIS analysis.

In Chapter 5, I revisit the theoretical framework of political ecology, to examine the effects of agricultural intensification and technological innovations on Hawai‘i’ transition from a loose collection of disparate chiefdoms into a feudal society. I make a case for the role of environment in informing the processes complexity, while underscoring the importance of human agency. I compare and contrast my analysis of North Kohala with other island examples of the environment interplaying with social complexity. Finally, I conclude by connecting the processes visible in the archaeology and ethnohistory of North Kohala to broader perspectives on Polynesian prehistory.

Chapter 2: Theoretical Perspectives on Space, Power, and Complex Societies

Introduction

The following discussion elaborates on the theoretical concepts that have influenced this research. First, I address the concept of Hawaii as a complex society, steering away from the term's roots in early evolutionary theory, to examine the concept as a useful frame for thinking about the ecological and economic pressures that drive social change. I then connect these discussions to the theoretical framework of political ecology—a useful reframing of ecology, power and practice theory that has been increasing in acceptance and relevance in recent years. Finally, I conclude with a discussion of landscape archaeology, the debates surrounding its practice, and its application in this project.

Hawaiʻi as a model complex society

A key assumption of this research is that Hawaiʻi represents a model *complex society.* Complex societies are notable for having a strongly hierarchical organizing principle and complex ancillary structures that support the mandate of the ruling class, such as a strong religious or bureaucratic class to extend the influence of the ruling class (McCoy 2006; Kirch 2007; Scarborough 2008). Complex societies are in large part the products of a regime of agricultural intensification. Increased productivity, through the expansion of agricultural works and the innovation or refinement of agricultural technologies and techniques, allows for a segment of society to forgo a food-producing role in favor of artisanal or elite roles in an increasingly complex system (Wolf 1982; Smith 1993; Scarborough 2008). The social and technological developments described in this research, manifesting in the 13th century A.D. and persisting through the period of contact and the unification of the Hawaiian Islands, are demarcated by a transition from a simple subsistence economy based on discrete family units and locally defined tribelets, to a surplus-driven regime organized around an expanding elite class (Kirch 1985 and 1994; Ladefoged and Graves 2007). Much of this research is concerned with examining how agricultural intensification affected the power relationships between the food-producing commoners and non-food-producing elites.

Deployment of the term *complex society* as a descriptor of social development does come with some associations—both from specific case applications and from environmentally deterministic, unilinear evolutionary social theory. Though complex societies are frequently typified in the scholarship of New World and Old World civilizations as culminating in an increasingly urbanized population—as in Wolf's (1982) seminal survey of world history and Smith's (1993) study of agricultural intensification in pre-contact Central America—it is sufficient for the purpose of this research to restrict the definition of "complex societies" to the superposition of hierarchy over a society's means of production (Wolf 1982).

Social theorist Talcott Parsons (1971) explored the idea of social evolution, particularly as it relates to the formation of complex societies, extensively throughout his career. He defined cultural development as a series of processes informing a sequence of developmental stages, predicated on the concept that a society is comprised of interactive, interconnected systems. By Parson's reckoning these processes—including the differentiation of the core system into subsystems, the evolution of subsystems into discrete functional systems, the inclusion of novel elements into existing systems, and the legitimization of new systems by social reinforcement of power relationships—propel societies along a pre-determined continuum of social development, (i.e. a unilinear evolutionary trajectory). Essentially, according to Parsons, cultures progress from "simple" hunting and gathering bands, through increasingly developed agricultural societies, into a period of "classical" chiefdom or statehood, before finally achieving what he described as the "empirical state" of modernity (Parsons 1971).

Parson's model added a powerful coda to the anthropology of Leslie White (1949)—who championed unilinear evolutionary models predicated on a society's ability to harness 'energy' through labor and calorie exchange—but the essentialism of European culture in Parson's theoretical framework is its downfall. Particularly, it pales in comparison to the multilinear evolutionary theories of the Boasian anthropologists, the contributions of several of whom are discussed in greater detail below. For the purposes of this research, I emphasize the processes by which cultural change is achieved through the differentiation of modes of production, divorcing complex society from its classically understood trajectory towards a Western ideal of culture. The key challenge of thinking about the past in this way is in identifying lines of inquiry that reveal evidence of this social change.

Studies in paleodemography provide a useful means of accessing the unwritten social record of increasing complexity and change. Ladefoged and Graves (2007) emphasized a temporal approach—pioneered by McCoy (2000) and Ladefoged *et al* (2003)—in their analysis of North Kohala's leeward field system by modeling the chronology of the palimpsests of agricultural features, trails, and household sites. Ladefoged and Graves' research revealed several phases of expansion and intensification across their study area within the leeward field system of North Kohala, from as early as 1250 AD through 1600 AD, suggesting a rapidly growing population and mounting social pressures to generate surplus.

Ladefoged and Graves' case study demonstrates the degree to which social forces and the processes of intensification can be observed in the archaeological record. This thesis examines data from windward North Kohala that supports their conclusions of changing social dynamics within Hawaiian society. Chiefly, archaeological evidence demonstrates a concerted effort to intensify agricultural production in the region that is temporally coincident with a period of social stratification and elaboration of social roles in Hawaiian society—through prehistory, into the period of greatest intensification starting in 1400 A.D. and further, into the period of contact. Taken in light of the body of literature on the formation of complex societies, this thesis serves to further the argument that Hawaii represents a model for complex society in Polynesia.

Political ecology

Political ecology has become an attractive theoretical position in the past twenty years for addressing the intersection of ecosystems, political systems, and economic systems at the local, regional and global levels. In essence, political ecology refers to the study of how power relations influence, mediate, and redefine the relationship between humans and their environment (Biersack 2006). Political ecology is distinct but not wholly divisible from more conventional views of political economy, particularly at local and regional scales. The principle difference is that political ecology places greater emphasis on the role of environment in creating and shaping power relationships, rather than on pure economic forces. In a sense, political ecology acknowledges more explicitly that the fundamentals of economy are intrinsic to the environment. Political ecology takes ecological processes more seriously than political economy, which typically views them simply as natural resources to be abducted into the economy.

The concept of political ecology was first defined by Eric Wolf (1972) in order to describe the complexity of relationships between ecosystems, people, and power present in communities within Northern Europe's alpine forests throughout their history. Wolf continued to develop the concept throughout the remainder of his career, but political ecology also found purchase among many social researchers, who saw political ecology as useful theoretical approach to addressing economic and political disparities rooted in environmental issues in the modern Third World (Bryant 1998).

A key valence present in political ecological thinking is the acknowledgment of the symbiosis between political, social and economic structures and the environment. These relationships feedback on one another: as culture shapes the environment, so too does the environment shape culture. A strong political ecology approach will examine how people make decisions about their environmental context, with consideration to structural inequalities in class, wealth, and power dissemination, while simultaneously seeking to avoid the pitfalls of an environmentally deterministic, political economic perspective (Lansing, et al 2006; Scarborough 2008).

This reflexivity with respect to environmental determinism is in large part due to the infusion of "practice" to the theoretical mix (Biersack 2006). Theories of practice ascribe motives and agency to individuals and collectives of individuals. This creates a "practical logic" which is organized to effect the fulfillment of individual or communal goals (Bourdieu 1977, 1998). This can manifest as resistance (as to hierarchy, see Ortner 1974), or in the construction of systems of meaning (Flannery and Marcus 1993). The tacit (and sometimes explicit) acknowledgment of personhood is an important heuristic device for framing and interpreting archaeological data in such a way as to represent the irrefutable fact that past peoples were recognizably *people*. The addition of practice theory to political ecology further segregates it from mainstream political economy's roots in early Marxian thought, which remained mired in the social and political biases of its progenitor for decades, particularly with respect to Marx's treatment of economic production in Asia, which produced what Marx and others have described as "oriental despotism" (Wittfogel 1957, Kirch 1994, Scarborough 2008).

Political ecology, as a theoretical perspective, has been underutilized in contemporary archaeological research. The primary value in this approach is that it deemphasizes simply looking at the way resource availability fueled the growth of society, as was common among cultural ecologists, but focuses on the ways that people's interactions with the natural environment shaped the formation and maintenance of social roles (Lansing, et al 2006). In Scarborough, Lansing and Schoenfelder's (1999) investigation of a Balinese *Subak* water temple and its associated agricultural complex, the researchers discovered that the contemporary agricultural landscape was the product of hundreds of years of construction and reconstruction of related systems, in a process that was constantly being renegotiated by local stakeholders—the priests, peasants and chiefs who either worked the land or benefited from the labor of local farmers. This process of negotiation served alternately to ensure a constant food supply and to validate and reinforce the social hierarchy in the *Subak* district, through ritual and tradition. Similarly, an objective of this thesis is to consider how the processes of agricultural expansion and intensification into increasingly marginal landscapes fulfilled the same purposes in the eastern gulches before the period of contact.

Like landscape analysis, discussed in greater detail below, political ecology is tied deeply to place, but it is also sensitive to a key element of archaeological research—temporality. The key to unraveling the ecological pressures exerted on the formation of social systems is through accessing the social memory constructed around the use, distribution and management of the landscape.

Hawaii has a rich oral tradition and benefits from an extensive ethnohistoric documentary record (Sahlins 1958 and 1985, Kirch 1984, Cordy 2000, for starters). By engaging the relevant literature, I intend to trace the social memory of institutions constructed around the management of land and resources in the North Kohala region, and relate that discussion to the archaeological evidence for agricultural intensification in the eastern gulches, drawing on examples set by Hodder (2004) and McCoy (2006). The dearth of intact settlement sites in the eastern gulch complex, due in large part to the effects of the sugarcane industry in the region requires that I take a sensitive approach to interpreting the social landscape from the material and written records (McCoy 2006). Studies set in North Kohala's benefit from the fact that the region's most famous resident, Kamehameha the Great, has been the subject of much scholarship. Furthermore, the Great Mahele land division has been subject to copious analysis, which provides provocative details regarding the apportionment of lands and their use in pre- and post-contact North Kohala.

The wet and the dry

As stated above, the contrast of wet and dry landscapes influenced the social world and the formation of hierarchical society throughout Polynesia. In fact, the wet and dry dichotomy is the essential contrast in discussions of Hawaiian agriculture (Kirch 1977, 1985 and 1994). The discussion of the wet and the dry resumes here, as it directly connects discussions of political ecologies and the formation of complex societies in Hawaii. The wet and dry dichotomy in Polynesia, discussed at length by Kirch (1985) owes its theoretical genesis to natural historian Karl Wittfogel (1957), whose *hydraulic society theory* (also called the "hydraulic hypothesis") posits that in societies dependent on large scale hydrological works (i.e. irrigation systems) for agricultural success, a centralized leadership and bureaucracy will emerge to manage, direct, and control water resources.

Wittfogel's analysis focused on the "great civilizations," including Egypt, Mesopotamia, Peru, China and India, for which there was the greatest amount of evidence at the time he wrote, and which were already largely acknowledged for their advanced social systems which stretched into antiquity. However, the underlying principle of his position is so generally applicable that it merits further discussion with respect to the case of Hawaiian agricultural and social development. Wittfogel's theory, when applied to the Hawaiian Islands and Polynesia in general, is perhaps most notable for being so dramatically inverted from his basic hypothesis. In fact, as Kirch (1985) contends, the most rigid, state-like, hierarchical, and expansionist societies formed in the regions of Polynesia that experienced the greatest paucity of resources—that is, in territories with either limited water resources (i.e. leeward Kohala) or challenging terrain and conditional or seasonal water availability (i.e. windward Kohala).

Despite seeming only to validate the idea that agriculture was a key element of complex society, Wittfogel's hydraulic hypothesis did serve to influence future theorists. Key among those theorists influenced by Wittfogel was Julian Steward. Steward, a student of Kroeber and Lowie, was among the direct heirs of the Boasian school of anthropology. The product of ethnologist Franz Boas, the Boasian approach to anthropology strayed away from the "orthogenetic," unilinear models of cultural evolution in favor of less deterministic, human-centric models of cultural evolution that ascribed particular importance to the social environment's role in the acquisition of cultural traits (Trigger 1996). Steward is most renowned for having championed the idea that human-environment interactions influenced the formation and trajectory of culture in a theory he termed *cultural ecology* (Steward 1955).

Steward, like Boas before him, espoused a multilinear perspective of cultural evolution, suggesting that the environment has more influence on the formation or acquisition of cultural traits than the deterministic evolutionary models of Parsons and White. Steward was drawn to Wittfogel's theory because it connected basic technological components of subsistence practices (particularly water and irrigated agriculture) to an evolutionary model that lacked a direct bias towards a Western ideal of progress towards urban city-states, and instead focused on the social and political consequences of intense water management (Scarborough 2008). Thus Wittfogel, despite his extremely generalized perspective on the consequences of irrigation on culture, prompted Steward to create a more nuanced approach to human-environment interactions that is still highly influential among archaeologists today.

Although Wittfogel has been largely relegated to the sidelines in all but very specific discussions of hydrology and human water systems, his influence on Steward, and Steward's subsequent theoretical contributions by way of cultural ecology, have had a lasting impact on arguments about the environment's impact on cultural evolution. Even though Wittfogel's model was deterministic in nature, suggesting that cultures progressed through specific and ordered stages, it was also largely free of the Western bias espoused by mainline unilinear evolutionary theorists like Parsons and White. Steward's multilinear evolutionary model more readily accepts case studies that defy the researcher's expectations, because the theory does not presuppose a particular ideal end—it only posits that societies increase in social and political complexity as they grow. Steward stands in clear contrast with Parsons and White, whose contributions to evolutionary theory, though valuable, were ultimately less significant than those who they inspired to go beyond the essentialist, Euro-centric models that they themselves are remembered for.

The contrast between wet and dry agricultural systems is highly visible in North Kohala district—perhaps more so than anywhere else in Hawaii. The eastern gulch region, with its deep drainages and ample rainfall, is an ideal locale for wet agricultural systems. Intra-gulch agricultural systems included terraced pondfields (*lo'i*) suitable for the cultivation of taro, as well as intricate irrigation ditches (*auwai*) that extended the taro pondfields to the tablelands between the gulches. The flow of water through the gulch system was malleable to the degree that seasonal restructuring of agricultural features could dramatically affect the dispersal of water throughout the system: in drier times, tableland plots could be foregone to ensure that more water reached plots at lower elevations, while wetter seasons allowed for the expansion of irrigated systems. In contrast, just a few kilometers away on the leeward side of the peninsula, the expansive dryland system of North Kohala produced sweet potato and yam in abundance and afforded scrub for domestic swine, in an arid environment prone to high winds and markedly little rainfall.

Hydrology is unquestionably important to the pursuit of agricultural successes, but it is just one factor of many that informed the decision making processes of ancient farmers. For a more comprehensive examination of environmental factors, it is necessary to view them from a holistic perspective that brings to bear a nuanced theoretical background with mechanisms to interpret evidence extant in the natural and the modified environment. To that end, I address the intersection of theory and space in a discussion of landscape archaeology in the following section.

Landscapes defined

Landscape archaeology is a broadly synthetic approach to the study of past peoples, incorporating elements of physical geography, ecology, settlement pattern studies, and regional analysis. In its simplest form, landscape archaeology can be defined as the study of the spatial relationships between cultural sites (Binford 1982). However, more nuanced approaches to landscapes demonstrate a complexity of theoretical and methodological concerns. For the purposes of this project, the term landscape possesses dual meanings. The term describes both the natural landscape—the physical environment as experienced by past peoples, the ecology and physical world—and the social landscape—the environment as modified, transformed, and "lived" by its inhabitants.

Landscapes, as units of analysis, have been approached in diverse ways, and have been a site of contention in recent archaeological thought. The fundamental divide in landscape archaeology is reducible to a difference in the application of quantitative and qualitative methodologies by practitioners from around the world (Trigger 1996). On one hand, the New World landscape archaeologists, whose approach is rooted in settlement pattern studies, have widely embraced the tools of physical geographers—namely Geographic Information Systems (GIS)—to better quantify and visualize the spatial relationships between archaeological sites within a complex or across whole regions. On the other hand, many Old World landscape archaeologists have adopted a more subjective approach to landscapes rooted in post-modern interpretive methodologies, by placing an emphasis on chronicling the researcher's experience of space or place as an approach to understanding the experiences of past peoples in their environment. It is in this fundamental difference that the seed of debate has taken root.

The landscapes debate

The dichotomous approaches of Old World and New World archaeologists have been the subjects of extensive debate (see Trigger 1996, Hodder 1991 and 1999, Ashmore 2002, and Flemming 2006 for some examples). Post-processual interpretive methodologies, rooted in post-modern phenomenology, have been employed to connect ancient architecture to the surrounding landscape (Hodder and Cessford 2004); in contexts in which the excavation of a site would be politically or culturally inappropriate; and in analyses of regional complexes of monumental features, as in the case of Tilley's (2004) study of early English barrows. As a further consequence of this emphasis on experiential methods, the interpretations made by many Old World landscape archaeologists are often laden with subjectivity and are ultimately untestable, or achieve paradoxically irrefutable conclusions based solely in the unique experience of the researcher (Flemming 2006).

The post-processual interpretive methodologies championed by Shanks and Tilley, Hodder, Patterson, and others, often rely less upon empirical studies of the archaeological record, and more upon the researcher's experience of the study environment and of the "lived" spaces of past peoples in the present (Shanks and Tilley 1988). Strongly hermeneutic and rooted in phenomenology, this approach to ancient landscapes generates intriguing, occasionally useful narratives that are often organized around the construction of meaning and metaphor as a key component of the interpretive process (Patterson 1989; Hodder 1991). According to Trigger (1996: 473), "A major weakness of many of these studies is their failure adequately to use the detailed information about ecological and sociopolitical behavior that archaeologists have already inferred for the specific societies being studied." Still, the experiential approach employed by many Old World landscape archaeologists has value when applied in the appropriate contexts, or as an ancillary component of a more scientifically rigorous investigation.

By contrast, New World landscape archaeologists have been criticized as being unreflexive in their application of new technologies and quantitative methods (Flemming 2006; McCoy and Ladefoged 2009). Landscape archaeologists of this stripe have been accused of being over-empirical and prone to lapsing into scientism, and for veering towards environmental determinism (Tilley and Bennett 2004). These criticisms have been met with the questioning rebuke: can archaeologists—or scientists in general—be "too rigorous" (Flemming 2006)?

This arm of landscape archaeology has its roots in the cultural ecology of Julian Steward (Kantner 2007), whose theoretical contributions to this research were discussed in greater detail with respect to wet and dry environments. The "New Archaeology" that began to formalize in the 1960's turned still greater attention to landscapes and regional studies, in tandem with a growing interest in quantitative analyses within the discipline (Kantner 2007). In recent years, the adoption of spatial technologies, such as geographic information systems (GIS), global positioning systems (GPS), and remote sensing technologies (RADAR, LIDAR, satellite and aerial sensor platforms), has lead to a methodological renaissance with respect to how archaeologists "find and record archaeological remains, manage data, and investigate the historical relationship between our species and the world around us" (McCoy and Ladefoged 2009: 279). In essence, the application of geospatial technologies in archaeological research has afforded archaeologists unprecedented new tools for collecting and analyzing increasingly large quantities of data, transforming the very nature of what constitutes data, and enabling us to draw meaningful connections across ever wider temporal and spatial scales.

Critics on either side of the divide within landscape archaeology are accurate to a point, particularly when addressing the outliers at theoretical extremes. A strong synthesis that falls near the center of this theoretical spectrum is preferable to strict adherence to interpretive or empiricist methodologies. Wendy Ashmore addresses the potentials of a reflexive "spatial archaeology" that embraces diverse theoretical approaches, the potential for multidisciplinary inquiry, and flexible methodologies to "explore more of the gamut of spatialized contributions toward understanding human lives, ancient and modern" (Ashmore 2002: 1180). It is in this hybrid theoretical space that landscape approaches become most effective for exploring the relationships between people, place and wider socio-political contexts.

This thesis is located firmly in that "hybrid space," in order to generate a practical synthesis of social and spatial data that encompasses the regional particularities of the eastern gulch system, and connects them to wider horizons of land use throughout North

Kohala and the Hawaiian Islands in general. The lines of data considered in this thesis include geospatial analyses of the study area, the physical reconnaissance and excavation of features within North Kohala's eastern gulch complex, and the ethnohistoric literature of Hawaiianist scholars. In examining these diverse lines of evidence, archaeologists can address the processes by which complex social systems are formed (McCoy 2006).

Agricultural systems, intrinsic as they are to the development of complex society, are an important locus in the power economy of place and demand special study (Ladefoged, *et al* 2003; Ladefoged and Graves 2007; Scarborough 2008). Applying methods of spatial analysis, particularly centered on quantifying the density of agricultural production, I intend to examine the intra- and extra-territorial pressures that influenced the social and agricultural development of the windward North Kohala region, and connect the region to wider horizons of social change in the Hawaiian Islands.

