THE WET AND THE DRY

Irrigation and Agricultural Intensification in Polynesia

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The Polynesian islands offer remarkable opportunities for comparative study of tropical agronomic systems, and of agricultural intensification among nonindustrialized societies. Early European explorers frequently commented on the intensity of agricultural production in the islands. During his second voyage of discovery, Captain James Cook explored the island of Tongatapu, seat of the powerful paramounts of the Tongan maritime chiefdom. On October 4, 1773, Cook with several officers ventured ashore to inspect the island's interior: “Shaded from the Scorching Sun by fruit trees,” Cook's observant eyes glimpsed a scene of intense industry and high productivity. “I thought I was transported into one of the most fertile plains in Europe,” he penned in his journal. “Here was not an inch of waste ground” (Beaglehole 1969:252). “Nature, assisted by a little art, no were [sic] appears in a more flourishing state than at this isle.”

Similar agricultural landscapes, assisted by a little art and indeed a great deal of intensive labor, typified the tropical chiefdoms of Polynesia at their first contact with Europeans. The Russian explorer von Kotzebue, who traveled in Hawaii between 1815 and 1818, wrote of O‘ahu: “The cultivation of the valleys behind Hanarura [Honolulu] is remarkable; artificial ponds support, even on the mountains, the taro plantations, which are at the same time fish ponds; and all kinds of useful plants are cultivated on the intervening dams” (1821, vol. 3:236). Archibald Menzies, surgeon on
HMS *Discovery* with Captain Vancouver in 1792, described this O‘ahu landscape in equally expressive terms: “The whole [valley] was watered in a most ingenious manner by dividing the general stream into little aqueducts leading in various directions so as to supply the most distant fields at pleasure, and the soil seems to repay the labor and industry of these people by the luxuriance of its production” (1920:23–24).

The stratified societies of Polynesia also hold something of a privileged place in anthropological theory, for they exemplify a classic political type, the *chiefdom* (Fried 1967; Service 1967; Sahlins 1963; Carneiro 1981; Earle 1987). While anthropologists have paid much attention to the political structures of these chiefly societies, they have less thoroughly investigated their economic and ecological bases. These complex polities—the more elaborate of them are said to resemble “archaic states”—were supported by highly intensive modes of agricultural production. Polynesian agricultural systems included pondfield irrigation of taro (such as described by von Kotzbue and Menzies, above), short-fallow dryfield cultivation of yams (as Cook witnessed on Tongatatapu), and perennial arboriculture coupled with intensive storage of breadfruit and other starch pastes in underground silos. This variation in Polynesian agriculture provides a fruitful avenue for exploring the linkages between intensification of production and sociopolitical complexity. As Malinowski—author of a pioneering work on Oceanic horticulture—observed, “Agriculture and its consequences enter very deeply into the social organization” of Oceanic peoples; “they form the foundation of political power and of domestic arrangements” (1935:x).

All Polynesian societies descend—as modern linguistics and archaeology have shown—from an ancestral Lapita culture which had first colonized the western archipelagoes of Samoa and Tonga by about 1200 B.C. (Kirch 1984a; Kirch and Green 1987). Subsequent dispersal and colonization led to the settlement of more than 38 islands and archipelagoes throughout the vast eastern Pacific (fig. 1). These islands exhibit a wide spectrum of ecological conditions, from large, high volcanic islands to diminutive coral atolls. Throughout this varied region, root-crop horticulture was transferred and adapted to local environmental conditions and challenges. Polynesia thus offers the possibility of historical and comparative analyses of the differentiation of agricultural production systems under a wide variety of ecological conditions, and of the interaction between these production systems and the social formations they supported (Kirch and Green 1987).

In a previous study (Kirch 1984a) I addressed the divergent evolution of the Polynesian chiefdoms from a broad comparative perspective, drawing primarily upon the evidence of archaeology, but also integrating data from
Figure 1 The Polynesian triangle and the Polynesian Outliers.
historical linguistics and comparative ethnography. In this book I explore in greater detail a key aspect of change and differentiation in the Polynesian chiefdoms: their agricultural subsistence base. Focusing primarily on a Futunan case study, I address a fundamental and widespread set of ecological and cultural contrasts between “the wet and the dry”: between taro and yam, irrigation and swidden, pigs and barkcloth, male and female. Without presuming any “determination in the last instance” of environment over society, I seek to explore the complex linkages between varied agricultural landscapes and the social relations of production. At the core is the issue of intensification—of both technology and labor—and the role intensification plays in the political evolution of chiefdom societies. I shall be concerned with a complex set of linkages: between contrastive wet-dry landscapes and the agricultural production systems they support, and between agricultural systems and the social formations they underwrite. The goal is not only to understand how particular systems of production developed within the constraints and challenges imposed by certain sets of environmental conditions, but also to explore the dynamic tension arising between contrastive production systems with differential abilities to produce surplus.