Applying landscape theory in analysis

In the context of this research project, landscapes—as both the physical environment and as a product of human action—provide the root of comparative analysis. An approach that synthesizes the tools of New World and Old World landscape archaeology is pragmatic for achieving both goals—first, through the application of spatial analysis to examine the processes of agricultural intensification in the eastern gulches, and then by relating the analysis of the eastern gulch region to broader patterns of social change throughout Hawaii. The *ahupua'a* of the eastern gulches of windward Kohala represent a discrete region, connected by social and political ties to neighboring regions. A landscape approach to the analysis of agricultural features within the eastern gulches serves two major functions. The first is to help create an understanding of the use of space within the gulches and on their adjoining tablelands—essentially, to model using geographic information systems, the potential extent of agricultural works within the eastern gulch *ahupuaʻa*. This approach to identifying potential agricultural plots is particularly useful with respect to the tablelands between the gulches due to on-going disturbance regimes affecting the area—namely the cattle ranching enterprises and terrain modification conducted by modern day trustees. Most, if not all of the tableland plots have been disturbed beyond recognition, thus a model drawing on known examples is useful for inferring the extent and type of land use occurring in the affected areas.

The use of predictive models for locating archaeological sites has received significant criticism for being environmentally deterministic and for drawing on overly-generalized assumptions about the behavior of past peoples (Wheatly 2002). I defend its applicability in the case of windward Kohala on the grounds that the phenomenon I am searching for—the expansion of agricultural infrastructure to the tablelands between the gulches—is clearly evident in the archaeology of the gulches. The predictive model in this case serves as an inferential tool through which the scale of the phenomenon can be explored. This undertaking requires an understanding of the relatedness between sites visible within the gulches, as well as a degree of inference—based on known phenomenon—transposed to areas that have not yet been the subject of ample reconnaissance, or contain archaeological contexts that have been destroyed or deeply disturbed by more recent phenomenon such as the introduction of cattle, sugarcane and guava to the landscape.

The application of GIS to this problem is particularly valuable, given the software's capacity to generate multiple working models based on parameters defined by the user (Conolly and Lake 2006). In the case of this project, a GIS model was generated to reflect the maximum possible extent of tableland agriculture based on the grade of slope of the landscape. Areas of extreme slope, estimated as being in excess of 20% grade, were omitted under the assumption that water would move too swiftly to effectively irrigate a plot of land. Additionally, areas with minimal slope, identified as having less than a 10% grade, were omitted under the assumption that water would be unable to be moved efficiently out of the gulches. Further refinements resulted in two models, one describing an "optimal range" and another describing the "maximal extent" of potentially arable tablelands. A detailed discussion of these models, their implications, and their shortcomings is presented in a subsequent chapter.

The second function of landscape analysis in this project is as a framework to consider the broader implications of agricultural intensification in the eastern gulches and then connect them to the wider social and political world of North Kohala and Hawaiian society in general. In this capacity, landscapes serve as useful proxy for engaging in discussions of regionality. Kirch (1985: 89) contends that "one of the main aims of Hawaiian archaeology is to discover and explain… patterns of cultural variation over time and space." By analyzing local variations in cultural development across the islands, a broader perspective can be achieved that attempts to engage with and explain the differences and congruencies in cultural sequences and culture change visible in the archaeological record across the Hawaiian Islands (Kirch 1985).

In its most basic sense, a region represents a large, continuous spatial association. The eastern gulches thus describe a region that extends from the community of Hawi in the northwest, to the Pololu Valley in the southeast, and well into the upland slopes of Mount Kohala. In contrast, the extensive dryland field system associated with Lapakahi on the leeward side describes another region in close proximity to the eastern gulches. Given their geographical nearness and political association as parts of the Kohala *moku*, it is safe to reason that the social and economic pressures that played out in one region, impacted the other, despite their ecological differences—and by further extension, that inter- and extra- island exchange played a significant role in transporting social, political and technological concepts throughout the islands (Kirch 1985 and 2000). In addition to examining the processes of agricultural intensification at work in the eastern gulches, a significant goal of this project is to contribute to the ongoing conversation about the processes of social change that affected not only North Kohala, but that operated upon the whole of Hawaiian society in the centuries preceding European contact. It is in the creation of this synthesis that political ecology and landscapes become inexorably connected.

The analysis of ancient water systems provides a particularly efficacious avenue for the application of geographic information systems and landscape approaches in archaeology. Given that water systems are frequently large and distributed modifications to landscapes, the capacities that GIS lends researchers to quantify and relate fragmented complexes of features at various scales is ideal for archaeological analyses of human-modified hydrology. To that end, a number of studies have utilized geographic information systems, in conjunction with traditional survey methods, to model and analyze systems for moving water.

As noted above, Lansing *et al* (2006) utilized geographic information systems extensively to describe the metaphorical "structures of the *longue durée*" by examining the physical structures underlying the irrigation networks of the *Subak* water temples of Indonesia through cycles of reconstruction that extend from the present, deep into archaeological time. They treat the water system as an intrinsic component of its client communities, as site to continually revisit and renegotiate relationships and community bonds. Lansing and his collaborators' study is a model for bridging spatial analysis with theoretically rich analyses of the recent and ancient past, and is a principle inspiration for this research.

Likewise, Crook's (2009) model of the hybrid floodwater fed/run-off fed irrigation system at Wadi Faynan in Jordan demonstrates the efficacy of models as tools to infer and reconstruct past systems. While the Wadi Faynan example has the relatively narrow focus of a single community site, the idea that basic attributes of the landform can be used to construct a valid model of the hydrologic past for archaeological purposes is essential to this research. On a larger scale, Ladefoged *et al*'s (2009) discussion of the opportunities and constraints affecting agricultural development in the Hawaiian Islands, applied GIS models to assess the distribution of rain-fed and irrigated agricultural sites across the islands. In many respects, the research in this thesis is a continuance of the broader theorizing and modeling conducted by Ladefoged and his collaborators.

Summary

The communities of North Kohala's eastern gulches are a prime example of how the ecological pressures extant in a region influence the formation of increasingly complex social systems over time. Agricultural intensification into increasingly marginal territories is an indicator of both a growing population and of mounting social pressure for cultivators to generate a surplus for redistribution among individuals with non-food-producing social roles. In the period of between 1400 and 1600 A.D., North Kohala observed both significant agricultural intensification, reflected in the eastern gulches as the development of tableland agriculture as an ancillary component of intra-gulch agricultural systems, and increasing social stratification commensurate with social processes occurring throughout Hawaii at that time. A landscape perspective is ideal for connecting the social and technological phenomenon visible in the archaeology of the eastern gulches to wider horizons of social complexity visible in Hawaiian prehistory. Political ecology, with its roots in the cultural ecology developed in the 60's and 70's, provides an invaluable analytical framework for examining the interplay of ecology, economy, and the social in formation of complex societies. In the following chapters, I will narrow my focus on the specific research undertaken in the eastern gulches and begin to relate that data to these theoretical perspectives.

Chapter 3: The Windward Kohala Study Area: Natural Environment, Field Survey and Methods

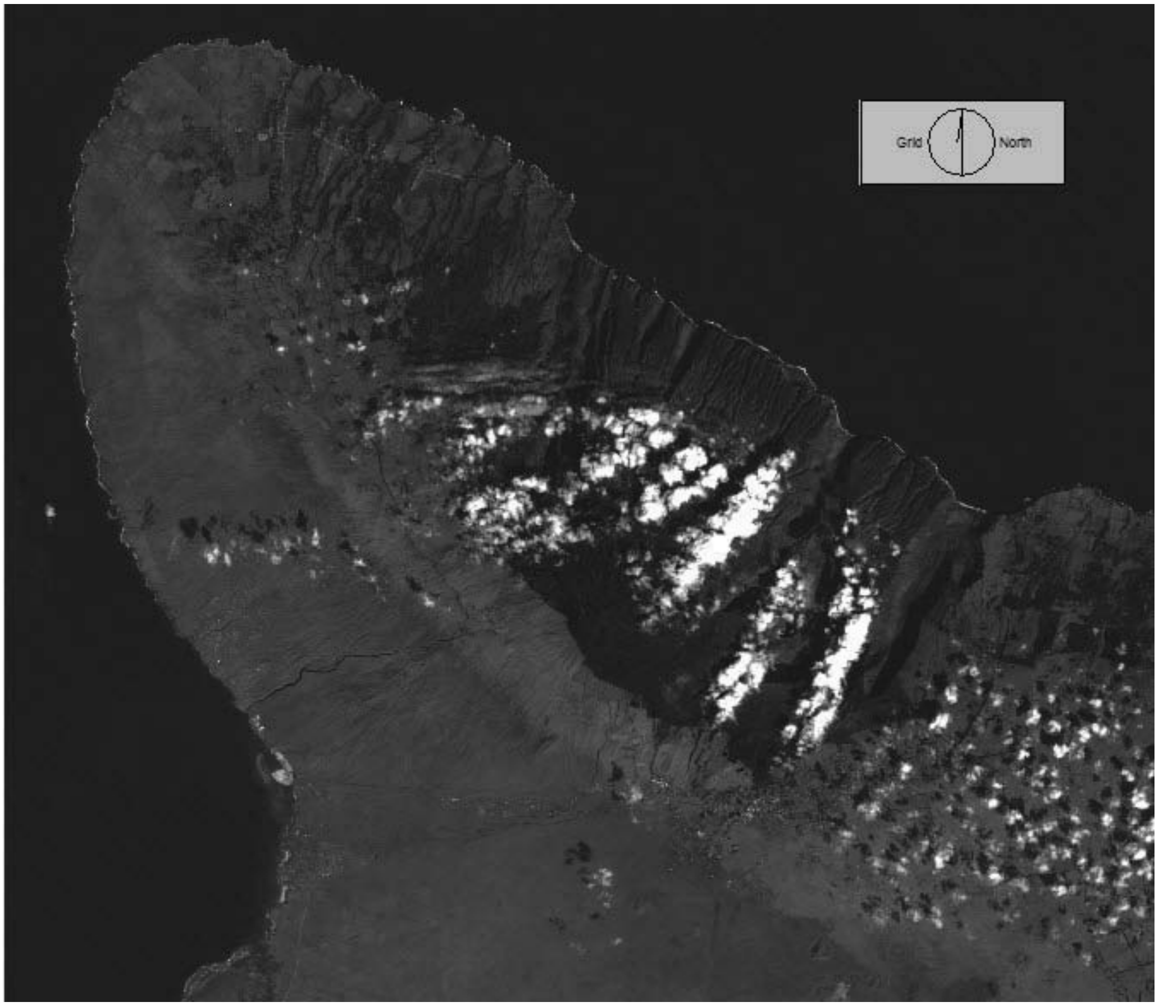

Figure 3.1: The North Kohala district, illustrating diverse climate zones. Source: Landsat Thematic Mapper.

Introduction

This chapter focuses on windward North Kohala's eastern gulches, the primary area of study for this research. In this region we can see the interaction of environmental and human forces in complex ways that both build our ability to understand the workings of political ecology and in ways that confound that endeavor. Part 1 of this chapter addresses the natural environment of windward Kohala—the ecological side of this equation. While the natural history of the region gives us clues to the agricultural developments made there, North Kohala's history of rough interactions with various post-contact industries beginning in the European era have altered the landscape and the quality of archaeological preservation throughout the region. Part 2 is a discussion of the field methods employed during the summer 2009 research season in Upper Waiapuka *ahupua'a*; specifically that community's Waikama gulch, which houses dozens of agricultural features including the clearest indication of irrigated "tableland agriculture" to date. Finally, part 3 of this chapter presents the results of three weeks of excavations conducted in Waikama gulch, including mounting evidence for intensified agriculture on the region's inter-gulch tablelands.

Part 1: The North Kohala Study Area

The North Kohala region is the northern most projection of Hawai'i Island. The peninsula represents the seaward slopes of Mount Kohala, the oldest of Hawaii Island's volcanoes. The region is, notably, the ancestral home of Kamehameha the Great, who unified the disparate chiefdoms of the Hawaiian Islands into a single kingdom in the early 19th century (ca. 1810). In what follows I describe the area in detail and examine the specific evidence that supports interpretations of agricultural development. This evidence is complicated, however, by the forces both natural and cultural, particularly the extensive history of disturbance in the area.

A history of disturbance

This area has seen numerous turbulent shifts in usage. The 1830's saw the rise of the Hawaiian sugarcane plantations, a statewide industry that reached its peak production in the 1960's (USDA-NASS 2008). Widespread sugarcane cultivation caused serious ecological degradation of the landscape. Beyond this, it had relatively dire effects on the preservation of many of the archaeological sites in the North Kohala region—in particular those features on the region's vulnerable tablelands. Much of the windward landscape was cleared to allow for sugarcane cultivation, which has accelerated soil erosion and post-depositional perturbation of archaeological features and sites. The imposition of large-scale ranching enterprises subsequent to the sugar industry's hold on the region further impacted the integrity of the archaeological record by introducing free-range cattle to the detriment of previous agricultural endeavors (Tuggle and Tomonari-Tuggle 1980, Kirch 1985, Tomonari-Tuggle 1988, McCoy and Graves 2007 and 2008). In addition, large tracts of the upland tablelands were at one time or another bulldozed or otherwise razed in order to clear them of rocky detritus—which undoubtedly included archaeological materials. Many portions of the uplands are presently subject to regular and potentially damaging efforts to reduce overgrowth by invasive species such as the widespread strawberry guava plant (*Psidium littorale*), through such means as tractor mowing or chain-towing.

The combined impact of these long-term disturbance regimes on the archaeological record of windward Kohala is that a substantial portion of the intact agricultural deposits in the region have been isolated to within the extensive gulch network that transects the slopes, where the preservation of agricultural deposits remains quite good. The extent to which the elevated tablelands between the gulches were utilized by ancient farmers has been obscured by post-contact interventions on the landscape and researchers must largely rely upon indicators within the gulches to make a case for agricultural expansion onto the tableland surfaces. Despite the loss of tableland features and the ongoing disturbance regimes affecting the area, windward Kohala remains one of the best preserved regions in Hawai'i, and much of the upland and portions of the coastal archaeology is protected by dint of private land ownership or limited access regulated by regional land trustees and organizations such as the Kamehameha Schools, the Surety Kohala Corporation and their lessees.

Agricultural opportunities and pitfalls in the natural environment

Mount Kohala rises 1,699 meters (5,480 feet) above sea level and has remained dormant some 120,000 years. The first of the five major volcanoes to breach the surface of the Hawai'i Hotspot to form the Big Island of Hawai'i, the soils of Mount Kohala's slopes are some of the most fertile to be found in the Hawaiian Islands, owing to the island's relative "youth" in comparison to its sister islands (Vitousek, et al 2004, Chadwick, et al 2006). The Kohala landscape was formed over hundreds of thousands of years in two eruptive series. The earlier Pololū Volcanic Series, which occurred approximately 450,000 years ago as Mount Kohala first breached the ocean surface, laid down layers of basaltic bedrock which were subject to a long period of erosion that resulted in the V-shaped valleys that characterize the central windward coast (Tomonari-

Tuggle 1988). The later Hawi Series, which occurred between 120,000 and 260,000 years ago, deposited primarily andesites over a portion of the extant Pololū Series basalts (Tomonari-Tuggle 1988, Vitousek, et al. 2004, McCoy and Graves 2007).

For ancient farmers growing food in the eastern gulch region, the distinction between soils derived from the earlier Pololū Series or the later Hawi Series might have been an important selection criterion when choosing potential sites for cultivation. Soils derived from earlier volcanic series are more likely to have been depleted of nutrients as a result of erosion and other ecological processes, and are thus more sensitive to anthropogenic land degradation, while soils derived from more recent volcanic series are likely to have higher soil nutrient levels (Vitousek, et al. 2004). Ancient farmers would have been able to observe these differences over time: by noting differing crop yields in plots in close proximity but in different soil series, and through continued trial and error, before eventually becoming common knowledge. There are confounds of course: the constant colluvial action within the gulches serves to enrich the soil within them, while the constant battery of rain and wind on the uppermost heights of North Kohala rendered the soils unfit for agricultural. In fact, evidence suggests that low soil nutrient levels (i.e. low soil fertility) likely precluded dry land agriculture in the uplands of the older islands, as a task too labor intensive for its limited returns and its vulnerability to relatively minute changes in the environment (Vitousek *et al*. 2004).

Yet here in North Kohala, the diminishing returns for investments made in dry land agriculture, as well as the demands placed on the citizens of dry *ahupuaʻa* to intensify agricultural production, likely predicated the increasing social and political complexity that began to emerge late in Hawaiian prehistory. Ultimately the pressures of scarcity on growing populations likely fomented the rise of aggressive, conquest-driven chiefdoms such as Kamehameha's in Kohala (Kirch 1984, 1985 and1994; Ladefoged, et al. 2000; Vitousek, et al. 2004). On the other hand, irrigated agriculture as was practiced in windward Kohala's gulches and in windward valleys across the island chain, produces greater yields with a smaller investment of labor and could be managed by small social groups under the direction of a local chief (Earle 2000). In a practical sense, the eastern gulches were likely an important strategic resource within Kamehameha's dominion.

Agriculture on the leeward and windward zones

The North Kohala landform projects north-by-northwest, availing the long eastern coast of the peninsula to wet weather carried by the north-easterly trade winds to the island. On the windward slopes, rainfall varies from 1,500 millimeters (59 inches) a year at the coast to as much as 5000 millimeters (+196 inches) or more at the mountain heights. By contrast, the leeward Kohala coast receives as little as 120 millimeters (4.72 inches) of precipitation a year. These wide variations in precipitation levels, as a consequence of the mountain's influence on prevailing weather patterns, results in starkly contrasting biomes between regions in relatively close proximity to each other. The dichotomy of wet and dry landscapes had an unmistakable impact on the development of Hawaiian social and agricultural systems; and indeed, this can be seen in analogous systems across Oceania (Kirch 1985 and 1994).

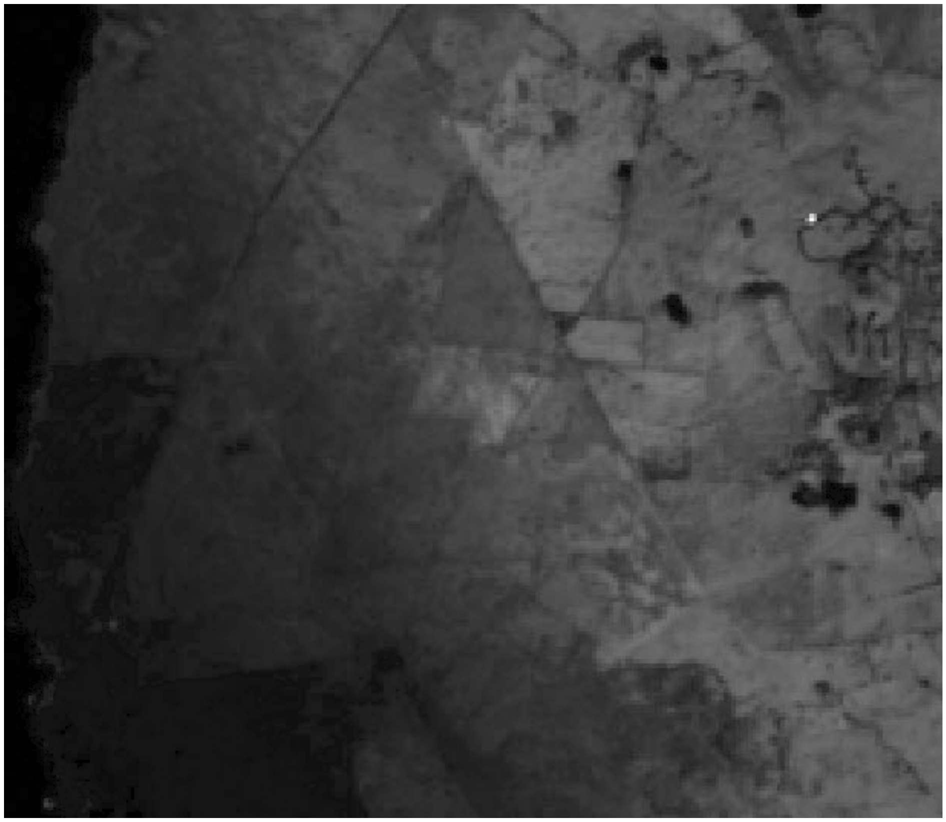

Figure 3.2: Remote sensing technologies reveal a palimpsest of old and new field boundaries in leeward Kohala. Source: Landsat Thematic Mapper.

The windward side of North Kohala has been subject to considerable erosion from constant exposure to wind and rain which has created extensive networks of gulches and valleys. Since the study area encompasses the eastern-most network of these gulches, it has come to be referred to as the "eastern gulches." The largest of windward Kohala's erosion features; the Pololū Valley defines the south-eastern boundary of eastern gulch region and is the northern-most of a sequence of v-shaped valleys that extends down to Hilo Bay on the central-eastern coast of the island. North of Pololū is the eastern gulch region of North Kohala, an area encompassing roughly 49 square kilometers of territory from the coast into the uplands. The windward side of North Kohala has been subject to some limited archaeological survey for academic or cultural resource management purposes (Tomonari-Tuggle 1988, McCoy and Graves 2007 and 2008 are most notable). However, it has largely been overlooked by researchers in favor of the sprawling dry land field system associated with Lapakahi on the leeward side (Ladefoged and Graves 2007, Ladefoged *et al.* 1996, 1998, 2003, 2005; Vitousek *et al* 2004; and others).

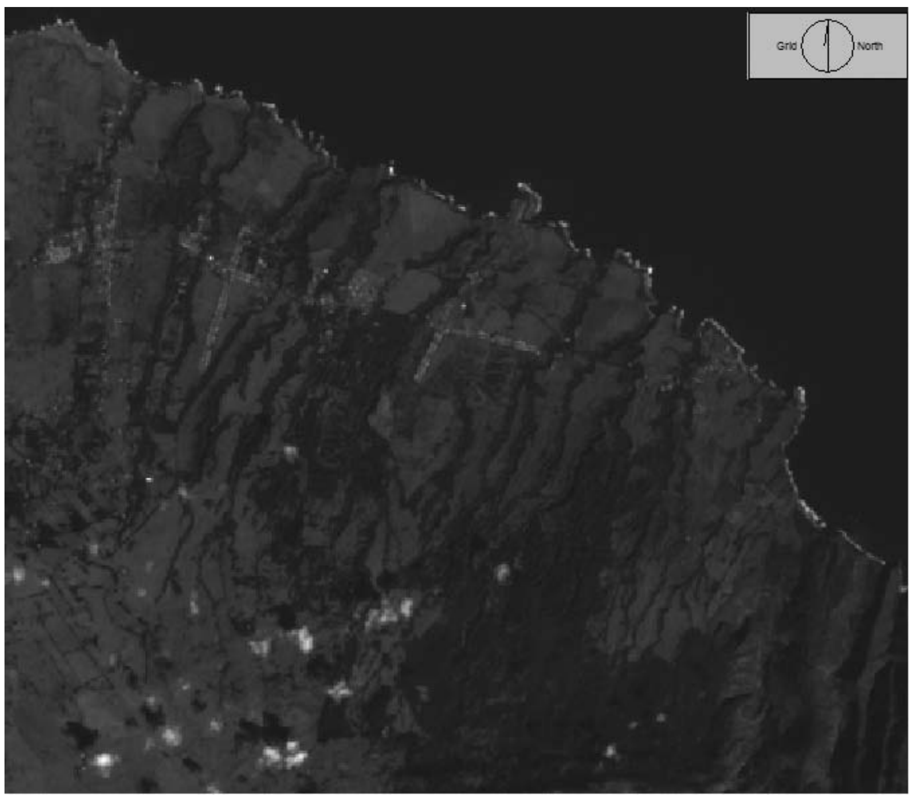

Figure 3.3: The eastern gulches of windward North Kohala. Source: Landsat Thematic Mapper.

Eastern gulch ahupua'a: a case study in wet agriculture

Although the field component of this thesis focuses on research undertaken in Waiapuka *ahupua'a*, the windward HARP study area extends northwestward into neighboring communities. In total, the study area encompasses five community districts organized around the eastern gulch system (see Table 3.1). Halawa, Makapala, Niulii and Waiapuka *ahupua'a* have coastal access, while the fifth, Aamakao *ahupua'a,* is situated inland. Niulii, Makapala, Waiapuka, and Halawa have so far been the subjects of HARP's research program (McCoy and Graves 2007 and 2008), while Aamakao has yet to receive significant coverage. Features in the eastern gulch communities share similarities in form and function, consisting largely of agricultural deposits. Terrace weirs (*lo'i*) and irrigation ditches (*'auwai*) are typical of components throughout the archaeological complexes.

The principle investigators have imposed the distinction between "upper" and "lower" territories in the eastern gulches in order to demarcate research zones on the landscape. This arbitrary distinction has been set at 750 feet above sea level, above which is the uplands, and below which is the lowlands. In reference to specific excavations, the term "level" is used to describe arbitrary splits imposed by the excavators, while the term "layer" describes natural changes in the deposits. The term *lo'i* is used specifically to reference pond field terraces and *auwai* to reference irrigation ditches.

Ancient and historic irrigation

The defining characteristic of the study area is the extensive network of gulches and drainages that transect the windward slopes of Mount Kohala and the elevated tablelands between them. The gulches generally range between 50 meters and 100 meters across and some run as far as 5000+ meters from the coast into the uplands (as in the case of Waikama gulch). There are numerous complexes of highly visible agricultural features within the gulches that indicate that extensive irrigated agriculture took place in the stream beds; however, the tablelands between the gulches have largely been cleared of surface architecture. The potential use-life of the tablelands requires further investigation, particularly with respect to how the known agricultural features within the gulches might have interacted with now-lost tableland agricultural sites.

Figure 3.4: A tableland surface flanked by over-grown gulches. A flat surface such as this is ideal for agriculture. Photo by author.

The gulch region of windward Kohala is characterized by the presence of seasonal arroyos that begin in the uplands and course down to the coast. The water flow in the upland gulches is highly variable and appears to be based primarily on seasonal rain fall and the limited occurrence of natural springs. Local knowledge contends that temporary or intermittent springs might have fed the gulches in the uplands more extensively—but not in recent memory—and that many active springs were most likely disrupted as an indirect result of the construction of the Kohala Ditch

The Kohala Ditch is one of the most notable historic features on the North Kohala landscape. Designed by renowned civil engineer M. M. O'Shaughnessy, the Kohala Ditch was a large-scale water project undertaken between 1905 and 1907 in order to feed an increasing demand for water by the district's then-growing sugarcane industry (Wilcox 1998). The effects of the ditch's construction on small springs and aquifers throughout the gulch region are difficult to measure as many were left unrecorded by early geological surveys or were seasonal and intermittent to begin with (McCoy and Graves 2007). We can, however, surmise that the creation of the Kohala Ditch did change the hydrology of the eastern gulches significantly from its pre-contact conditions by altering the upland water table (Wilcox 1998). A 1919 USGS report on "The Water Supply of Hawaii" noted that the Kohala Ditch "diverts water from a larger number of small streams," with a variable flow rate from 6 million to 32 million gallons per day (USGS 1919: 158). The confounding factor of this massive water project needs to be kept in mind constantly when drawing conclusions about ancient irrigation patterns from contemporary assessments, satellite imagery and on-the-ground survey.

Part 2: Field survey and methods

In the summer of 2009, I participated in the continuation of the Hawaii Archaeological Research Project's (HARP) windward Kohala archaeological field school as a graduate student instructor. The windward Kohala component of HARP is directed by Drs. Mark D. McCoy (University of Otago) and Michael Graves (University of New Mexico). My primary research objective was to continue to investigate evidence of tableland irrigation by locating irrigation channels (*auwai*) on the gulch sidings in Upper Waiapuka *ahupua'a.* Waiapuka is a traditional Hawaiian community district encompassing Waikama gulch and its ancillary drainages. Waikama gulch extends 5,217 meters from its origin point in the uplands before giving way to Neue Bay at the coast**.** Like its neighboring gulches, Waikama gulch contains well-preserved examples of terraced pondfields used for the cultivation of taro (McCoy and Graves 2008). These intricate systems of weirs and "barrage-style" terraces, created flat-planed, inundated spaces suitable for wet agriculture, but without completely halting the continued flow of water towards the coastal outlets and lower elevation garden plots. Kirch (1977) presents a typology of wet agriculture features, which includes constructions of this type, with the barrage-style terraces common here classified primarily as "Type I" systems.

In the summers of 2007 and 2008, HARP researchers surveyed portions of the eastern gulches and recorded 493 unique features in 48 complexes. These features consisted primarily of agricultural constructions, including intra-gulch terraces and garden walls within the gulch bottoms and sidings. Unique among the findings in 2008 was a sequence of irrigation ditches (‘*auwai*) revealed in a trench that was excavated perpendicular to the flow of the stream into the siding of Waikama gulch, at a site identified by the community district’s name: Waiapuka-4W (WAI-4W). The ‘*auwai*, which would have flowed parallel to the flow of the stream—albeit up above it on the gulch siding—appeared to have served the function of carrying water from higher elevation gulch plots to lower elevation tableland plots, presenting researchers with perhaps the clearest indication of pre-cane era tableland agriculture to date.

As a consequence of those findings, HARP returned to upper Waiapuka *ahupua‘a* in June and July of 2009 to continue excavations in order to search for more evidence of agricultural intensification and expansion on to the tablelands in the gulch region. During that research season we found significant supporting evidence for the case of tableland agriculture, including additional *auwai* on the gulch siding, as well as identifying multi-course stone retaining faces which appear to have supported *auwai* that emanated outwards from previously identified barrage terrace features in the gulch bed, on a course for nearby tablelands.

Soil conditions

The soils in the study area are a clay-loam at the surface, with rocky inclusions that vary in size from a few millimeters across to pebbles several centimeters around, as well as fist-sized cobbles and some small boulders. The soil becomes more richly loam as the subsurface depth increases, and it retains its rocky inclusions to the bedrock, roughly 50 centimeters below the surface. The soil color within the gulch is generally a very dark brown (Munsell color: 10YR2/2).   The gulch soils are typically moist, regardless of any lack of standing water or active streams, as the tree cover that fills the gulches tends to trap much of the near daily rains and locks it in the soil, in contrast to the dry and often dusty tablelands which are exposed to the sun between downpours. As another consequence of the gulch canopy, the gulch soils tend to be rich with fallen organic detritus to a depth of at least 10 centimeters. There is a notable soil color and consistency changes within the subsurface *‘auwai* features however, as the ditches accumulate silt over their use life. This transition results in a soil yellow-brown in color (Munsell color: 10YR 3/4) and consisting primarily of highly friable silt loam. Soil changes of this type are a key indicator of subsurface ditches.

The bedrock in the Waiapuka study area is comprised of timeworn *a‘a* lava flow. *A‘a* lava is characteristically “chunky” and dense, but also porous and absorptive, which has implications for ‘*auwai* cut into the bedrock—primary of which is that such ‘*auwai* would need to be well calculated in order to carry water to tableland *lo’i* efficiently, and without significant water loss by seepage into the bedrock. The bedrock and the soil in Upper Waiapuka are products of the later Hawi Volcanic Series.

Much of the surface material in the gulches, and especially on the gulch sidings, is colluvium that has fallen down from higher elevations; material that has either rolled down from the tablelands, or from higher up on the gulch siding—or alluvial material that washed down the streambed during periods of increased water flow, such as during the rainy winter months. There was no water flow in the upland portions of Waikama gulch during the 2009 field season, although other gulches, such as Lower Halawa, had some stream activity.

In sections of the gulches where agricultural features are clearly visible, as in upper Waiapuka, there are often piles or loose agglomerations of fist-sized and larger stones settled at the base of a siding. These stones are generally disassociated from their original context, but can indicate the presence of subsurface features in the gulch siding, as such stones may be the remnants of retaining walls or pieces of the stone faces sometimes used to baulk *'auwai* and prevent their collapse from below. Several examples of such retaining faces were identified in Waiakama gulch during the 2009 field season and are described in greater detail below.

Continuing research in Upper Waiapuka, Waikama Gulch

The 2009 excavations in Upper Waiapuka were especially targeted to investigate the siding of Waikama gulch for additional evidence of ancient *'auwai*, in order to add to the growing body of evidence in support of intensive tableland agriculture. This decision by the principle investigators was catalyzed by the findings of 2008's investigations in Waiapuka, during which a sequence of *'auwai* on an apparent course for the tablelands were discovered in a test unit trench on the gulch siding (McCoy and Graves 2008). Consequently, the decision was made to excavate a 1 meter by 14 meter trench perpendicular to the flow direction of the gulch on the east siding of Waikama's western drainage, in the vicinity of a complex of barrage-style in the gulch bed *lo'i* that had been identified as WAI-4W in the previous field season. The trench consisted of three test units arranged end to end, from the bottom of the gulch siding to the edge of the tableland above. A long, contiguous trench was selected over alternative excavation strategies because it was surmised that exposing a section of the gulch siding to the bedrock would make the *auwai* sequences we were searching for more readily visible. Catching the *auwai* in profile would make them easier to identify and improve our capacity to measure their trajectories, so that we could approximate where they would have exited the gulch and landed on the tablelands down-slope of the excavation site.

Soil survey methods

Soil samples were collected from the excavation units in one gallon increments from each five gallon bucket of soil removed. The soil samples were taken to our field laboratory for floatation using the traditional "bucket, trowel, and hose" method in order to locate charcoal deposited when the sites were burned for clearing purposes. *Auwai* deposits—the the silted soils and materials accumulating at the bottom of potential irrigation ditches—were collected in full in order to conduct float for charcoal. All of the excavated soil was dry screened with 1/8 inch mesh, aside from the samples reserved for floatation.

In addition, several soil samples were drawn from beneath the stone retaining faces that were cleared as the field season came to a close. In cases where we drew a sample from beneath a stone construction, the bottom-most course of stone was identified, carefully cleared and soil extracted from directly beneath it. Particular care was taken when recovering soil samples from beneath standing structures, in order to ensure that the feature remained relatively undisturbed and intact. Gathering sub-feature samples was deemed especially important, as soil samples drawn from beneath agricultural features in the region have been demonstrated to frequently contain charcoal sufficient for radiocarbon dating the last burn cycle before the feature's construction. In these cases, the architecture itself serves to "cap" the desired soil and prevent contamination from other sources. Great care was taken to ensure that sub-feature soil samples were obtained from *directly* beneath the feature, and not at the interface of the feature and surrounding soils, which could contain carbon from subsequent burn cycles

PART 3: 2009 Upper Waiapuka Excavations

WAI-4 (Barrage Terrace Complex; Waikama gulch)

WAI-4 is an intra-gulch agricultural complex comprised of primarily of barrage-style terraces and irrigation ditches situated within an upstream ancillary drainage of Waikama gulch situated in Waiapuka *ahupua'a.* The complex of features at WAI-4 was first mapped by A.B. Lobenstein in 1904, who had previously worked to survey and map transects of the Kohala and Hilo coasts on behalf of the interim Republic of Hawai'i's (1894-1898) Department of Interior ("Report" 1897). Lobenstein's map of the Waikama gulch environs included tableland agricultural features that have been subsequently lost to the previously described disturbance regimes that affected the region after the period of contact, including the cultivation of 122 acres of sugarcane on the adjacent tablelands (Lobenstein 1904).

WAI-4 was the subject of archaeological survey in the summer of 2008, during which HARP researchers identified 65 features within the terrace complex, including 52 *lo'i* terrace features in the streambed and 3 more on the gulch sidings, the remains of 5 *auwai*, 4 *ahu* (stone cairns with ritual significance), and a possible ritual garden (McCoy and Graves 2008). The complex was originally divided into eastern and western branches by the principle investigators for ease of cataloging, and to distinguish features in the western drainage from features in the eastern drainage. Features in the eastern drainage branch are classified under the designation WAI-4E and those located in the western drainage are classified as WAI-4W. The two drainages have been further separated by a contemporary four-wheel drive access trail.

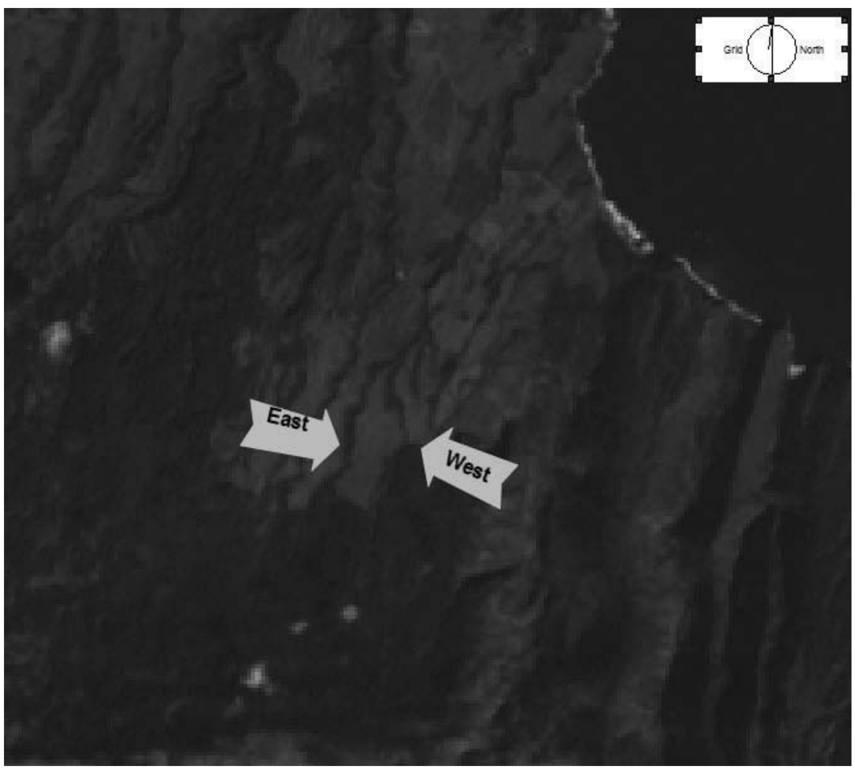

Figure 3.5: Waikama gulch's two drainages. Excavations were conducted in the west branch during 2009. Source: Landsat Thematic Mapper.

The continuation of the Upper Waiapuka component of HARP's research was situated in the western extent of WAI-4. The western drainage is the better preserved of the two, and also contains the majority of the terrace features thus far recorded in Waikama gulch. The principle excavation was undertaken in an area associated with a barrage-style *lo'i* designated WAI-4W-J. Features in WAI-4 were given alpha designations starting with "A" at the highest elevation feature in the gulch. The alpha ascends for each subsequent down slope feature.

WAI-4W-J:

Figure 3.6: WAI-4W-J, Unit 1. The first of three units comprising a 14 meter trench that was excavated perpendicular to the gulch bed. Photo by author.

WAI-4W-J is a barrage-style *lo'i* centrally located in the WAI-4W complex. It was selected as a site for excavation as it is situated downstream of WAI-4W-H where, in 2008, a trench was excavated to reveal five *'auwai* dug into the gulch siding. Our objective in excavating at WAI-4W-J was to locate possible continuations of the previously excavated *auwai*, and to search for any additional irrigation ditches emanating from the *lo'i* at 4W-J or that coursed past it from sources further upslope.

Three test units were laid out end to end, perpendicular to the gulch bed, starting with Test Unit 3 at the top of the gulch siding near the interface of the gulch and the tablelands, and ending with Test Unit 1 near the gulch bed. Test Unit 1 was 1 x 5 meters, Test Unit 2 was 1 x 4 meters, and Test Unit 3 was 1 x 5 meters. The resulting excavation was a 1 x 14 meter long trench that revealed the bedrock of the gulch siding. Additionally, a 2 x 4 meter northern extension was added to Test Unit 2 in order to clarify potential *auwai* features in that unit. In all, the excavations at WAI-4W-J covered 22 square meters of the gulch siding.

Test Unit 1 (WAI-4W-J-TU1)

TU1 was the unit positioned closest to the gulch bed. It measured 1 x 5 meters and was excavated to an average depth of 50 centimeters below surface (cmbs). TU1 contained an especially large number of surface and subsurface rocks of various sizes, including pebbles, fist-sized cobbles and a small number of larger boulders. This concentration of rocky soil was unsurprising, as TU1 was subject to the greatest accumulation of colluvial material rolling off the gulch siding. Consequently, roughly half of the soil matrix was rock. TU1 was excavated down to the bedrock layer of decaying *a'a* flow at the east end of the unit, but was only brought to level in the far west end, where no cultural deposits had been located at a depth of 50 centimeters below surface. The only potential feature identified in TU1 was at the unit's border with TU2 at the east end of the unit. The feature in question was tentatively identified as an *auwai* and was given the designation TU2-Feature 4.

Test Unit 2 (WAI-4W-J-TU2)

TU2 was the unit centrally positioned on the gulch siding. It initially measured 1 x 4 meters, but was later expanded northward by an additional 2 x 4 meters, in order to improve the visibility of possible features contained within the unit. Like TU1, TU2 had notable rocky inclusions, but to a far lesser degree than TU1. Test Unit 2 contained, in part or in whole, all of the potential cultural features exposed during the course of the WAI-4W-J excavation.

Feature 1, was a shallow north-south running *auwai* deposit high on the gulch siding, situated on the eastern edge of the TU2. Feature 1 originally appeared to have a nearby neighboring *auwai* which we identified as Feature 2, but as we continued to remove fill the two *auwai* appeared to actually be one construction—a wide, shallow channel in the bedrock, roughly 50 centimeters below surface and 30 centimeters across. Of the features identified in TU2, Feature 1/2 is the clearest example of what we expected of a bedrock *auwai*—a shallow depression worked into the bedrock to create a stable surface for water to flow along the gulch siding. Such an *auwai* would have been reinforced from below with a stone retaining face constructed on the gulch siding to prevent an outward collapse of the soil bulk.