Rather than ranging broadly over the whole of Polynesia in a comparative vein, this study is primarily focused on a particular case—the twin high islands of Futuna and Alofi in Western Polynesia. Futuna and Alofi are among the few tropical Polynesian islands to retain a largely self-sustaining, integral system of agricultural production, in consort with an intact chiefdom political structure. They offer virtually unique opportunities for ethnographic inquiries into the linkages between production, intensification, and chiefship. Futuna and Alofi encapsulate much of the ecological and agricultural variability found throughout tropical Polynesia, with intensive taro pondfield irrigation in “wet” environments and extensive yam-centered swidden cultivation in “dry” environments. These contrastive production systems support two independent chiefdom polities, with a long-standing history of competition. This study privileges ethnographic and ethnobotanical materials, but the contributions of archaeology and of prehistory will also be brought to bear.

**The Hydraulic Hypothesis and Agricultural Intensification in Polynesia**

Traditional Polynesian agriculture shares both its crops and its key agronomic practices with a large number of societies distributed throughout the Indo-Pacific tropics. In these systems, vegetatively propagated root
crops such as *Colocasia* taro and *Dioscorea* yams are the central focus of the cropping systems, supplemented by a wide variety of other herbaceous annuals and by perennial tree crops. The most important mode of cultivation is that known variously as "slash-and-burn," "shifting cultivation," or "bush-fallow rotation" (Conklin 1957, 1963; Spencer 1966). Plows and the use of draft animals are unknown, and most agricultural work is accomplished with the aid of the digging stick, or dibble. This lack of complex tools does not imply an absence of intensive systems of production, for throughout Polynesia are myriad examples of intensified cultivation. Intensified agricultural systems in Polynesia may be roughly defined as those which involve either a significant reduction in fallow length (intensity of cropping) from the typical long-fallow swidden regime or the construction of permanent agronomic facilities that allow continuous cropping. In all cases a higher yield per unit area is implied, and this is further associated with increased labor inputs (see Turner and Doolittle 1978). Our knowledge of intensive agriculture in Polynesia derives both from ethnohistoric and ethnographic accounts of particular islands prior to the major economic changes following Western contact, and from recent archaeological studies of the physical remains of field systems and irrigation complexes (Kirch 1991b). These intensive systems may be classified into (1) those utilizing some form of water control for the continuous cropping of taro; (2) short-fallow, permanent field systems in dryland areas; and (3) arboriculture associated with long-term storage of starch pastes.

Despite the importance of short-fallow dryland systems and of arboriculture, it is the taro irrigation systems of Polynesia which have attracted the most scholarly attention, in part because the physical infrastructures of canals and flooded fields are visually impressive, but also because such irrigation works have figured in the long-standing debate over the role of hydraulic control in the rise of complex sociopolitical formations (e.g., Wittfogel 1957; Earle 1978, 1980; Spriggs 1984). While classic pondfield irrigation like that in Hawaii is the best known of such water-control systems, it constitutes only one of three major types of Polynesian water control for continuous taro cropping (Damm 1951; Spriggs 1984; Thaman 1984). These are (1) pondfield irrigation; (2) raised-bed (also called "island-bed" or "garden-island") systems; and (3) pit cultivation. The distribution of wet taro cultivation systems in Polynesia is indicated in table 1. *Pit cultivation systems* are found primarily on atolls, such as the northern Cook Islands and throughout the Tuamotu Archipelago (Chazine 1977). Pits of varying dimensions are excavated through the coral rubble and sands of an atoll islet, to tap the thin Ghyben-Herzberg lens of fresh water, in which *Colocasia* taro (or, in the western atolls, *Cyrtosperma chamissonis*) are planted. The pits must be heavily mulched, as the calcareous sand ma-
Table 1 Distribution of Wet Cultivation Methods for *Colocasia* Taro in Polynesia