Diagnosing TU2's Features 3 and 4 proved more problematic. In both cases, we believed we had correctly identified the basic signals that denote the presence of buried *auwai*. In particular, we identified a soil shift towards a silty composition indicative of persistent water flow, and a generally linear profile suggestive of human interventions on the landscape. In the case of Feature 3, which was centrally located in Test Unit 2, we observed a channel cut into the bedrock, roughly 20 centimeters across (approximately the width of a typical *o'o* digging stick), to a depth of up to 60 centimeters below surface. Feature 4 proved equally promising, appearing to be a bedrock *auwai* 30 centimeters across, with flat stones capping its opening. The Feature 4 deposit extended over a meter into the ground, to a depth nearly 1.8 meters below the surface. It was the extent of these features that prompted us to open a 2 x 4 meter northern extension to TU2, in order to improve the visibility of the deep deposits and to aid in properly interpreting them. In doing so, however, it became increasingly clear that Features 3 and 4 were most likely results of the natural decomposition of the *a'a* bedrock and not, in fact, artifacts of agricultural engineering. Essentially, the naturally blocky and "chunky" qualities of *a'a* appeared to result in a "sloughing" effect, with great sheets of bed rock peeling off along the gulch siding creating the extraordinary (and deceptive) channels in our excavation.

Figure 3.7: WAI-4W-J, Unit 2 Northern Extension. The soil was removed to expose the a'a bedrock of this steep grade. Photo by author.

Of course, the probable natural origins of the *a'a* channels did not preclude their use in the complex agricultural works in place in Waiapuka. If partially exposed by ancient farmers, the natural barricades created by the decomposing bedrock could have obviated the need for retaining faces or retaining walls, or required only minor crenellations in sections of *auwai* that utilized the natural subsurface features. However, it is exceedingly difficult to determine from this excavation whether or not the natural features of the bedrock were utilized in an unmodified fashion. The excavation of Features 3 and 4 underscore a chief challenge of conducting research in ancient agricultural systems—especially irrigation systems—and in conducting research in protean landscapes such as windward Kohala. That is, looks can be deceiving; the line between an agriculturally-applied natural feature and a geological red herring is arguable at best.

Test Unit 3 (WAI-4W-J-TU3)

TU3 was the easternmost unit excavated at WAI-4W-J. The unit was positioned at the top of the gulch siding near the interface of the gulch and the tableland. TU3 measured 1 x 5 meters and was cleared to its bedrock layer of decomposing *a'a*, a depth of roughly 50 centimeters below surface. Like Test Unit 2, TU3 had some rocky inclusions, but notably less so than TU1 as much of the rocky surface material gradually settled to the gulch bed. The sole cultural feature identified in TU3 was a bedrock *auwai* deposit situated at the western edge of the unit and that overlapped with neighboring Test Unit 2. The *auwai* deposit, labeled Feature 1, contained the characteristic silted soil typical of disused irrigation features which was collected for flotation. However, insufficient charcoal was recovered for radiocarbon dating. Feature 1 is described in greater detail under the heading of Test Unit 2.

Further investigations: WAI-4W-M1 "Exposures"

Following the excavation at WAI-4W-J, we continued to search for evidence of *auwai* on the east siding of the gulch further, down slope of the previous WAI-4W excavations. In the vicinity of a terrace feature identified as WAI-4W-M we identified a two-course stone alignment emanating from the *lo'i* beneath WAI-4W-M's retaining wall. After identifying the structure as a retaining face for an *auwai*, we began to identify still more exposed stone faces, or “exposures,” intermittently intact along the eastern siding at roughly similar elevations. These exposed stone faces were used to reinforce the *auwai* from below, preventing the irrigation ditch from collapsing outward.

Strung together, the exposed stone alignments followed a course from their source *lo’i* at WAI-4W-M to a flat area on the tableland surface roughly 100 meters *makai* of their starting point. This *auwai*, that was at one time on a clear course for a tableland *lo‘i*, was given the designation 4W-M1 and each exposure was given an alpha designation, “a” through “f.” Exposures “a,” “b,” and “c” were located directly adjacent to the retaining wall above 4W-M, with “a” and “b” actually emanating from the wall. Exposures “d,” “e,” and “f” exited the *lo‘i* and followed the curve of the siding, with exposure “f” situated within 5 meters of exiting to the tableland. Soil samples were drawn from beneath 4W-M1a, 4W-M1b, and 4W-M1c using the previously described method for recovering sub-feature soil samples. After flotation, 4W-M1a and 4W-M1b yielded sufficient charcoal for radiocarbon dating.

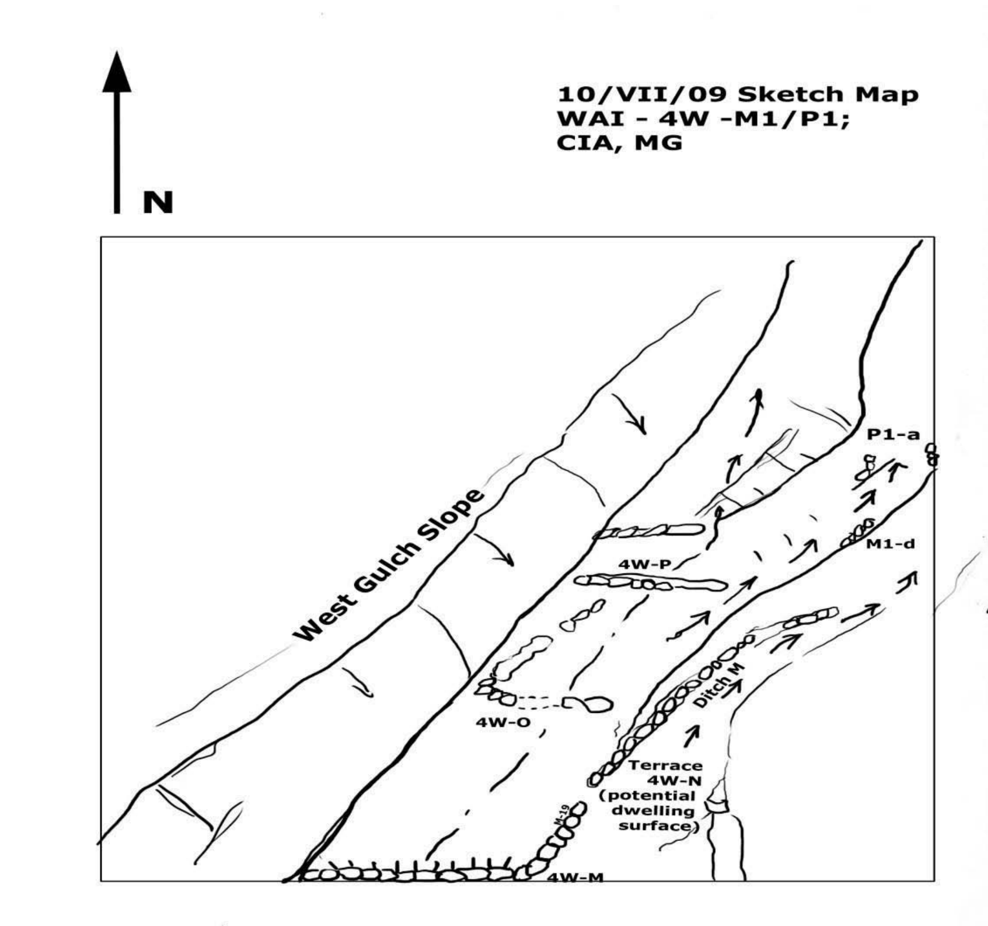

Figure 3.8: Sketch map of WAI-4W-M/P exposures. Map depicts possible water courses in relation to terrace walls and newly identified retaining faces. Map by author.

WAI-4W-P1 "Exposures"

WAI-4W-P1 is a sequence of retaining faces similar to WAI-4W-M1 in design and in state of preservation. In the case of sequence P1, the *auwai* emanated from feature 4W-P, a barrage-style terrace, and followed the eastern siding roughly 200 meters before apparently terminating down slope of WAI-4W-M1. It is possible that 4W-P1 also took in water from the neighboring *lo'i* identified as WAI-4W-O, as the first exposure identified in 4W-P1 is situated just down slope of an apparent interface of terrace features

4W-O and 4W-P. Like the retaining faces comprising 4W-M1, 4W-P1 exposures were given alpha designations from “a” to “g.” Each exposure in 4W-P1 had at least 2 courses of stone, with several numbering three or more courses. Exposure 4W-P1b was in close proximity to a test unit excavated in 2008 in which several *auwai* were identified, suggesting a possible association between the retaining faces and the previously noted *auwai* (McCoy and Graves 2008). Soil samples were taken from beneath the retaining faces with the approach described above. After floatation, sufficient charcoal from was recovered from beneath exposures “a,” “b,” and “f” to merit radiocarbon dating.

Conclusion

Windward North Kohala is a landscape in which the intersections of ecology and society reflect the complexity of relationships that ancient cultivators had with the environment and with each other. The excavations in Waiapuka *ahupua’a* undertaken in the summers of 2008 and 2009 have generated ample evidence to support the hypothesis that a push towards agricultural intensification expanded irrigated agriculture out of the region’s network of gulches and onto the intra-gulch tablelands. When one considers the further possibility of non-irrigated or rain-fed agriculture on the tablelands, the value of windward Kohala as surplus producing agricultural stronghold becomes increasingly apparent.

While these excavations provided useful evidence as well as confounding factors, such as preservation issues and natural rockforms, in the discussion that follows I add an analysis of the landscape through Geographic Information Systems. This spatial analysis reaches beyond the limitations of excavations by using existing data about the intra-gulch *auwai*. It helps to connect the dots between these snapshots of physical evidence, and a broader picture of agricultural expansion onto the table lands. From there, a discussion of the political ecology of the region's social complexity rests on a more complete foundation than it would relying on excavation data and previous work alone.

Chapter 4: Spatial Analysis of the Eastern Gulch Region, North Kohala

Introduction

Spatial technologies afford archaeologists an exciting array of tools with the potential to alter the scope of archaeological analyses and our discipline's approach to research in general. This thesis research utilizes spatial technology—specifically geographic information systems (GIS)—to examine phenomena outside the relatively limited scope of physical investigations imposed by the seasonality of fieldwork. GIS was a key analytical tool, including the collection of data, metadata, and graphic analysis of the gulch structures of Northern Kohala described in the previous chapter. The results point to the region's vast potential to support tableland agriculture and open up discussions of space and land use in the eastern gulch region. This interpretive use of GIS is consistent with a number of developments in archaeologists' application of these technologies (McCoy and Ladefoged 2009).

Broadly, GIS enhances researchers' abilities to acquire, manage, analyze and visualize spatial data and the metadata associated with it (Conolly and Lake 2006, McCoy and Ladefoged 2009). Archaeologists have increasingly been using these technologies in the field to track and manage archaeological data with great accuracy. To that effect, GIS and other spatial technologies are frequently used to make a record of excavated artifacts within the total spatial context of a site as they are discovered, or to capture stratigraphy as it is revealed (Connoly and Lake 2006). However, archaeologists have not limited themselves solely to these applications.

Spatial technologies have achieved a strong foothold among landscape archaeologists, who have utilized them to enhance survey, reconnaissance, integration and interpretation in regional analyses (Kavamme 1999). These developments have an obvious impact on the sampling strategies used by field researchers: it can predispose them to seek out the most favorable subsurface targets, rather than employing a random sampling strategy that may catch phenomena not visible through GIS. But the ability for researchers to recover data in more efficient and less destructive ways through effective applications of GIS returns what is lost with the passing over of random sampling for a targeted strategy.

Furthermore, the application of spatial technologies affords archaeological researchers novel opportunities to conduct research that is both meaningful and yet minimally destructive to archaeological resources. Such technologies can be used to explore the spatial relationships between features or sites across a universe of data, rather than conducting invasive excavations by necessity. While not obviating the need for exploratory excavation, the application of remote sensing platforms and ground-based geophysical sensors can aid in targeting subsurface archaeological resources with greater accuracy, and generate data that, when applied in tandem with GIS, can be used to research archaeological phenomena in novel ways.

GIS can also be used to compelling effect to tie together regional analyses. McCoy's (2006) study of the Kalaupapa region on Moloka'i is a compelling contemporary example of this kind of synthesis, applying GIS to connect sequential archaeological studies with social and historical evidence. Similarly, Sassaman's exploration of the relationships between the Poverty Point mounds in northeast Louisiana illustrates how spatial analysis can be used to demonstrate political and economic relationships over great distances (Sassaman 2005). In both cases, spatial technologies were applied to a regional analysis as a means to synthesize large data sets and to generate inferences about the uses of space and the formation of networks by past peoples.

It is this use in analyzing landscape features over a region, and synthesizing that with other types of data, that I use here. In the following sections, I detail my application of GIS as an inferential tool in the study of agricultural expansion and intensification in windward North Kohala. In so doing, I reflect on the process and address the principles and methods used. In the sections below I describe in detail the tools and analytical methods applied to this research, as well as the process of conceptualizing, building and analyzing the model, and the process of drawing inferences about possible agricultural regimes. Some of these findings begin to highlight insights into the political ecology of the region, which will be addressed in greater detail in the chapter following this one.

The tools of spatial analysis

The specific GIS platforms utilized in this research include ESRI's ArcGIS 9.2 and 9.3.1 software and Quantum GIS (QGIS) by Open Source Geo. ArcGIS remains the industry standard for geographic information analysis. ArcGIS is a powerful toolset with a monumental capacity to edit, quantify, analyze and visualize geographic data. QGIS is the product of an open source collaboration to create a lightweight and flexible GIS (an

"OSGIS") that is freely available to practitioners and students. The majority of this analysis was conducted with ArcGIS, as a testament to its stability and the versatility of its analytical suite. However, many of the data layers were created in QGIS, as its impressive accessibility and ease of use for this purpose is a virtue it holds over ESRI's software. Both platforms were invaluable for the purposes of this research and I developed my facility with them in tandem while conducting this analysis.

Spatial analyses and modeling in North Kohala

HARP research conducted in the summers of 2008 and 2009 revealed evidence of tableland agriculture in windward North Kohala, contemporaneous with processes of agricultural intensification occurring in leeward North Kohala (McCoy and Graves 2007 and 2008; Ladefoged and Graves 2007). Attempts have been made to quantify the processes that played out in the leeward field system (Ladefoged and Graves 2007), but the extent of agricultural expansion in the eastern gulches remains unclear. A goal of this research has been to begin the process of quantifying the potential of the eastern gulch region to support the population explosion that began to unfold during the 14th century and to create a model that provokes discussion of the scale and complexity of the agricultural intensification occurring in the windward gulch region.

The purpose of the GIS applied to this research was to create a model that reflected the potential for irrigated agriculture situated on the tablelands between the eastern gulches. It is important to note that "models" can assume many different roles in a project's design, for example they can variously be used to describe or illustrate a process or to predict the location of un-surveyed sites. Consequently, the term “model” is ladened with great uncertainty as to its meaning. For the purposes of this research, “model” essentially refers to a hypothetical description of the processes of agricultural intensification and expansion that occurred throughout the eastern gulch region prior to the period of contact.

More specifically, the model designed in this research examines the hypothesis that prehistoric cultivators expanded their agricultural systems into marginal territories in order to support an increasingly complex and hierarchical society undergoing a significant surge in population numbers and social stratification (Kirch 1984). It does this by showing the extent to which marginal areas in the region—in particular, the exposed and windswept tablelands situated between the gulches—might have been irrigated or otherwise utilized to increase the amount of agricultural land available to ancient farmers working and dwelling in the gulch region of North Kohala. Essentially, the goal of this analysis is to quantify, to various degrees, the potential extent of tableland agricultural expansion and to consider the implications of various expansion regimes.

Environmental variables and other considerations

Since the purpose of this research is to explore the processes of agricultural expansion and intensification in windward North Kohala, and in particular how ancient cultivators utilized the marginal tablelands between the gulches, I conducted an analysis of tableland area by constructing a GIS model that reflects the variation of slope across the region. This involved considering five key environmental variables for possible analysis: slope, elevation, soil series, soil erosion, and water flow.

The principle variable examined in this analysis is the gradient of the slope, as slope appears to be the primary extent factor with an impact on land usage both in and out of the gulches. In addition to slope, elevation also appears to be a significant variable, as it relates to both physical accessibility and to soil health, and correlates to slope (i.e. the greater the elevation, the higher the grade and its reverse are generally true across the sample area).

Soil derivation—that is, which volcanic series sourced the soil bed—is also an important regional variable. However, historic era agricultural sites are distributed relatively evenly between areas with Hawi derived soils and areas with Pololū derived soils. This suggests that while soil nutrient variations between the two soil series are notable, they were not a significant barrier to agriculture, except at the uppermost slopes where the brunt of the wind and rain rapidly accelerate soil nutrient depletion. USGS surveys suggest minimal variation in soil erosion rates across the region. Practically the entire eastern expanse of North Kohala is flagged as "highly erodible," given the frequency and volume of rain and exposure to high winds at all elevations.

The other key environmental variable operating in the region is the flow of water in the gulches, which was noted previously as having been dramatically altered since the early 20th century and the construction of the Kohala Ditch. Thus slope, and to a lesser degree elevation, emerged the as the most consistent measurable variables for the purpose of exploring the extent of intensified agriculture in windward North Kohala.

The resulting model, described below, is intended to serve as an inferential abstraction. Its development has some parallels to the practice of "predictive modeling," an important although controversial application of spatial technologies to site identification that employs environmental sampling and variables discerned from known sites in order to "predict" the locations of undiscovered archaeological resources (Aldenderfer 1998, Kavamme 1999, Connoly and Lake 2006, McCoy and Ladefoged 2010). The most important distinction to note is that this model's purpose is not to "accurately depict" agricultural systems in North Kohala as they existed at any one point in time. Like other conceptions of archaeological data, the metaphor of a palimpsest, layering possibilities through time, is relevant here. This model serves as a virtual palimpsest that illustrates the potential of the terrain to support the expansion of agricultural projects out of the gulches and on to the surrounding tablelands, based on the utility of the landform as defined by its gradient. The value of such an abstraction is to provoke and contribute to the continuing discourse on the role of agricultural intensification in the formation of the early Hawaiian state.

Building a model of agricultural intensification

The first step to constructing the geographic information system for this project was constructing the digital elevation model (DEM) in ArcGIS. A DEM records elevation-above-sea-level data on a point-by-point (or pixel-by-pixel) basis and organizes it in a data-laden raster format. A properly constructed DEM contains key geographical data including elevation above sea level, and slope and aspect values for the landform that it models. The core of the DEM developed for this research was a 100' contour shapefile acquired from the Hawaii Statewide GIS Program (HIGIS N.d.). This set of poly-line contours was overlaid on a digitized USGS base map of Hawaii Island and gradually rectified to closely match the USGS base map's contour lines. Once the contour overlay file matched, the contour shapefile was cropped to encompass only the eastern gulch region. Finally, the 100' contour file was converted from imperial measurements into meters-above-sea-level (MASL) for metrical consistency with existing data layers (100 feet = 30.48 meters).

The initial DEM was derived by mapping points on the contour layer overlay and rendering a raster image of the landform based on point-by-point associations in a process called inverse distance weighting (IDW) interpolation. The first DEM was flawed in several ways that I explain below, but I include it because rectifying those flaws shaped the logic of later phases of the analysis.

Next, I derived raster images reflecting the aspect and slope of the study region's landform from the DEM. The initial conjecture was that there would be a 'prime' range in which potential tableland *lo'i* would fall, based on the general directional course of the landform and the grade of the slope. To test this hypothesis, I positioned 100-by-100 meter "test squares," consisting of a densely packed grid of 10,000 points, near suspected tableland sites in association with HARP's previously documented sites in Upper Waiapuka *ahupua'a* cataloged as WAI-1 and WAI-4. These test squares were used to conduct a Surface Spot Analysis, referencing both the aspect raster and the slope raster. The Surface Spot tool functions by interpolating a value for each point (or "spot") from a reference raster layer. The resulting values consisted of both a degree facing (for aspect) and a percent grade (for slope) for each point in the 100 by 100 meters matrix (Figure 4.1).

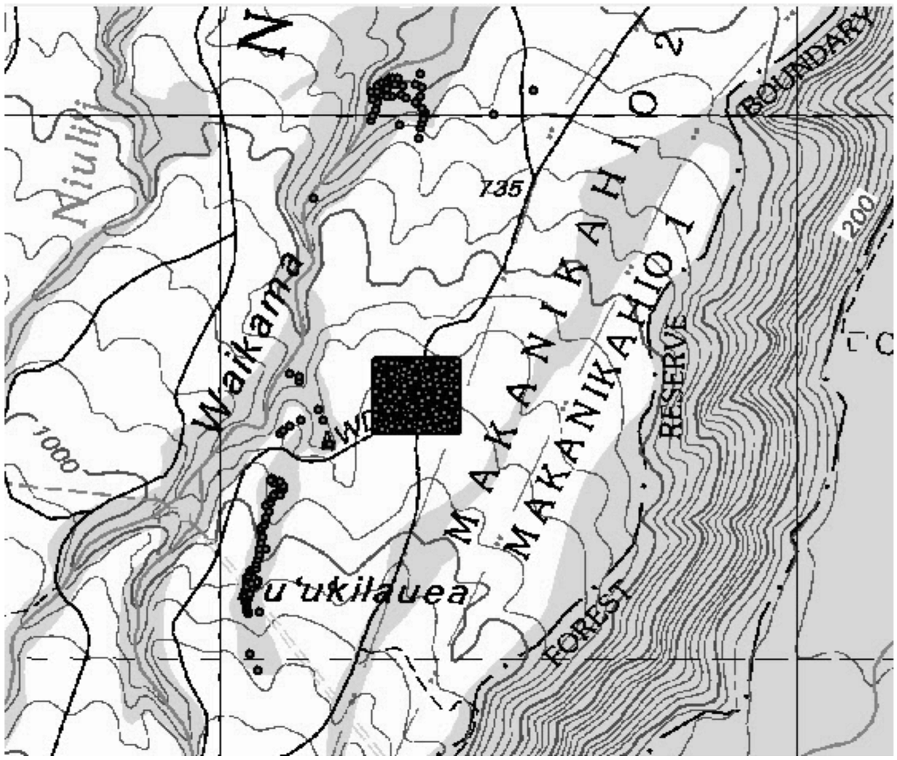

Figure 4.1: A 100x100 meter surface test square positioned on the tablelands adjacent to sites in Waikama gulch.

I maintained two assumptions in this analysis. One was that this granular level of analysis would reveal the parameters within which tableland *lo'i* would generally conform. The other was that the model landform would likely reflect the region's north-northeast orientation, rendering aspect a relatively superfluous variable, and that the gradient of the slope must be great enough that it would impel water out of the gulch, through the *'auwai* out to the tableland, but not be so great as to move the water so fast that it would simply roll off the slope.

Unfortunately, as noted above, the initial DEM proved to be flawed. The points along the contour layer's polylines were not sufficiently arrayed to create an accurate representation of the landscape. A common problem when deriving surface models from contour lines is that the data points used for the interpolation of the model are either too close, or too far apart. Because the interpolation process relies on referencing nearby points to model the terrain, the GIS software could not generate a valid DEM based on the apparent paucity of data present in the contours. The resultant DEM was skewed in that it exhibited a high degree of "bowling"—which occur when spaces between the contour lines which contain no data are interpolated as below the surrounding contours in elevation, creating a rippled surface model—and "plateaus"—places where the points of equal values are so closely packed that they are rendered as elevated flat surfaces that follow the contour lines. Consequently, the first DEM and the results derived from it had to be discarded in favor of a more accurate alternate version.

To address this flawed representation of "bowling" and "plateaus," a denser concentration of points was re-mapped selectively across the contour layer. This was sufficient to create a second, valid DEM that more accurately reflected the contours of the actual landform. I used this improved contour data to generate a triangulated irregular network (TIN). TIN interpolations resolve by rendering a tessellation of triangles over a large quantity of points, creating a network of triangular polygons that reflect the contours of the landform (Figure 4.2). While TIN's have their flaws—most notably that they often retain a faceted or angular quality that can result in some artificial flattening of the model's surface—they are among the best surface models achievable using contour data as the core of the model.   The result of this second attempt at modeling the landscape was a more accurately representative surface model from which to generate slope and aspect raster images for analysis (Figure 4.3).

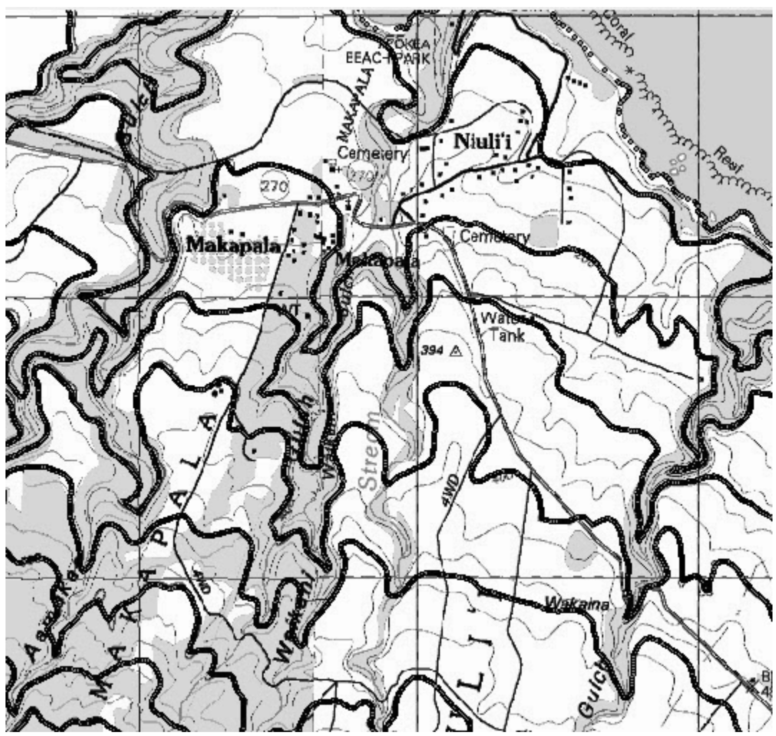

Figure 4.2: Points mapped along the contours of a USGS contour map, creating a feature set sufficient to generate a TIN.

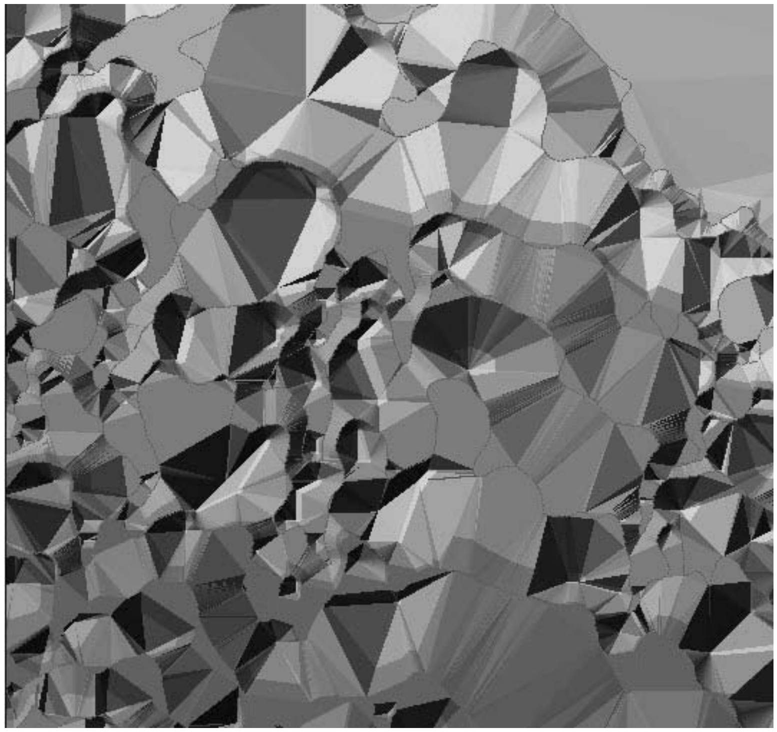

Figure 4.3: The above contours reflected in the completed TIN. Color shifts denote changes in elevation range.

The sampling strategy for the TIN DEM was identical to the process undertaken for the original IDW DEM. Surface Spot testing was conducted for both slope and aspect. Aspect proved, rather predictably, to be even more overwhelmingly north-northeast facing with the enhanced DEM, reflecting the natural shape of the landform. This quality was so extreme that I deemed aspect analysis unnecessary, as it appeared to be a relatively superfluous trait—the aspect of windward Kohala's slopes is too consistent to be a worthwhile variable. Consequently, all attention was turned towards the slope values for the sample areas.

Surface Spot analysis of the TIN DEM reflected wide variations in the slope of the hillside in the areas tested. Thorough analysis of suspected tableland plots revealed that there was a preponderance of values between 10.00% and 14.00% grade in the sample areas, with significant portions of the sample reaching up to 18.00% grade. The 10.00% to 18.00% grade range thus became the hypothetical "sweet spot" range for the first round of analysis, based on the conjecture that if the slope were any steeper, it would have likely had the unfortunate consequence of propelling the water too fast for agriculture (i.e. rushing over the tableland or unevenly inundating tableland plots). If the slope was significantly less than 10% grade, the conjecture followed, the flow would have likely proven too sluggish to move the water over the long distances required to channel water from the gulch bottoms to the tablelands for irrigated agriculture. In a region with a relatively "soft" and porous *a'a* bedrock, constancy of flow is an important attribute when moving water out of the gulches and onto the tablelands, in order to minimize loss to absorption.

To better visualize this data, I generated and modified ("re-jenked") a raster image depicting the slope to occlude any values above or below the 10.00% to 18.00% range (see Figure 4.4). From there, the remaining data was separated into two bins, encompassing 10.00% to 14.00% and 14.01% to 18.00% ranges. At this point, the 10.00% to 14.00% range was classified as "prime real estate," and the 14.01% to 18.00% range as the "maximum extent." Further discussion of this scale continues below.

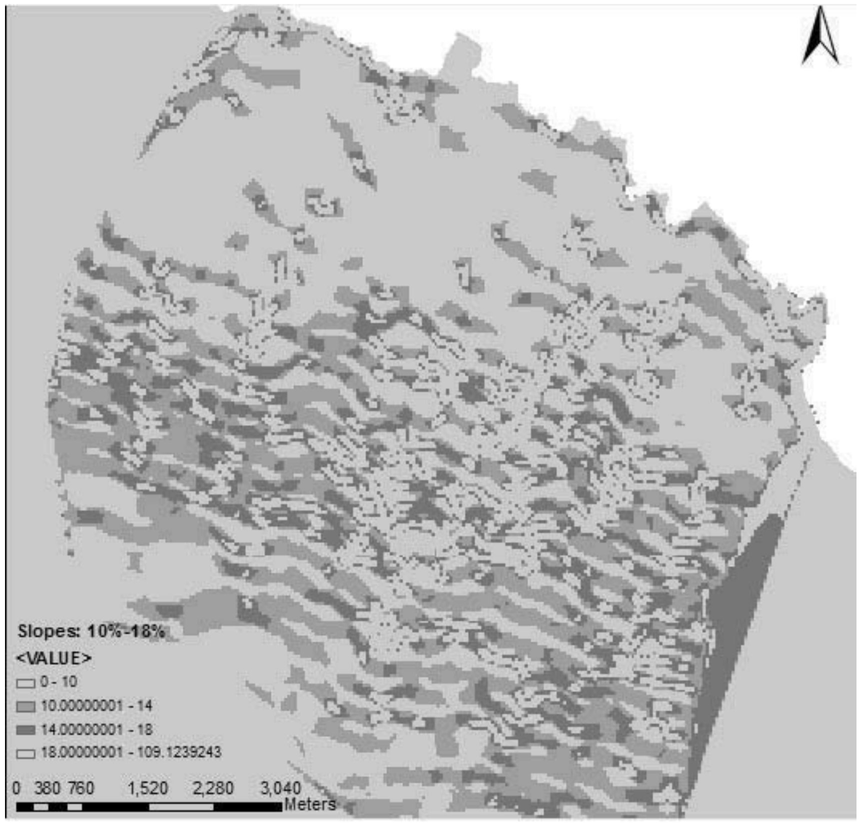

Figure 4.4: This image depicts areas with grades ranging from 10% to 18%, with the lighter selection ranging from 10% to 14% and the darker selections ranging from 14.01% to 18%.

Setting the scale

A core assumption of this model is that potential tableland plots should fall within a certain percentage range of slope. Testing suggested that the target range fell between 10.00% and 18.00% grade (a range that spans roughly 8 to15 degrees incline). This range was identified as optimal for three reasons: the average slope, the implications of elevations, and the implications of average flow speed.

First, after examining the DEM in light of previous surveys of the gulches, it became clear that the average slope of the tablelands is greater than the average slope of the gulch beds themselves, which generally range from 4% to 11% grade (see table 3.1).

Therefore an 8% gradient range starting at the high end of the gulch slope range offers a wide catchment for potential tableland sites, especially in the uplands (750+ feet above sea level). Second, the practicality of moving water from higher elevation *lo'i* to lower elevation tableland plots would logically improve over the long run if the water moved at a constant, steady flow rate—thus limiting absorption by the relatively porous *a'a* bedrock into which the *'auwai* bottoms were cut. Since the gulch sidings generally follow the landform associated with the tablelands, tableland targets for irrigation would have been selected by ancient farmers to minimize water loss across the roughly 50 to 200 meter run of the *'auwai* trench from the source *lo'i*, along the gulch siding, and out to the target plot. Thus, a higher percentage grade would ensure that more water reached the target than was absorbed by the porous bedrock. Finally, the same flow speed which ensured that water reached the tablelands served the dual functions of improving coverage in the targeted plot and potentially allowed for the "daisy-chaining" of sequential plots fed by a single arterial *'auwai*, in a fashion described by Kirch (1977) as a Type II system—a design in which a single ditch deposits water in the topmost plot of a sequence of garden plots, and which is then allowed to flow through into lower elevation plots through outlets in the garden walls.

However, the cap of 18% was set upon consideration of the fact that the flow and dispersal of the water itself must have been manageable. If the grade of the targeted plots was significantly higher than 18% to 20% (roughly 12 degrees), it is conceivable that the water may have simply overflowed the tableland *lo'i* or unevenly inundated the targeted plots by dint of flowing too rapidly.

As noted above, the 8% range of slope identified by the Surface Spot analysis was aggregated into 4% increments, with 10.00%-14.00% encompassing the optimal range and 14.01%-18.00% encompassing the maximal range in which one would expect to find tableland plots in a process that is discussed in greater detail below. Aggregating the model data in this way has two primary consequences. First, it creates a more realistic impression of land use, under the assumption that prehistoric cultivators would first develop the most easily accessible and workable (i.e. the most level) plots located on the least extreme inclines. In addition, aggregating the data creates a more flexible data set that is more easily manipulated for testing purposes at different scales.

Process of analysis—putting the pieces together

In order to begin the process of quantifying the maximum potential for tableland *lo'i,* I created two polygon layers reflecting the data in the previously described extents. First, I created 128 polygons, through the process of heads-up (point-and-click) digitization, encompassing the 10.00% to 14.00% slope range, and omitting areas that were either very small outliers or that directly overlapped a waterway. I then created a second polygon layer consisting of 80 polygons that extended the catchment to cover the range from 14.01% to 18.00% grade, again careful not to directly overlap with waterways, and omitting very small areas of one or two discrete pixels. Furthermore, I omitted the few targets below the 750 feet-above-sea-level line, noted in the previous chapter as distinguishing the uplands from the coastal lowlands. Below the 750 foot line, the average slope of the region is significantly lower than the uplands, averaging between 4% and 8%. Since HARP's research into windward North Kohala's tableland agriculture has primarily been situated in the uplands of the eastern-most gulches, restricting this analysis to the uplands validates an important geographic distinction with respect to the current research agenda (see Figures 4.5, 4.6 and 4.7).

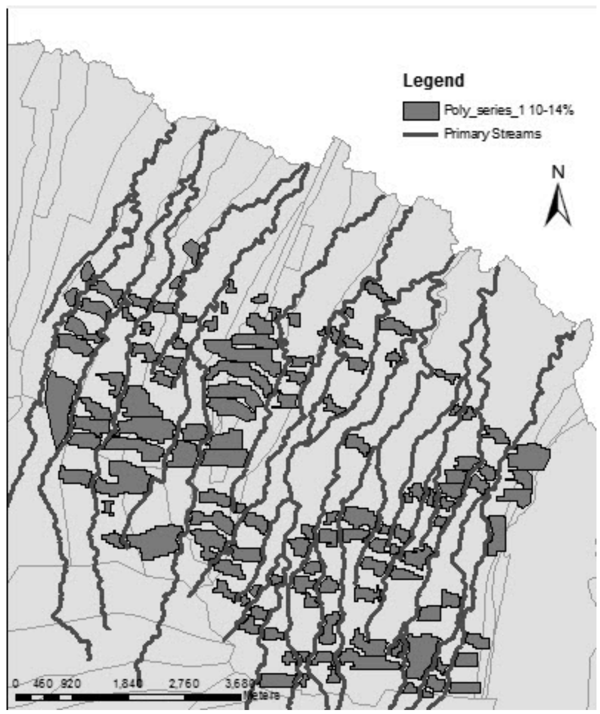

Figure 4.5: Polygons encompassing slope surfaces ranging from 10.00% to 14.00% grade.

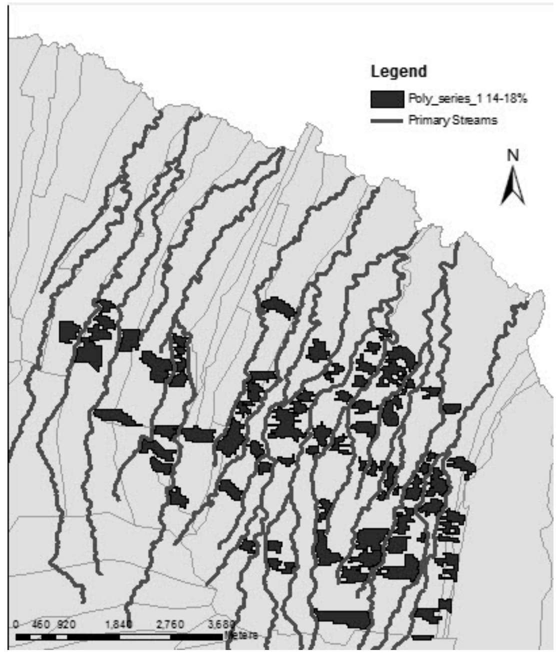

Figure 4.6: Polygons encompassing slope surfaces ranging from 14.01% to 18.00% grade.

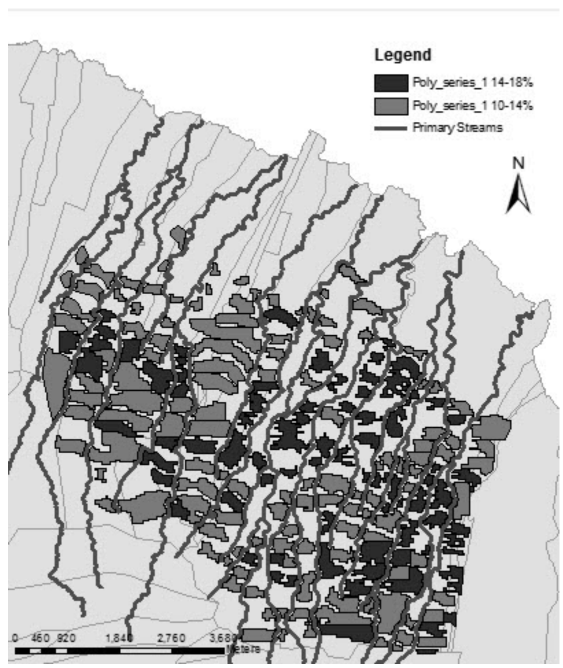

Figure 4.7: A composite of the initial polygon layers encompassing areas ranging from 10%-14% grade and areas from 14.01% to 18% grade.

Those conditions, particularly the omission of single pixels and isolated clusters of a very few pixels was decided upon under the assumption that small, isolated signals were likely indicative of "noise," rather than a meaningful signal indicating a substantive site with potential for agricultural development. This decision was a byproduct of utilizing a 100' contour as the basis for the digital elevation model. A 100' contour map provides a relatively broad-stroke impression of the landform, in contrast to the highly precise modeling afforded by LIDAR and related technologies. I concluded that large, concentrated signals were more likely indicative of a plot suitable for agricultural development, while remote or diffuse signals could as likely be an artifact of the DEM's construction as a meaningful "hit." Thus the decision to omit those signals from the analysis erred on the side of creating a more conservative estimate of the potential for agricultural development, by acknowledging the constraints of the DEM.

In order to isolate the streams that transect North Kohala's slopes, a Big Island stream layer was downloaded from the extensive Hawaii State GIS repository (HIGIS N.d.). The stream vector layer was rectified to closely match the base map and cropped to encompass only the Eastern Gulch region. Notably, this layer included only primary waterways and the largest of the secondary drainages or gullies. The gulches average between 50 meters and 100 meters across (McCoy and Graves 2007), so a 100 meter buffer was constructed and centered on the stream poly-lines which served to isolate the streams from the surrounding terrain and represent the extreme of the gulch boundaries.