<table>
<thead>
<tr>
<th>Island/Group</th>
<th>Cultivation Methods</th>
<th>Agricultural Importance</th>
<th>References</th>
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<tbody>
<tr>
<td>Futuna</td>
<td>Irrigation</td>
<td>Dominant</td>
<td>Burrows 1936; Barau 1963; Yen 1974; Kirch 1975</td>
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<tr>
<td></td>
<td>Raised bed</td>
<td>Minor</td>
<td>Kirch 1975</td>
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<tr>
<td>'Uvea (Wallis)</td>
<td>Raised bed</td>
<td>Significant</td>
<td>Barrau 1963; Kirch 1978</td>
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<tr>
<td>Samoa</td>
<td>Raised bed</td>
<td>Minor?</td>
<td>Ishizuki 1974</td>
</tr>
<tr>
<td>Pukapuka</td>
<td>Pits</td>
<td>Dominant</td>
<td>Beaglehole and Beaglehole 1938</td>
</tr>
<tr>
<td>Manihiki-Rakahanga</td>
<td>Pits</td>
<td>Dominant</td>
<td>Buck 1932</td>
</tr>
<tr>
<td>Rarotonga</td>
<td>Irrigation</td>
<td>Significant</td>
<td>Buck 1944; Bellwood 1978</td>
</tr>
<tr>
<td></td>
<td>Raised bed</td>
<td>Dominant</td>
<td></td>
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<tr>
<td>Mangaia</td>
<td>Irrigation</td>
<td>Dominant</td>
<td>Buck 1934; Allen 1971; Kirch et al. 1992</td>
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<tr>
<td></td>
<td>Raised bed</td>
<td>Significant</td>
<td></td>
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<tr>
<td>Society Islands</td>
<td>Raised bed</td>
<td>Significant</td>
<td>Green 1961; Oliver 1974</td>
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<tr>
<td></td>
<td>Irrigation</td>
<td>Significant</td>
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<tr>
<td>Marquesas</td>
<td>Irrigation</td>
<td>Significant</td>
<td>Handy 1923; Bellwood 1972</td>
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<td>Tuamotus</td>
<td>Pits</td>
<td>Significant</td>
<td>Emory 1975; Chazine 1977</td>
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<tr>
<td>Mangareva</td>
<td>Irrigation</td>
<td>Minor?</td>
<td>Buck 1938</td>
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<tr>
<td>Rapa</td>
<td>Irrigation</td>
<td>Dominant</td>
<td>Stokes ms.; Hanson 1970</td>
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<td>Rurutu</td>
<td>Irrigation</td>
<td>Dominant</td>
<td>Verin 1969</td>
</tr>
<tr>
<td>Tubuai</td>
<td>Irrigation</td>
<td>Dominant</td>
<td>Aitken 1930</td>
</tr>
<tr>
<td>Ra'ivavae</td>
<td>Irrigation</td>
<td>Dominant</td>
<td>Marshall 1961</td>
</tr>
<tr>
<td>Hawaii</td>
<td>Irrigation</td>
<td>Dominant</td>
<td>Handy 1940; Handy and Handy 1972; Kirch 1977; Earle 1980</td>
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<td></td>
<td>Raised bed</td>
<td>Minor</td>
<td>Kirch 1977; Earle 1980</td>
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...is lacking in organic nutrients. *Raised-bed systems* are found on many high volcanic islands with coastal alluvial plains or swampy valley bottoms (fig. 2). In these systems the agronomic problem is controlling water flow through the naturally hydromorphic soils, achieved by the excavation of reticulate canal networks that create slightly elevated planting surfaces (raised beds or garden islands) between the ditches. Such raised-bed systems have been described ethnographically from 'Uvea (Kirch 1978), the Cooks (Allen 1971), and the Society Islands (Handy 1930) and are known archaeologically from Samoa (Ishizuki 1974), where they may have been more extensive in prehistory.

Best known among Polynesian water-control technologies, however, is *pondfield irrigation*, in which a water source such as a spring or stream is tapped and diverted to irrigate a set of artificially terraced or bunded, flooded fields. Such pondfield irrigation systems vary in scale and hydraulic complexity, ranging from small sets of 10 fields or less, to extensive valley-bottom complexes with hundreds of fields covering many hectares (fig. 3).
Figure 2  Raised-bed garden islands in the Society Islands (photo by E. S. C. Handy, courtesy of Bernice P. Bishop Museum Photo Archives).