Where the target areas indicated by the slope analysis intersected the stream buffers, I instead constructed their polygons by following the stream buffer edge. This measure creates a more realistic impression of the tablelands by representing the extent of the gulches' horizontal dimensions. It further ensured that the area polygons would not encompass and subsequently record areas considered "out of bounds" by dint of being principally "within" a gulch. These buffers did have an unintended consequence, however: as the gulch width does vary widely, portions of the known historic tableland plots recorded in Lobenstein's (1904) turn of the century maps fell within the 100 meter buffer range despite their placement on or near the tablelands (see Figure 4.6).

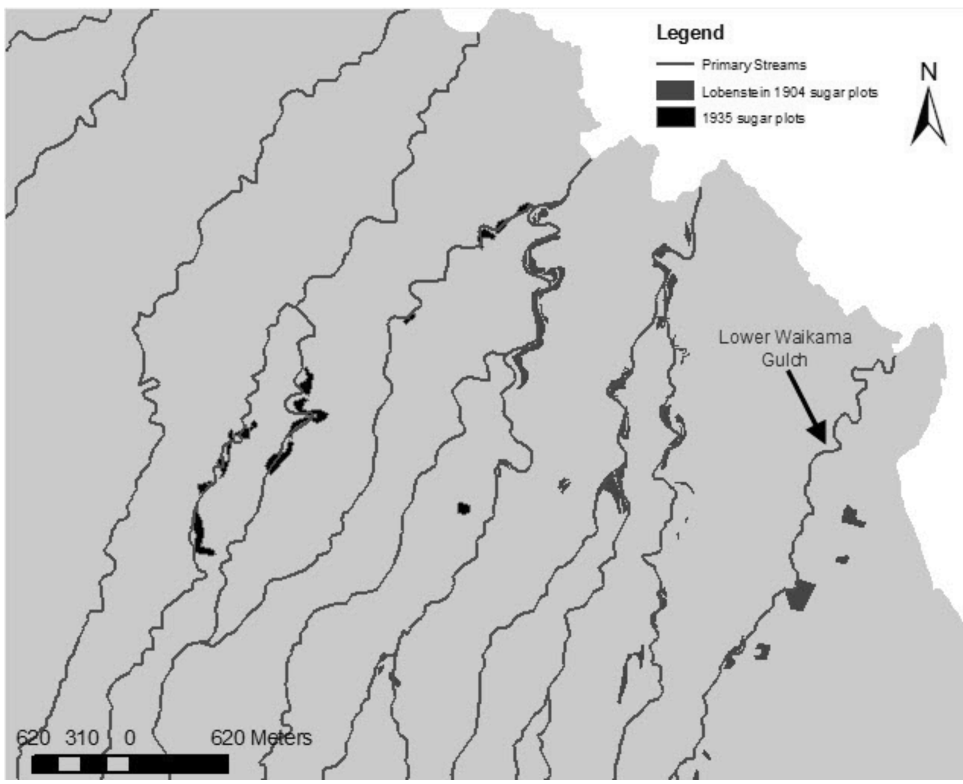

Figure 4.8: Historic era agricultural plots in the eastern gulch region.

This process highlights a key problem of imposing artificial geometries on geographical features: that natural variation of landforms is difficult to approximate. In order to fully rectify the issue, a comprehensive survey of gulch dimensions would be necessary, and is presently outside the scope of this analysis. Regardless, the 100 meter buffer essentially trades one form of sampling error for another, creating a more conservative estimate of tableland areas than a closely mapped, but un-buffered approximation of gulch dimensions. In the end, I chose to use the buffers, and erred toward generating a conservative estimate.

The process of heads-up, or point-and-click, digitization is time consuming and painstaking. It is also prone to the accumulation of topological errors due simply to the human factors involved in the digitization process (Connolly and Lake 2006). These errors include slivering—or the inclusion of gaps between objects that should be justified with one another—overhangs—places where two objects overlap but should not—and simple unconnected nodes—corners that should join, but do not. Great care was taken to ensure that the polygons were mapped to avoid these issues. Polygons were "snapped" where necessary, a function available within ArcGIS and most other GIS software that joins objects seamlessly—either to neighboring polygons that share a common border, or to the stream buffer where appropriate.

Once the polygon layers reflecting the two slope ranges were complete, I used a spatial statistics tool, referencing each polygon layer, to calculate the area of individual polygons in meters squared (m^2). With a value established for each polygon, I exported the data to a database and converted each value from meters squared to hectare through manual conversion of each value.

Two values that described the potential area available for tableland agriculture were achieved with the completion of the manual data processing. The first includes the area of the polygons with a grade falling between 10.00% and 14.00%, equaling roughly 1039.71 hectares (rounded to two decimal places). The second value includes the area of the polygons with a grade that falls between 14.01%-18.00%, an area of roughly 555.15 hectares (again, rounded to two decimal places). Cumulatively, the upland tableland polygons cover an area of 1594.86 hectares, practically one third of the entire gulch region's 49 square kilometers. In contrast to that value, intra-gulch agricultural areas in the region, including *lo'i* surveyed in the gulch region, and others located in the neighboring Pololū and Honokane valleys, have been estimated at 55.8 hectares (McCoy and Graves 2010).

Table 4.1: Results of the first area analysis

Grade of slope	Number of Polygons	Total Area/ha
10.00% - 14.00%	128	1039.71
14.01% - 18.00%	80	555.15
Totals	**208**	**1594.86**

In addition to sampling suspected tableland sites in association with gulch *lo'i*, I conducted a second analysis of historic era tableland plots. These plots, recorded on survey maps early in the twentieth century, are clear indicators that tableland agriculture, irrigated or otherwise, was a viable practice in the region. Some of the known tableland plots are certainly cane era or were utilized by the cane industry, as Lobenstein indicates. It is plausible, however, that some of the historic plots were actually in a cycle of reuse, having been utilized previously by native Hawaiian farmers for subsistence purposes.

Applying the same process of slope analysis that was undertaken previously to the historic era tableland plots derives a range of signals from 4% to 16% grade—a wide range that encompasses a significant portion of the landscape. Since all but three of the 62 plots identified in the cane era maps fall within 200 meters of a stream, I constructed 50 meter buffers to account for a low estimate of gulch dimensions, and 200 meter buffers around each stream to define the catchment of the analysis. I then calculated only the areas from 4% to 16% grade that fell within the area defined by the buffers.

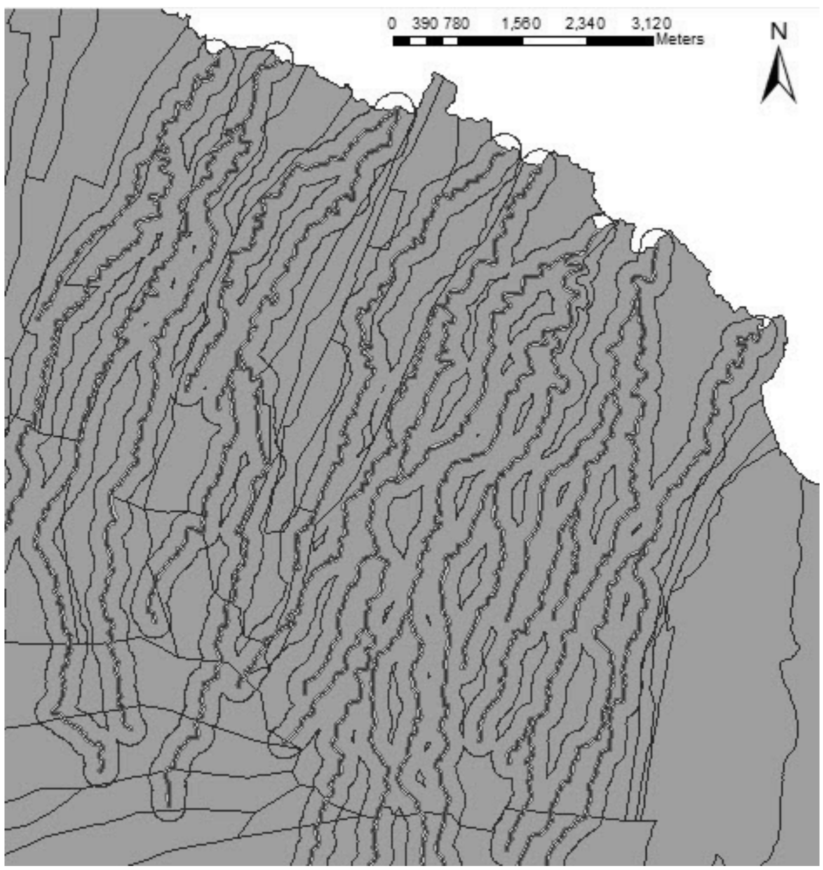

Figure 4.9: Primary waterways with 200 meter buffers define the catchment of the second area analysis.

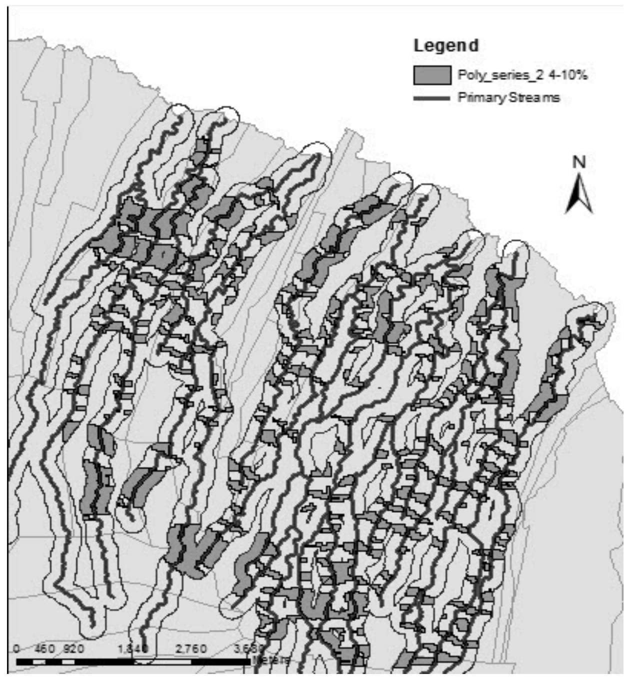

Figure 4.10: Polygons encompassing slope surfaces with gradients ranging from 4% to 10% falling within 200 meters of a primary waterway.

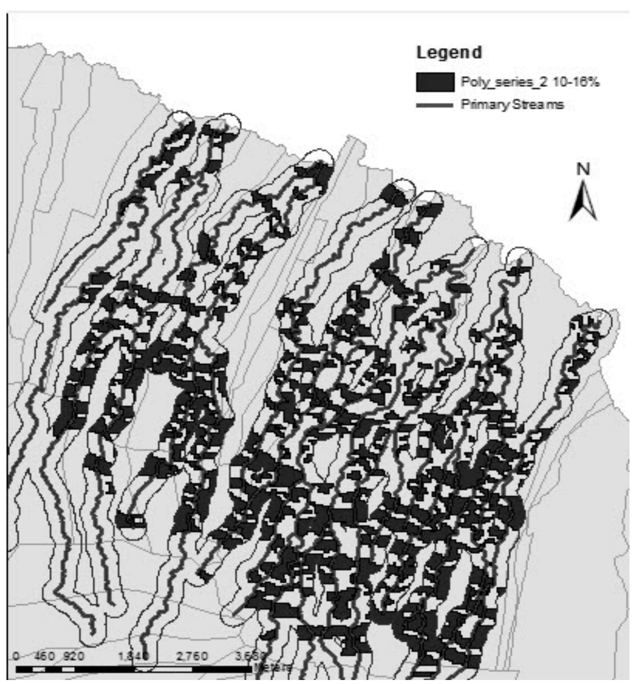

Figure 4.11: Polygons encompassing slope surfaces with gradients ranging from 10.01% to 16% falling within 200 meters of a primary waterway

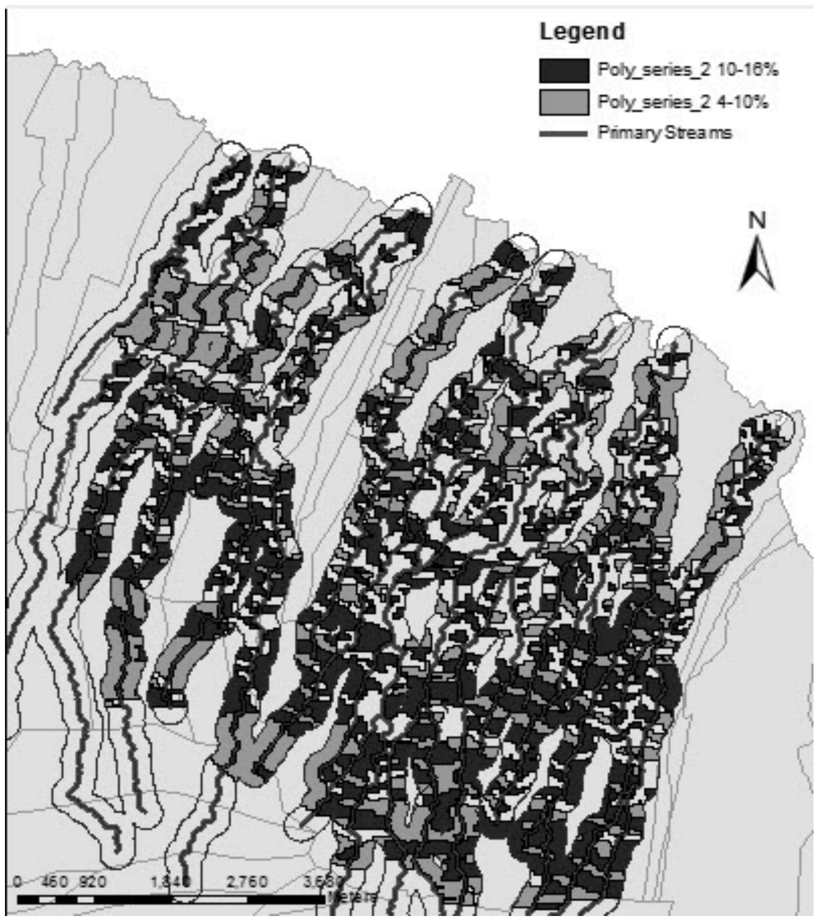

Figure 4.12: Both layers of polygons from the second round of analysis, consisting of slopes ranging from 4% tto 16% grade.

The result of this analysis was a value of 2289.84 hectares that stretched from the coast into the uplands, in close proximity to the primary drainages and waterways. By design, this analysis encompassed a significantly higher proportion of known tableland plots than did the previous analysis, although I omitted some values as outliers (i.e. less than 4% grade, greater than 16.01% grade), in part because of triangulated networks' tendency to flatten surfaces and in part due to a strong decline in signals above 16% grade. While the previous analysis concentrated on quantifying the upland tables, this analysis was focused on generating a pragmatic estimate of potential agricultural land area based on historic evidence. With great consideration to the validity of this analytical approach, I believe that this subsequent analysis, focusing on the parameters of known historic tableland agricultural resources, better reflects the potential of the gulch region's tablelands to support intensified agriculture.

Table 4.2: Results of the second area analysis

Grade of slope	Number of Polygons	Total Area/ha
4% - 10.00%	292	1038.21
10.01% - 16.00%	331	1251.63
Totals	**623**	**2289.84**

Seeing slopes, envisioning agriculture

It is clear that ancient farmers cultivating the diversity of lands represented in windward North Kohala had ample room to expand their growing efforts to encompass areas on the region's elevated tablelands. In fact, there is sufficient evidence to support the claim that irrigated agriculture was at least moderately practiced on the adjoining tablelands (Tuggle and Tomonari-Tuggle 1988, McCoy and Graves 2007, 2008, and 2010). But the model detailed above suggests an extent of tableland utilization that merits further discussion.

It is, of course, highly improbable (or, more likely, simply impossible due to the twin constraints of labor and water availability) that ancient farmers utilized the entirety of the available tableland area for agricultural purposes at any one time. Indeed, one of the key strengths of the tableland irrigation system that appears to be in place in Upper Waiapuka is its inherent flexibility. Ancient farmers could selectively irrigate target areas based on seasonal water availability, with more restrictive irrigation practiced during drier years and more permissive practices employed during wetter periods.

Politics would have undoubtedly played an important role in the disposition of water resources in the Eastern gulch *ahupua'a*. As noted previously, higher status families dwelled close to the coast for access to marine resources, but also kept plots to feed themselves, to tend by themselves or have tended by others (Kirch 1985). This being the case, it would have been imperative to ensure a relatively unimpeded flow of fresh water to the lower elevations. This vertical community organizing principle (inverted as it is from the typical Western conception of the vertical hierarchy wherein high status groups tend to gravitate towards higher elevations) would have exerted pressure on communities to irrigate tableland plots very selectively. To ensure sufficient water reached the lowland, they would have likely irrigated tableland plots selectively over portions of a gulch's length, rather than irrigating wherever possible along its entire length.

Current evidence from Upper Waiapuka also suggests that only one side of a gulch was tapped for tableland irrigation at a time—at least at any given elevation on the slope. This further restricted irrigated agricultural development with respect to the geography of individual drainages (McCoy and Graves 2010). Ancient farmers seeking to expand irrigation onto the tablelands would have had to survey their targets and their water source carefully, to have the greatest effect. However, nearly 2290 hectares were identified as having a suitable gradient for agriculture in the analysis of the tablelands directly adjacent to streams. Even if only 10% of them were actively irrigated and farmed at any given time, cultivators working in the region would have more than quadrupled the growing area present within the gulches and the drainages of the neighboring valleys.

The primary crop of the intra-gulch *lo'i,* as was the case in irrigated fields across the Hawaiian Islands, was *Colocasia esuculenta,* commonly referred to as taro (*kalo*). Carried across the Pacific aboard the voyaging canoes of the earliest settlers (ca. 500 A.D.) and widely cultivated across the islands, ancient Hawaiian farmers identified and utilized hundreds of varieties of taro plants (Kirch 1985). A taro crop's yield of mature corms—the fleshy body-stalk of the taro plant—is generally measured by weight. This is somewhat variable, however, based on the variety of the plant, the placement of the plants in relation to one another (their crop density), and the environmental context of their cultivation (e.g. irrigated versus dry land growing conditions). Under modern growing conditions, with the benefits of fertilizers, pesticides and mechanization, yields up to 70 metric tons per hectare (70 t/ha) have been recorded in Hawaii, with yields as great as 20 metric tons per hectare (20 t/ha) typical under modern growing conditions (Queensland DEEDI 2010). Assuming a relatively modest and "easily achievable" yield of 2 metric tons of mature corms per hectare (2 t/ha), the estimated yield of intra-gulch taro production would have been roughly 112 metric tons annually in the Eastern gulches and the surrounding valleys, based on current estimation of gulch *lo'i* capacities (Tuggle and Tomonari-Tuggle 1988, McCoy and Graves 2010). With the addition of just ten percent of the region's tablelands dedicated to irrigated taro cultivation, annual regional production may have reached as high as 450 metric tons of mature taro corms, based solely on the most modest estimates of crop densities and yields, and in actuality may have produced vastly more.

Figure 4.13: Top: *Ipomoea batatas*, the sweet potato (*ʻuala*). Photo by Wikimedia user Miya, used under the Creative Commons license. Bottom: *Colocasia esuculenta*, the leaves of the taro plant (*kalo*). Photo by Wikimedia user Kahuroa, released into the Public Domain.

A further confounding factor, as of yet unexplored, was the potential use of the tablelands for the cultivation of traditionally dry land crops. Sugarcane, cultivated widely across Hawai‘i from the late 18th century through the middle of the 20th century, is an excellent example to consider, as it was grown extensively on the tablelands beginning early in the historic era. Sugarcane requires up to 24 inches of moisture annually—well within the average minima of rainfall across windward Kohala, regardless of the cane industry's support for the creation of the Kohala Ditch to bolster their growing efforts (Wilcox 1998). The cane industry in the eastern gulch region operated solely by dint of regionally accessible resources before the construction of the Kohala Ditch. This suggests that tableland agriculture was a viable practice before the creation of large scale water projects, by utilizing gulch-to-table irrigation and by reliance on the near daily rainfalls.

Likewise, the exposed tableland surfaces seem ideal for the cultivation of another staple crop enjoyed by Hawaiians past and present: *Ipomoea batatas,* the sweet potato (*‘uala*). Sweet potato, like taro, was transported to the Hawai‘i early in the island's cultural history. The sweet potato is a starchy tuber with edible foliage, calorie rich and high in protein and complex carbohydrates. A hearty plant, the sweet potato can thrive in dry conditions, but does exceedingly well with moderate rainfall and can take hold even in soils with relatively low soil nutrient levels (Kirch 1994). It's the sweet potato's resilient nature—that is, the plant's capacity to thrive in marginal landscapes—that made it an ideal crop for cultivation in the extensive leeward field systems of Kohala and Kona (Kirch 1985). Those same attributes make the sweet potato an ideal crop for tableland cultivation in windward Kohala.

Kirch observed during his analysis of the Kaloaloa gardens of the Anahulu Valley on Oʻahu that irrigated taro plots may have been bounded on the margins by small plots dedicated to growing traditionally dry land crops (1992: 143). I propose that dry land crops, and in particular the sweet potato, would have been noted by ancient Hawaiian farmers as ideal crops for tableland cultivation. Historic era maps and archaeological evidence seem to indicate that irrigated tableland *loʻi* were largely restricted to areas close to the interface of the gulch and the tableland. If this was in fact the case, then ample lands would have been available for the cultivation of dry land crops, and for use by other domesticates such as swine. The selection criteria for dry crop tableland plots would have remained generally the same as the proposed criterion for irrigated tableland plots—cultivators would select the plots with as minimal amount of slope as possible for easier access. However, dry crop plots would not have had the constraint of being in direct proximity to a gulch. Ancient farmers could have placed dry plots on the wide open tracts between the gulches, which are often times hundreds of meters across.

Hawaiʻi's Expansion Period (1200 to 1600 A.D.) pushed the island's inhabitants into increasingly marginal hinterlands—resulting in the rise of leeward settlements and field systems, the development of settlements and agricultural resources in the inland valleys, and the inhabitation of higher elevation slopes where the soils are generally less favorable for growing. Given the degree of this pressure, it seems to be a foregone conclusion that the eastern gulch region's tablelands would have been turned to agricultural uses as a matter of course. The fundamental problem with the proposition that non-irrigated agriculture was practiced on the tablelands (in addition to irrigated agriculture) is that the tableland surfaces lack the detritus associated with the more visible dry agricultural systems on the leeward side of the island, such as the stone and earthen walls that gridiron Kohala's sprawling leeward field system.

It is conceivable, however, that low windbreaks of compressed soil were used to shield vulnerable crops from the blistering wind, as present-day experiments in dry land cultivation are bearing out in leeward North Kohala. These constructions would have been less persistent in the long term than stone constructions but also less labor intensive to build: a shallow trench would be excavated to expose a growing surface and the fill would be used to create speed bump- like windbreaks. Furthermore, given the extent to which the sugarcane industry expanded in windward Kohala, and the aforementioned disturbance regimes that both accompanied and followed it, a lack of evidence for dry land agriculture on the tablelands should not be construed as evidence of lack (Tuggle and Tomonari-Tuggle 1988). Lingering evidence of such earthen constructions is precisely the kind of phenomena that would have been obliterated by later use-patterns.

Defense of predictive modeling strategies

Predictive modeling is the process of extrapolating the potential for unknown sites within a region from existing archaeological and environmental data. The process of predictive modeling ascribes great value to one or more variables in the sampled environment when examining how past peoples may have utilized the landscape (Kvamme 1999). For this reason, predictive modeling has been characterized as environmentally deterministic for stressing environmental over human factors (Wheatley and Gillings 2002), or for failing to connect the modeled phenomena to the underlying anthropological processes that drive them (Aldenderfer 1998). These accusations, while sometimes fair, detract from the practical application of predictive strategies. Predictive modeling has been most widely applied within the field of cultural resource management, in order to "predict" the location of settlement sites based on resource availability across a landscape, or to identify potential sites by other characteristics of the environment, such as the landform itself (Kvamme 1990 and 1999). Predictive modeling is an inferential system that reflects the archaeological axiom of "working from the known to the unknown," as the characteristics of known sites are used to infer the existence of unknown sites—typically through regression analysis.

While the approach used here does not explicitly conform to the practice of predictive modeling—in that it does not utilize a structured regression analysis, and relies upon the sampling of suspected sites based primarily on evidence gleaned from within the gulches and from historic sources rather than from known cultural resources—this strategy appeals to predictive modeling in principle. The objective undertaken here was to extrapolate what was known of strongly suspected tableland sites in Waiapuka *ahupua'a*, as well as known historic sites across the region, in order to evaluate the potential distribution of other tableland sites. In truth, the model presented here represents an effort to quantify the potential extent of agricultural expansion in the eastern gulches, rather than structured statistical analysis intended to accurately locate existing archaeological sites. The value of this analysis is as a visualization of the processes of agricultural expansion that altered the face of the Kohala slopes.

Limitations of the model

This model is an attempt to begin quantifying the potential for tableland agriculture in the eastern gulch region. Maps depicting historic era sugarcane plots have been the primary evidence in favor of the proposition that agricultural development was expanded on to the tablelands, along with evidence of tableland targeting irrigation ditches emanating from the gulches. Because the initial slope sampling was conducted in the uplands, on areas suspected to have been the targets of irrigation ditches transiting out of the gulches, the model did not locate some known tableland plots. For example, it did not suggest the location of the sugarcane fields associated with Father Bond's residence in coastal 'Iole (Tomonari-Tuggle 1988: 49), where the percentage of slope is much lower on average (post hoc-sampling indicates that the average slope in the area of Lower 'Iole is only in the neighborhood of 3% grade). Additionally, some of the historic era sugar plots documented in the eastern gulches were either obscured by the stream buffers, as noted above, or otherwise fell outside of the catchment of the first analysis' 10.00% to18.00% gradient range.

Post-hoc analysis demonstrated that the historic plots in the region ranged 4% lower than the upland sample areas on average, but large portions of the historic plots still fell within the catchment of the original analysis. Expanding the catchment to include the extended range of slopes defined by the cane era plots only served to enhance coverage in the lowlands and did not significantly enhance the analysis of the uplands. However, it must be acknowledged that this early attempt to model potential agricultural resources did not identify the full extent of the known *historic* sites until a second analysis was conducted using slope variables specifically gleaned from an analysis of the historic tableland sites.

Consequently, the second analysis, based on the sampling of historic tableland plots which demonstrated an overall greater degree of variance in slope values, may have implications that better reflect the general characteristics of tableland sites and of the selection criteria used by ancient farmers to choose sites for cultivation. If that is the case, then it is increasingly likely that the slope of the tablelands was not the sole limiting factor for tableland farming except in the most extreme cases where the grade makes working the land impractically difficult. Instead, the limiting factors would depend on the intentions of growers to irrigate a plot or to cultivate drop crops. Irrigated plots would have to be proximate to a gulch and strictly down slope of the highest elevation gulch *lo'i*. In contrast, dry plots could be positioned quite nearly anywhere, with preference for the most accessible, flattest tableland surfaces. In my opinion, the areas defined in the latter analysis (derived from the documentation of historical tableland plots) better reflect the preferred areas for cultivation. This is additionally supported by the proximity of water resources and the apparent relationship gulch *lo'i* to tableland plots as indicated by the field research detailed in this thesis.

Conclusion

Although there is a dearth of intact archaeological sites on the tablelands of windward North Kohala, historic evidence combined with a growing body of archaeological evidence collected from within the gulches suggests that tablelands were utilized—perhaps extensively so—for agricultural purposes. The surface analyses detailed in this chapter are intended to define the uppermost limits of how much land area could have reasonably been dedicated to agricultural investments. These analyses are limited in that they cannot account for many on the ground realities, such as space allocated to habitation and animal husbandry, or space allocated for paths, structures, or ritual. They do, however, suggest that intensified agriculture might have taken in the gulch region, in contrast to the vast leeward field system. What is certain is that ancient farmers had to cultivate increasingly marginal land in order to support the demands of a swelling population and a commensurately growing elite class. This examination of the tablelands is an attempt to show the possible extents of wet and dry agriculture on the tablelands, to visualize this area of possibility for the sake of future investigations, and to place surface sampling and excavations of 2009 in a larger regional context of environmental systems.

The following chapter returns to theoretical discussions in light of the evidence presented in this chapter and in Chapter 3.

Chapter 5: Water and Power

Introduction

The term landscape was primarily used in the preceding discussions to describe the natural and modified environment of North Kohala. Similarly, much of this text has been focused on how space may have been appropriated across the eastern gulch region to support agricultural expansion and intensification processes. However, in this chapter, the focus shifts to encompass ecology and the meanings embedded in the concept of landscapes.

In the forthcoming sections I address the social implications of agricultural expansion and intensification by applying the framework of political ecology—an underutilized perspective in contemporary archaeological research. I will evaluate the findings of this research through the theoretical lens of political ecology and connect this project to ongoing discussions of Hawai‘i’s transition from a collection of subsistence driven communities into a sprawling and highly stratified complex society. I go on to discuss the tension between ecology and agency present in political ecology and how it manifests in the archaeology of windward North Kohala. I draw on an example from southeastern Polynesia to illustrate the importance of ecology on the formation of complex society, and to highlight the often deleterious effects of the feedback cycles that connect human society, symbiotically, to the environment. Finally, I conclude with a discussion of how these concepts connect the agricultural innovations of the eastern gulches of North Kohala to broader horizons in Polynesian prehistory.

Revisiting social landscapes

Many of the discussions throughout the early chapters of this thesis have addressed the issues of physical landscapes and geographic regions as units of analysis—that is, something to be measured and quantified, or compared and contrasted. McCoy (2006: 22) noted an important distinction arising from within landscape archaeology: "landscape research is often divided into that focused on human-environment relationships under the heading of 'natural landscapes,' or on human-human relationships, in terms of 'social landscapes.'" Likewise, Ashmore (2002: 1172) underscores the idea that "space is actively inhabited, and that social relations and spatial structure are linked recursively," highlighting the need for a synthesized archaeology that bridges the spatial and social divides to create a more holistic image of human experience. Thus far, the treatment of landscapes throughout this thesis has been from a primarily spatial perspective and focused on human-environment interactions. The emphasis herein has been on the use of space by past peoples for agricultural purposes, coupled with brief discussions on the inter-relatedness of complex systems on the landscape, such as the leeward and windward agricultural centers of North Kohala.

Landscapes encompass the physical world, but are also social and economic spaces that are "lived" by their inhabitants (Shanks and Tilley 1988, Joyce 2004). In light of post-modern hermeneutical, interpretive theories of landscapes, it can be said that landscapes form the root of human experiences, as the environment both subtly and overtly effects the formation of social systems and the congress of daily life.

Furthermore, landscapes leave their impression on culture, as surely as culture impresses itself upon the landscape: the Big Island's complex leeward field systems are an excellent example of social and environmental pressures culminating in sweeping landscape modification so vast that the remains are plainly visible even in satellite imagery. The construction of the elaborate field systems on the arid portions of the islands was a result of increasing social and political pressure to escalate the production of food surpluses, in defiance of the relatively poor growing conditions present there. Growing strategies were adapted to meet the challenges posed by the environment, and cumulative investments in infrastructure were the result of the escalating demands of a changing society and its political elites. The results of this push and pull of dynamic forces on ancient farmers and means of production is still visible on the Hawai‘i's modern landscape.

The application of practice theory to landscape studies has seen limited traction in the field of archaeology thus far (McCoy 2006). Practice theory, championed most notably by social theory pioneer Pierre Bourdieu (1977), ascribes people with agency or the capacity for individuals and for collectives of individuals to act as decision-makers in their world. Practice theory draws a distinction between "practices," or discrete human behaviors, and "structures," which are the underlying lattice works around which society is organized. The social structures described by practice theory take diverse forms: they can reflect the orthodoxy of religion, or a political caste system, but they are not, by some definitional necessity, comprised solely of macro-institutions—the customs that dictate family life or the embedded practices surrounding food preparation and subsistence strategies could also be defined as structures. Regardless of the level at which they operate, social structures serve to inform the practices of people as they navigate their social world. As a further note, structures are often self-perpetuating. The patterns of behavior that they promote tend to reinforce the validity of the operating social structure, even if the institution is somewhat deleterious for those that are affected by it; in essence, they create pockets of cultural hegemony that help to grow or reinforce entrenched power relationships.

As a further elaboration of practice theory, Bourdieu employs the concept of *habitus*. On the surface, *habitus* appear as the frames of reference which people use to make culturally appropriate decisions, and around which practices are organized. In fact, *habitus* is both the process and the product of practices becoming part of existing social structures. Additionally, *habitus* can form entirely new social structures through the repetition and eventual absorption of discrete practices or clusters of practices into the underlying structures of society.

Bourdieu's practice theory and his use of *habitus* present a useful framework for grounding the broader transformative patterns explored in landscape analysis within the actions of past peoples. However, Bourdieu's application of practice theory does not explicitly account for the influence of the environment upon the formation of social structures. His primary caveat is only that social structures are formed recursively, through the repetition and accumulation of *habitus*, which, as deeply embedded practices, can be *influenced* by the lived environment or by external environmental pressures at any phase during their formation. A more explicit acknowledgement of the environment's role in the formation of societies is desirable in light the focus upon landscapes. My argument for the environment's role in the elaboration of social systems should not be construed as an acceptance of environmental determinism, but rather as a step towards a middle position that favors a more nuanced interpretation of human and environmental factors in the formation of societies.

As noted in Chapter 2, the framework of political ecology, a contemporary retooling of Marxian political economic theories that focuses on human-environment interactions and agency, offers the most comprehensive blending of practice-centric, environmental and economic theories to explore the interactions of the social and natural landscapes. The focus will now turn to the political ecology of North Kohala and the social and environmental feedback cycles that lead to the creation of innovations that increased agricultural production and, ultimately, social complexity in Hawaiian society.

The political ecology of North Kohala, Hawai'i Island

A principle question of this research is how ancient Hawaiian society was shaped by its ongoing interactions with and within the island environments. Within the rubric of political ecology it is absolutely essential to recognize the influence of social actors in shaping society—to recognize that past peoples were decision-makers and action-takers, navigating social and physical worlds, and affecting the ancient landscape through their actions. However, beyond the social consequences of human-human interaction, it is also essential to acknowledge the effects of environmental pressures acting upon society. As noted in Chapter 2, it is political ecology's emphasis on agency and the human valence of human-environment interactions that most strongly distinguishes it from the more environmentally deterministic cultural ecological approaches. Political ecology explicitly acknowledges the symbiotic relationships between political, social, and economic structures.

Political ecology also embraces the simple logic that as culture shapes the environment—through cultural agents acting upon and modifying the landscape—so too does the environment act on culture by exerting its own unique pressures (Rappaport 1968; Biersack 2006). Flora, fauna, resource availability, terrain, weather, and countless other environmental traits influence and inform the processes by which culture is created and recapitulated through time, through the accumulation of ecologically influenced *habitus*. That is not meant to suggest that the environment is the sole determinant of culture's expression, but rather that the environment, in concert with people acting on the landscape, is an important factor affecting the formation of society.

In Hawai‘i, the practical expansion of communities and agricultural resources was in many respects circumscribed by the insurmountable physical barriers of island life—chiefly, that island environments are naturally isolated by the sea. Islands have a finite land area—only a fraction of which is suitable for agriculture or for long term human habitation. The Hawaiian Islands are also comprised of many unique climate zones, the most significant division being along the leeward/windward axis, with distinct opportunities and challenges intrinsic to each zone. These environmental differences had an irrefutable effect on Hawaiian social systems as evidenced by the creation of novel adaptive agricultural technologies, as well as the escalation of territorial conflicts and drive towards expansionism among the chiefly classes in resource poor regions. The unique environmental features of the islands also drove agricultural innovation across the archipelago along three axes: adaptation, expansion and intensification. The following sections explore these drivers of innovation through the lens of political ecology.

Drivers of innovation: adaptation, expansion and intensification

Kirch (1985) presents a brief account of the expansion of settlements and agricultural resources across the Hawaiian archipelago. The earliest settlers of the Hawaiian Islands arrived circa 300 to 500 A.D., occupying the verdant windward valleys and lowlands of the principle islands. By the end of the first millennium (ca. 900-1100 A.D.), populations were so densely concentrated on windward resources that permanent settlements began to form in the most accessible or resource rich leeward zones, particularly on the western coast of the Big Island, in North Kohala and Kona, where the expansive field systems remain. A scant few hundred years later, steady population growth followed by a nearly exponential population boom (ca. 1400-1650 A.D.) cemented the leeward settlements and drove continued settlement and agricultural expansion into increasingly marginal territories: flood-prone inland valleys, higher elevation slopes, and marginal hinterlands such as windward North Kohala's tablelands.

In addition to a change in the distribution of settlements and exploited territories, Hawai'i's Expansion Period (1250-1650 A.D.) also witnessed an abundance of innovation, both technological and social. Agricultural innovations such as the gulch-to-tableland irrigation systems described in this thesis (and also in McCoy and Graves 2008 and 2010), and the windbreak fields (Ladefoged, *et al* 2003; McCoy and Graves 2010) utilized in leeward Kohala and as noted herein, potentially in other marginal areas such as on windward Kohala's tablelands, are representative of the technologies implemented to derive greater and greater returns from the environment. These technological developments were coincident with the expansion of the leeward field systems, and with regimes of intensification that reduced fallow periods and generally increased the output of agricultural systems to meet increased demands. However, as Kirch (1985) has observed, commensurate with this rapid growth in population, there was a dramatic increase in social stratification to manage the expanding populations and systems. Likewise, oral histories corroborate the archaeological evidence and support the notion that the formation of the earliest large chiefdoms, on the Big Island occurred at roughly the same time, ca. 1200-1300 A.D. (Cordy 2000).

The expansion and intensification of agricultural projects, in addition to the innovation of novel agricultural technologies, denotes an important transition from simple subsistence strategies to the development of a surplus economy. The surplus economy was predicated on the appropriation of the surplus by the chiefly class for redistribution to favored retainers and priests, or to feed warriors and thus fuel the engine of conquest. In at least two notable examples on the Big Island the expansion of farming efforts and the innovation of novel farming technologies in the affected regions in the early 15th century A.D. occurs concurrently with a war between neighboring polities (McCoy and Graves 2010). These are the leeward Kohala field system and the eastern gulch region of windward Kohala—the primary site of this research. The correspondence between martial conflicts and agricultural intensification reflects the degree of relatedness between growing surpluses and escalating territorial warfare and expanding chiefly dominions (McCoy and Graves 2010).

Once more, Kirch (1985) describes agricultural development in Hawaiʻi as being the product of three major processes: adaptation, expansion and intensification. The process of adaptation occurred early in Hawaiʻi's human history as settlers brought familiar crops such as taro (*Colocasia esuculenta*), sweet potato (*Ipomoea batatas*), sugarcane (*Saccharum officinarum*), bananas (genus *Musa* variants), and coconuts (*Cocos nucifera*), among others, from the Polynesian homelands far to the south and found niches for each in Hawaiʻi's diverse climates, as it was the northern-most Polynesian outlier. During this phase, settlement and resource utilization was focused on the territories most favorable for agriculture or with the greatest access to essential, but alternative resource bases, such as marine resources, mineral resources, or useful but inedible plants.

The process of expansion logically follows the process of adaptation, as it reflects "the pioneering process of introducing an agricultural landscape into a natural one" (Kirch 1985:217). During this stage, land is cleared and the basic agricultural infrastructure is put into place in order to maintain a simple subsistence economy. In keeping with the "pioneering" element of the expansion phase, marginal territories such as inland valleys and leeward slopes began to see greater use, as a growing demand for crops drove ancient farmers to utilize more of the arid or flood prone reaches of the islands. It is also during one such agricultural expansion phase in North Kohala culminating circa 1400 A.D. that innovations like the irrigated tableland farming observed in Waiapuka *ahupuaʻa* began to emerge.

Intensification is the final process described in Kirch's sequence of agricultural development. Intensification is the process of applying increasingly greater amounts of energy—in the form of labor—to agricultural systems in order to achieve greater and greater yields on that investment. Escalating labor inputs, either through the direct management of crops (i.e. fertilizing, regular and persistent weeding, reducing or eliminating fallow periods, etc.) or through the development of additional or advanced infrastructure (i.e. constructing wind-breaks, terracing or irrigating the landscape, etc.), was essential to improving the outputs of existing systems and absolutely paramount to supporting continued growth as more and more agricultural land was subsumed by expansion. The process of intensification is characterized by the implementation of large scale agricultural projects, labor intensive infrastructural investments and practices, and by the exploitation of marginal or fringe landscapes. This process is most evident in leeward Kohala's field system, where recent studies suggest that there were periods of concentrated effort spent expanding and elaborating the network of windbreaks and field boundaries from roughly 1400 A.D. to 1650 A.D. (Ladefoged, *et al* 2003, Ladefoged and Graves 2007, McCoy and Graves 2010).

Intensification of agricultural production has historically been linked to increasing social complexity and in particular the creation of social hierarchies and embedded class structures (Wolf 1972). In Hawaiʻi, the period of greatest agricultural intensification—in the decades and centuries just prior to European contact—was also a period of increasing strife, as neighboring polities began to vie for control of desirable resources. These conflicts served a number of purposes that ranged from enhancing the prestige of militant chiefs, to increasing the resource base of the triumphant polities, to entrenching the shifting power dynamics and social stratification affecting Hawaiian society, and were an essential element of Hawai‘i’s increasing social complexity.

Growing hostilities

At the time of contact, Hawaiian agriculture was nothing if not intensive, and few regions exemplified the processes of intensification more holistically than North Kohala. The expansive leeward field system and the intricately irrigated gulch region and valleys made North Kohala perhaps the most agriculturally productive district on the Big Island—certainly, only Kona’s field systems rivaled it for size. Agricultural systems such as these were essential to supporting a swelling population and a growing class of elites—both of which comprise the primary pressures Kirch identifies as driving intensification (Kirch 1985).