Figure 3  Irrigated pondfields in the Hanalei Valley, Kaua'i Island, Hawaiian Islands (photo courtesy of Bernice P. Bishop Museum Photo Archives).
The irrigation systems of Hawaii have been more thoroughly studied than any others in Polynesia (Handy 1940; Handy and Handy 1972; Earle 1978, 1980; Kirch 1977, 1990b; Allen 1991), although pondfield irrigation was widely practiced in such islands as Futuna, Rarotonga, Mangaia, Mangareva, Rapa, Tubuai, Rurutu, Raivavae, the Societies, and the Marquesas (table 1). Under ideal conditions the productivity of these irrigation systems is remarkable, as various estimates of yield indicate. For example, based on field trials in Vanuatu, Spriggs (1981, 1984) derived a mean corn yield of almost 40 tons/hectare/year for pondfield systems. Raised-bed systems in Fiji have produced measured yields of nearly 20 t/ha/yr (Brookfield 1979, in Spriggs 1984:129). In contrast, a typical Oceanic swidden produces yields on the order of only 5–15 t/ha/yr. Thus, wet taro cultivation systems have the potential to produce a substantial surplus, in turn fueling Polynesian political economies.

The “hydraulic hypothesis” advanced by Wittfogel (1957), drawing a causal connection between the managerial requirements of complex irrigation and the development of complex sociopolitical structures, has been influential in anthropological considerations of the role of irrigation in nonindustrialized societies (e.g., Adams 1966; Downing and Gibson 1974; Donkin 1979). Wittfogel referred specially to the Hawaiian case (1957:239–43) in his major treatise, and indeed a hydraulic bias has characterized most of the ethnographic and ethnohistoric work on traditional Hawaiian society. Even though 19th-century indigenous Hawaiian scholars such as Malo (1951:204–8) and Kamakau (1976:23–37) explicitly noted the importance of both irrigated and dryland cultivation, later ethnographers consistently emphasized the importance of irrigation to indigenous production and to the support of the ruling elite. Handy (1940), in his classic work on Hawaiian agriculture, certainly stressed the irrigated culture of taro over dryland systems. In his highly influential study of Polynesian social stratification, Sahlins (1958:15, 123) cited the “superiority” of irrigation as a productive technique over shifting cultivation, a theme echoed in his later writings on chiefdom economies (1972:141–42). This ethnographic tradition of emphasizing irrigation in discussions of Hawaiian production and economy continues in recent works (e.g., Linnekin 1985:52, 1990:90; Dunis 1990:96–99). A consequence of this received ethnographic wisdom regarding the dominance of irrigation is that the true variability in agricultural production in Hawaii and throughout Polynesia has been overlooked. Intensive dryland (short-fallow) and arboricultural production systems, so well documented in the journals of early explorers and missionaries, have been left out of the theoretical equations drawn between production and political power.

Despite having rediscovered—over the past two decades—the true sig-
inificance of intensive dryland agriculture, archaeologists have also been guilty of a hydraulic bias. Earle (1978) was one of the first archaeologists to focus on the physical remains of prehistoric and early historic agricultural systems in Hawaii, and his research design incorporated an explicit test of the “hydraulic theory.” Although Earle’s innovative work on the irrigation complexes of the Halele’a District, Kaua‘i, did not lend support for the Wittfogelian managerial model linking irrigation and complex society development, the differential importance of irrigation across the Hawaiian archipelago was insufficiently remarked. Most readers of Earle’s monograph, being unfamiliar with the primary ethnohistoric and archaeological sources, would be inclined to see in the Halele’a data a general model for Polynesian chiefdoms at large—a model in which irrigation played the dominant role through its ability to increase “the flow of staples collected by the centralized redistributive hierarchy” (1978:195). Spriggs, who investigated prehistoric irrigation complexes on the eastern Melanesian island of Anuam (1981, 1985, 1986), also stressed the importance of irrigation over all other forms of intensive cultivation in indigenous Oceanic societies. Spriggs argues that “the greater potential for intensification of agricultural production sets irrigation apart from many of the dry land gardening techniques of the Pacific and gives it thus a more than purely technological significance in Pacific prehistory” (1981:184).