In the specific case of North Kohala, where oral-histories suggest that powerful lines of chiefs reigned over a cluster of polities, intensification of agricultural resources in windward and leeward Kohala was essential to consolidating power, and ultimately pivotal to Kamehameha I’s eventual bid for dominance over the all islands of Hawai‘i (Kirch 1985, Sahlins 1985, Cordy 2000). However, before North Kohala’s agricultural resources were consolidated under a unified power base, they were first the subjects of territorial conflicts and regional strife.

As agricultural innovation allowed for and supported the formation of non-food-producing elite classes of warriors, chieftains and priests, it thus became essential to continue to produce surpluses in order to sustain the new social order. High population densities, combined with the uneven distribution of resources across a naturally ocean-bound and climatically-diverse island environment has been characterized as an ideal site for territorial conflict (Kirch 1985 and 1988, Johnson and Earle 2000). The intensification of agricultural production, besides creating surplus quantities of staple crops to meet chiefly tithes, *could* have also served to ameliorate a direct stress that promoted inter-territorial conflicts—primarily the need for food in less productive regions. However, ethnohistoric evidence suggests the exchange of goods by trade between polities was limited (Johnson and Earle 2000). Instead, the goods generated by a community's food producing members were generally cycled within the same or related territories and not utilized as commodities of exchange beyond the collective polity. So while there may have been an informal structure to mediate the exchange of goods between families within a single community or within related territories, very few goods were likely to end up in competing polities (Johnson and Earle 2000). What foodstuffs that were not consumed within a given polity were appropriated as tithes by ascending hierarchies of chiefs to sustain the non-producing classes. Since surpluses were essential to the social maintenance of the upper classes, increasing production capacities was an "essential goal" of chiefly territorial conflict (Kirch 1985: 235). It is unsurprising then that the chiefdoms most prone to expansionist conflict were those situated in hardscrabble, resource poor regions such as the arid leeward coast of the Big Island or the most soil-nutrient depleted windward reaches of the islands (McCoy and Graves 2010).

Genealogies and oral-histories offer access points to the social memory and culture history of the region's inhabitants. Oral tradition suggests that North Kohala was the site of three discrete political entities at the beginning of Hawai'i's Expansion Period, ca. 1200-1300 A.D. (Cordy 2000). Of these three polities, two were located on North Kohala's leeward coast; one centered on the community of Waimea in the district's south, and another centered on Kukuipahu in the north. The third North Kohala polity was situated on the windward coast, centered on Niuli'i *ahupua'a* in the eastern gulch region (Cordy 2000). Cordy further cites a conflict between the polity of Niuli'i and the polity of Kukuipahu, in which the warriors of Niuli'i defeated the warriors of Kukuipahu, unifying the northern expanse of the North Kohala district (2000:141). By studying the genealogies of chiefly clans and reconciling variations, Cordy situates this conflict somewhere between the mid-1200's and the early 1300's A.D.

As noted above, McCoy and Graves (2010), observed the co-incidence of these inter-polity hostilities in North Kohala with the expansion and intensification of the agricultural resources throughout the region. Cordy notes, however, that contemporaneous with these conflicts and agricultural intensification, was the emergence of a tripartite social organization principle—particularly in the windward polities—in which a high chief would manage a cadre of regional chiefs, who would in turn oversee their region's commoners (Cordy 2000). This clear stratification of social status, separating the *ali'i 'ai moku* (high chiefs who administer districts, small countries or *moku*) from the *maka'ainana* (commoners) through intermediary *ali'i ai ahupua'a* (sub-chiefs) who tended matters at the community level, resonates with Western conceptions of feudalism and denotes a sea change in social organization and governance in Hawai'i. These developments, which served to distance leadership from the commoners, thus increasing their authoritative mystique, signal the foundations of archaic statehood and the formation of social structures that are indicative of complex societies (Cordy 2000, McCoy and Graves 2010).

It is unsurprising that these social transformations began in the windward polities such as Niuli'i, as Cordy indicates. As mentioned elsewhere, evidence suggests that the windward coasts and valleys saw the earliest inhabitation by early Polynesian settlers, and were thus the first regions of the islands to be widely exploited (Kirch 1985). As a further consequence of this early settlement distribution, the windward polities also supported the densest populations up until Hawai'i underwent its period of expansion. The eastern gulch *ahupua'a* of North Kohala, located as they are between the northern interface of the island's windward and leeward climate zones and the rugged windward valleys to the south, would have been particularly susceptible to the growing pains brought about by a swelling population and the geographical limitations of expansions brought about by the rugged environment. These pressures provided the critical impetus for chiefs to march to war in order to increase their holdings, and for ancient farmers to innovate novel strategies for exploiting the landscape for greater returns. In essence, the feedback cycles formed by the interactions of population growth, military conquest and agricultural expansion operating simultaneously upon one another within in the unique island environment catalyzed the processes of continued social development. The feedback cycles formed by these processes were essential to the symbiotic relationship between people and their environment, which is discussed in greater detail below.

The role of agency in the formation of complex human-ecological systems

By focusing this discussion exclusively on the environmental, social and political pressures that compelled structural changes within Hawaiian society, there is a risk of short-changing the impact of individual actors on the social and natural landscapes. Similarly, it is easy to underscore the growing importance of the role of the chiefs as Hawaiian society became increasingly stratified and elevated its rulers further above the common people. The relative accessibility of chiefly genealogies and thus the centrality of chiefly lines in narrative histories of Hawaiʻi does, at times, create the impression that ancient Hawaiʻi was strictly defined by the decisions and actions of what some late sociologists referred to as "Great Men." Herbert Spencer, the early social theorist and strict adherent to social Darwinism, suggested that these so-called great men of history, many of whom his contemporaries saw as solely defining history through their actions, were in fact products of their social environment and elevated by their response to the circumstances of history (Spencer 1896). This theory of Spencer's stood in opposition to notions that there was some kind of inherent greatness possessed by the special few empowered to shape history. To his credit, Spencer's assertion was far ahead of his time; however, he failed to take the further step of acknowledging the agency of common people—only that common people can be great under the right circumstances.

It is often difficult to distinguish the role of agency in the formation of complex systems, particularly if those systems are deeply embedded or interact with the environment under a centralized authority. Actively acknowledging the impacts of human agency is an essential part of the political ecology framework, and identifying the role of agency in the formation of complex systems is an important theoretical undertaking. For example, on the Indonesian island of Bali, intricate irrigation systems support networks of communities and are administered by water temples (*Subak*) that adjudicate regional resource conflicts and issues of distribution throughout the network (Lansing, *et al* 2006). The argument that Lansing and his co-authors present is that a complex system of water management such as the Balinese *Subak* does not necessarily need global oversight in order for its construction and continued functioning—instead they maintain that deeply embedded networks can coalesce through the self-organization of the participants and their continued buy-in to the system (Lansing, *et al* 2006: 355). Likewise, one could argue that the novel irrigation technologies observed in windward North Kohala represent emergent adaptive strategies engineered to meet the challenges confronting the growers themselves.

From an agency-centric perspective, the adaptation of agricultural techniques to the Hawaiian environment, as well as the expansion of agricultural works and the innovation of new techniques, was not *just* a response to increasing social and environmental pressures, but could also indicate calculated efforts by growers to anticipate and meet the challenges facing them head-on. In this “bottom-up” paradigm, the feedback cycle begins with the farmers, who, by refining their trade to the extent that they increased the productivity of agricultural landscapes, created an environment suitable for the rise of ever more powerful chiefs. Kirch (1992:173) opens the debate as to whether or not the intent of agricultural innovation and intensification is a response to population pressures or to a demand for increased surplus. However, Kirch notes in no uncertain terms that, "control of the means of production by chiefs is typical throughout Polynesia" (1991:130). It is safe to assume, regardless of however much agency growers in windward Kohala had to design and implement agricultural infrastructure on their own recognizance that as commoners were ensconced by the feudal land tenure system, operative power over labor increasingly belonged to society's elites. Even prior to the transition into the three-tiered power dynamic that emerged during the late Expansion Period, Hawaiian society still largely operated under the two-tiered hierarchy of local chiefs as community rulers, characteristic of Polynesian societies (Sahlins 1958; Kirch 1991; Johnson and Earle 2000).

It is safe to assume that North Kohala was not exceptional with respect to its patterns of governance, which likely adhered to the patterns observed across the islands. Moreover, given the region's notability as the ancestral home of several lines of powerful chiefs, whose influence had great impacts on the formation and unification of the future Hawaiian kingdom, the North Kohala district may prove to be an exemplary case for reflecting the role of chiefly authority in the development of complex systems. Thus the critical element of this examination of power relationship is in considering how the promotion and resistance to the relationships between the commoners and the hierarchy of chiefs acted upon the environment and promoted the complex patterns of land use that are becoming increasingly apparent in the archaeology of windward Kohala, and that contributed to development of Hawai‘i as a complex society. The keenest way to reflect that interplay is through the contrasting example presented by the Marquesas Islands.

Symbiotic landscapes: contrasting Hawai‘i and the Marquesas Islands

Hawai‘i has been described as a model context for studying the formation of complex societies (McCoy 2006). This is in large part due to the Hawaiian Islands' relative ecological resilience, in contrast to the fragility of most of Oceania's island environments. That isn't to say that the Hawaiian Islands were exceptional in this regard, but their relative youth, favorable winds and rains, thriving marine environments, and ample size provided tangible benefits to their ancient inhabitants. These traits are not ubiquitous across Oceania, and the absence or addition of one or another altered the natural ecodynamics such that a burgeoning society could either thrive or wither based on these environmental variations (Kirch 1985, 1994 and 2000).

The relationship between people and landscapes is best described as symbiotic. The environment persist without human interaction or influence, but landscapes—even natural landscapes—are the product of feedback between the environment and human effort (Biersack 2006). Careful stewardship of the environment is rewarded with positive feedback, in the form of economic and social capital (Wolf 1972). Likewise, increased energy inputs are rewarded with increased returns—at least until tipping points are reached that result in systemic failure. As ancient cultivators modified the landscape with increasingly complex agricultural technologies to support a swelling population, they were also modifying the fabric of society—inadvertently perhaps—to support the emergent social systems that gradually increased social complexity and eventually ensconced the means of production to be completely under the control of social elites (Lansing *et al* 2006; Scarborough 2008).

This level of managerial authority stewarded by social elites did not necessarily translate into more effective systems, however. While other Polynesian people did engage in intensified agriculture to varying degrees, nowhere else was the extent of agricultural and aquacultural intensification as pronounced as in the Hawaiian Islands (Kirch 1985). Even among the Hawaiian Islands, North Kohala *moku* is particularly notable for the extent and apparent effectiveness of its agricultural infrastructure. Neither are there strong equivalents to be drawn for the complexity of relationships between commoners, greater and lesser chiefs, priests and warriors elsewhere in Polynesia, save perhaps in the older and well established societies of Tonga and Tahiti (Kirch 1991). In many respects, the successes of Hawaiian agricultural intensification and its concomitant process of "social intensification," or the increase of social stratification and power relationships, were possible due to the relative youth and resilience of the Hawaiian ecosystem. That these characteristics were not ubiquitous across Oceania, however, is exemplified by the example made by the Marquesas.

The Marquesas Islands, situated far southeast of Hawai'i in Central Polynesia, offer a strong contrast to Hawaiian social development in light of the influence of ecology on the formation of complex societies. The Marquesas are a far older island chain than the Hawaiian Islands, with the youngest island Fatu Hiva, estimated to be 1.3

million years old, and the oldest island Eiao, estimated at roughly 6 million years old. These dates stand in contrast to Hawai‘i's range of roughly 600 thousand years for the oldest reaches of the Big Island, to diminutive Ni‘ihau's 5 million years of age. Consequently, the soils of the Marquesas have suffered from erosion and natural depletive processes far longer than the soils of the Hawaiian Islands. Likewise, the Marquesas are smaller on the whole, present a rougher terrain, and are frequently subjected to periods of extended drought; still they support the essential Polynesian cultigens, as well as the ubiquitous swine (Kirch 1991). It is notable however, that the dearth of reef environments around the Marquesas did make fishing and marine gathering strategies a less rewarding enterprise for the Marquesans than for ancient Hawaiians, though marine mollusks remained an important source of protein.

The Marquesans, like the early Hawaiians, organized themselves into small tribes with two primary tiers of social stratification (Sahlins 1958, Kirch 1991). Under this system, the community chief, priests, and the heads and kin of the most prestigious families formed the chiefly class, while craftspeople and cultivators constituted the commoners (Sahlins 1958). This mirrors the early social patterning of Hawai‘i in many respects, and is recognizable across Polynesia as the basic pattern of social organization (Kirch 1985 and 1991). However, unlike Hawai‘i, and the well-established chiefdoms of Tonga and Tahiti, the people of the Marquesas never approached the level of archaic statehood that the larger island groups achieved. The Marquesan chiefdoms were somewhat more fluid in the ways power manifested and was reapportioned; chiefs did not necessarily command strict social authority, but did control—and frequently fought over—the means of agricultural production, and the priests exerted great influence on the procession of ritual and warfare, and thus great influence upon the fabric of Marquesan society (Sahlins 1958).

Agriculture in the Marquesas underwent similar periods of expansion and intensification as Hawaiian agriculture. By the time Hawai'i began its Expansion Period, circa. 1200 A.D., the Marquesas were already undergoing a similar boom. This period saw the islands' population swell dramatically and a commensurate augmentation of subsistence and ritual strategies, that included the creation of irrigated and non-irrigated growing terraces for taro cultivation, expanded subsistence gathering and food storage efforts, the creation of new ritual sites and feasting platforms, and the introduction of fortifications to defend resource hubs from conquest by neighboring polities (Kirch 2000). By the end of the Marquesan Expansion Period (circa 1400 A.D.), nearly all of the ecological resources of the islands were being utilized to greater or lesser extents. Coupled with the aforementioned periodic droughts and the natural erosion of healthy soils, plus the further degradation of arable land through increased production, the level of ecological exploitation achieved by Marquesans was unsustainable, and far outstripped the carrying capacities of their islands. Ultimately, these processes lead to more prestige-based and territorial competition, hunger, and the unsavory practices of ritual murder and cannibalism (Kirch 1991).

While it is true that resource scarcities and favorable access to resource hubs stoked competition on the Big Island and others, the ecologies of the Hawaiian Islands were far more robust than the Marquesas throughout the entirety of their human histories.

Though the population of the Hawaiian Islands vastly outstripped the Marquesas at the time of contact, by as much as 5 to 1, ancient Hawaiians had not nearly reached the extent of their islands' capacities to support population growth by the period of contact.

This "room to grow," as it were, was in itself an incubator for social development, allowing for contestation over the most favorable lands while supporting expansion into less favorable hinterlands. It afforded chiefs the capacity to compete for prestige, wealth, and power, but also enough social stability to forge dynasties. By spreading the burden of production across the population of commoners in a diversity of environments, Hawaiian paramount chiefs could both ensure a measure of food security by diversifying the means of production, and minimize discontent by dividing the laborious tasks associated with agriculture as widely as possible, which could ameliorate the "Hawaiian tradition of *maka'ainana* revolts" (Kirch 1991:171-172; McCoy and Graves 2010). These conditions created a positive feedback cycle which strengthened the Hawaiian elite classes, further entrenching their powerbase, and granting them still more influence over the means of production (McCoy and Graves 2010).

Ultimately, the case of the Marquesan chiefdoms is raised here to underscore the importance of the environment and the role of ecology in the formation of complex societies. Common patterns of social organization persisted throughout ancient Oceania which both the early Hawaiians and Marquesans exemplified. However, due to a plethora of insurmountable ecological dilemmas, the chiefdoms of the Marquesas never flourished in the same way that the chiefdoms of Hawai'i managed. Thus, ecological stressors contributed to Marquesan society consuming itself both figuratively and in a very literal sense. The example set by the Marquesas illustrates how ecology informs practice, for good or ill, and how repetition of deleterious practices can embed contra-positive *habitus* in the deepest structures of society. In the contrasting case presented by North Kohala, Hawai‘i, where a measure of ecological resilience buffered inhabitants from inescapable scarcity, similar social and economic practices achieved vastly different ends, culminating in the rise of a Polynesian Kingdom.

Reflections and considerations for future research

Windward North Kohala remains a notably understudied part of the island. This thesis is intended to contribute to the slow but steady increase of attention by scholars on the complex windward agricultural systems of windward Kohala. The field research done herein was limited in scope by practical necessity, as it was just one component of an all-too-brief field season, intended to corroborate the findings of the preceding season. These constraints lead to some unfortunate, if somewhat predictable consequences, including less than ideal recording of some data, and the decision to abandon the extensive excavation at WAI-4W-J without fully documenting the final layer. This did enable us to more fully document the retaining faces of WAI-4W-M and P, however, which brings to mind that old archaeological truism: “You always find the most compelling evidence at the end of the field season.”

After due reflection, I believe that excavating a sequence of half (.5) meter wide test trenches into the gulch siding perpendicular to the gulch bottom may have been more efficacious than the substantial earthmoving project undertaken at WAI-4W-J, given the limited window of time available for excavations. This strategy would enable researchers to search for *'auwai* on the gulch siding *and* to follow their course down slope. This expanded coverage would help in identifying and tracking subsurface features over a greater distance and enable researchers to generate a rough map of at least one sequence of irrigation ditch features terminating on the tablelands. This strategy would also minimize the impact of anomalous ecofacts, such as lava sloughs, on the process of identifying cultural constructions by making multiple observations across a site continuum. As a consequence of focusing so extensively on the WAI-4W-J excavation, we were unable to excavate corroborating test units further down slope.

Additionally, a comprehensive survey of discrete retaining features that may indicate the presence of irrigation systems, like the exposures emanating from WAI-4W-M, could help reveal patterns of use along the gulch siding and on the tablelands. A GPS analysis of such features may clearly indicate probable tableland sites, and open up the possibility of tableland excavations, at least at the interface of the gulch siding and the tables, where post-depositional disturbances may have had less impact than in the prime grazing terrain of the central tablelands.

Likewise, there have been few efforts made to specifically survey and explore the recorded historic era plots briefly addressed in this project. It stands to reason that some of these plots, particularly the late 19th century sugarcane plots recorded by Lobenstein, likely dated to earlier periods and were seeing reuse by later inhabitants. Future excavation and analysis of these sites may reveal interesting facts about long term patterns of land use in the eastern gulches through time, as McCoy and Grave's (2008) excavation of a sequence of frequently reconstructed *lo'i* retaining walls in lower Halawa has by revealing the complexity and depth of use and reuse in a gulch *lo'i*. For the time being, windward North Kohala remains an area rich with opportunities to explore the processes embedded in agricultural practice and innovation in ancient Hawai'i.

Conclusion: innovating complex society

The on-the-ground research component of this project was primarily focused on exploring the novel irrigation technology discovered in Waiapuka *ahupua'a* in the North Kohala region of the Big Island by McCoy and Graves in 2008, and revisited by this author in 2009. This approach to tableland irrigation, which uses oblique irrigation ditches dug into the gulch siding as it declines to propel water out of a gulch *lo'i* and onto the tableland surface, is unknown elsewhere in Hawai'i and demonstrates a drive to achieve greater and greater returns on labor investments in agricultural systems. Spatial analysis of known tableland agricultural sites, in relation to the gulch geography, reveals a portrait of the eastern gulch region that may have been more extensively utilized for agricultural purposes than was first imagined. By investigating the patterns of use that are suggestive of intensification, our archaeological imagination becomes more capable of imagining the processes that contribute to the formation of complex societies.

This study is intended to contribute to the ongoing discussions regarding the evolution of societies, *vis a vis* Talcott Parsons, introduced in Chapter 2. I do not, in this final statement, intend to validate the European essentialism that early cultural evolutionary theories often espoused. Instead, I acknowledge that societies do transform through a procession of phases, not on a trajectory towards some European republican ideals, but through increasingly complex iterations of themselves. In Polynesia and elsewhere, the intensification of agriculture and the transition from subsistence to surplus economies, marks a key juncture in these processes at which society can afford to increase its "depth" through the accumulation of social roles which do not participate in production of food. This is often commensurate with the lengthening of social hierarchies and the addition of specialist classes. The relatively isolated nature of ancient Hawaiian society makes it an ideal context in which to research these processes.

Ancient Hawaiian farmers were active participants in increasing social complexity. By navigating and responding to social and ecological pressures, and meeting those challenges by innovating solutions to ameliorate the resource driven conundrums they encountered, it was the *maka'ainana* farmers who contributed the most to the creation of an environment suitable for the gradual transformation of society into iterations of ever greater complexity. Perhaps nowhere else in Hawai'i is that contribution better reflected than in North Kohala, where evidence of continued agricultural innovation correlates so neatly to periods of social transformation, and where the most powerful chiefs eventually became kings.

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