A consequence of this biased emphasis on taro irrigation in anthropological writings on Polynesia is a near-total neglect of the significant role played by other kinds of intensified agricultural production: (1) short-fallow dryland cultivation, in which field boundaries were permanently demarcated and in which soil fertility was maintained through labor-intensive mulching; and (2) arboriculture, or perennial tree cropping. In dryland field systems, taro was planted in rotation with yams, sweet potato (in Eastern Polynesia only), bananas, and other crops. Intensive dryland field systems are not well described ethnographically, since this kind of labor-intensive agricultural production was often the first to be abandoned following Western contact and consequent population decline. However, dryland field systems are well described by early visitors to the Hawaiian Islands (e.g., Beaglehole 1969; Menzies 1920; see Kelly 1983 for further references), and Yen (1973b) investigated a surviving system on the isolated Polynesian outlier of Anuta. Similarly, arboriculture as a dominant mode of agricultural production is ethnographically attested for the Society Islands (Wilder 1928), the Marquesas (Handy 1923), and Tikopia (Firth 1936; Kirch and Yen 1982).

The neglect of intensive dryland cultivation by anthropologists and archaeologists—attracted to the more visually impressive and readily accessible traces of irrigation—has masked the fact that it was not irrigation but
short-fallow dryland systems that were the most demanding of labor inputs. As this study of Futuna-Alofi demonstrates, when both irrigation and short-fallow dryland systems are differentially and unequally represented in adjacent sectors of an island or archipelago—as they commonly are in Polynesia—the potential exists for a dynamic tension in the political economy. More important, the most hierarchically structured and hegemonic Polynesian polities are usually associated, not with the irrigation-dominated production zones as the hydraulic theorists would predict, but with the intensive dryland sectors. Thus, a more inclusive analysis of Polynesian agricultural variability results in a virtual turning of the hydraulic hypothesis on its head.

Arboriculture—the third form of agricultural intensification in Polynesia—has perhaps been the most overlooked by ethnographers and prehistorians alike. Breadfruit (*Artocarpus altilis* [Parkinson ex Z] Fosberg), grown in extensive plantations typical of valley landscapes in the Society and Marquesas Islands (Wilder 1928; Handy 1923; Ragone 1991), was the primary Polynesian tree crop although Tahitian chestnut (*Inocarpus fagiferus* [Parkinson ex Z] Fosberg), coconut (*Cocos nucifera* L.), and other species were also important. The numerous clones of breadfruit with differing properties of yield, fruit characters, timing of harvest, and other aspects of morphology (leaf shape, etc.) provide a classic example of genetic innovation through selection. Since breadfruit produces high yields in a short harvest period (usually two times per year), the crop generally cannot be completely consumed at the time of harvest. This problem was overcome by technological innovation of anaerobic fermentation and subterranean storage of the uncooked fruit in silos, where the fermented paste may be kept for periods of several years to be consumed as required (Kirch 1984a:132–35; Cox 1980). In the Marquesas Islands, where arboriculture and breadfruit paste storage reached their developmental peak, some storage pits had volumes as great as 216 cubic meters (Linton 1925:103). This emphasis on storage also permitted the accumulation of large reserves, and control of these lay in the hands of the chiefly elite, who deployed these resources to political ends (Buck 1938:207; Linton 1925:103; Oliver 1974:238; Kirch 1991a). Thus, in Polynesian arboriculture we have an example of both genetic and technological innovation providing substantial opportunities for particular individuals within society to increase, concentrate, and gain control over surplus production, without the need for significantly increased labor inputs. In part II of this monograph, I will draw upon Tikopia to further illustrate the arboricultural pathway to agricultural intensification in tropical Polynesia.
Wet and Dry: A Hierarchy of Contrasts

The French ethnobotanist Jacques Barrau singled out “l’humide et le sec”—the wet and the dry—as a fundamental contrast of Oceanic island ecologies with major implications for indigenous systems of agriculture and the societies they support. The ecological templates of the most important cultivated plants of Oceania—taro and yam—mirror this geographic and climatic contrast between wet and dry. Systems of taro and yam cultivation, moreover, possess distinctive modes of intensification, irrigation in the case of the hydrophytic taro and short-fallow field cropping of the tropophytic yams. As fundamental as these contrasts are to the student of tropical agriculture and human ecology, their significance extends more broadly to the social and political realms of island cultures. The ability to produce a surplus, the extent of landscape modification and investment in permanent hydraulic facilities, the nature of land tenure, and such fundamental social relations as the organization and investment of labor—all of these are intimately tied to the contrasts between the wet and the dry, between taro and yams. For Oceania, l’humide et le sec are integral to what Fernand Braudel termed the longue durée, part of “a history which unfolds slowly and is slow to alter, often repeating itself and working itself out in cycles which are endlessly renewed” (1980:3). As the title of this book (borrowed from Barrau’s seminal paper) implies, the contrast of wet and dry environments, crops, and agricultural technologies holds a key to understanding the history of Polynesian agriculture.

The wet-dry contrast is far more complex than a simple classification of gross climatic zones and major crops might suggest. When focusing upon the agricultural systems of tropical Polynesia, it is useful to think in terms of a taxonomic hierarchy of wet-dry contrasts, both spatial and temporal, that includes not only environments (at several scales of resolution) but crops and technologies (fig. 4).

The islands of tropical Polynesia fall within a broad zone of dominantly southeastern trade winds that carry moisture-laden oceanic air across the islands lying in their path. The generalized annual rainfall in this zone ranges from 4,000 to 2,000 millimeters (mm), decreasing from west to east. On high volcanic islands, rainfall is induced orographically, so that most of the rain falls on the windward sides of islands, and rainfall gradients across an island can be remarkably steep. The importance of this windward-leeward difference on agricultural production was noted by early European explorers, such as Morrison (1935) and Wilson (1799), who commented on the effects of this contrast on breadfruit yields on the island of Tahiti:
Figure 4 The hierarchy of wet and dry environmental contrasts in Oceania.

The seasons differ much on the opposite sides of this Island, . . . this makes a material difference in the Bread-fruit Harvest (Morrison 1935:142).

When the trade wind gets far to the south, and blows freshly, it generally rains on the south side of the island, bringing the clouds from the mountains of Tiaraboo, and emptying their contents at Pappara and the adjacent districts. This occasions a great difference in the bread-fruit season between the north and south sides of the island (Wilson 1799:316).

This windward-leeward climatic gradient, so critical to Polynesian agricultural systems, is expressed not only on individual island landscapes but at the grander scale of entire archipelagoes. When islands are arrayed linearly along the path of the dominant trades, large islands to windward create rain shadows for those to the lee. Hence, in the Society Islands the large windward islands of Tahiti and Mo'orea receive substantially greater rainfall than the leeward isles of Huahine, Raiatea, and Borabora. Likewise, in the Hawaiian group, Maui and Moloka'i cast a rain shadow over smaller Lana'i and Kaho'olawe, which as a consequence are arid and lack substantial stream valleys. These environmental contrasts set fundamental constraints on the potential pathways to agricultural intensification.

At the archipelago-wide scale, a further environmental gradient which
commonly affects the potential for irrigation is that of weathering and dissection, although this relates more to geological age than to rainfall. Most Polynesian archipelagoes have a “hot spot” origin (Menard 1986), and thus islands increase in age as one progresses further from the hot spot of volcanic activity. Geologically young islands have relatively undissected volcanic flow slopes lacking suitable valley terrain for irrigation system development, while older islands offer attractive permanent streams and alluvial plains. The Hawaiian Islands illustrate this geological age progression splendidly, where irrigation dominated Polynesian agricultural production on the older islands of Kaua‘i, O‘ahu, and Moloka‘i, in contrast to geologically youthful Maui and Hawai‘i, which were dependent largely upon rainfed dryland field systems (Kirch 1990a, b).

The wet-dry contrast also asserts itself in the temporal dimension of island ecologies. A seasonal rhythm in the distribution of rainfall characterizes virtually all tropical Polynesian islands, even though the degree of seasonal contrast may vary. A distinct dry season of lowered rainfall occurs throughout central Polynesia beginning about the end of March, and lasts until about August or September. In Futuna, this climatic periodicity closely determines the agricultural calendar, especially for yam cropping. The availability of rainfall, however, also affects taro and other crops.

Beyond the annual cycle of wet and dry seasons there is a longer-term, stochastic variation in rainfall marked by the periodic occurrence of droughts and by intense deluges associated with tropical cyclones. The effect of droughts is most pronounced in relatively arid (generally leeward) environments with dryland cultivation, although irrigation systems may also be affected by reduced stream flow. On the other hand, the destructive force of intensive cyclonic deluges frequently is most apparent in the naturally wet environments, where irrigation structures can be destroyed overnight by flooding and erosion.

This hierarchy of wet-dry contrasts (or gradients) in island environments is matched, as Barrau recognized, by the ecological templates of the key Oceanic cultigens. On the wet side of the spectrum lie several species of the family Araceae, particularly taro (Colocasia esculenta L.), but also the “elephant ear” taro Allocaea macrorrhiza (L.) Schott, and the giant swamp taro or pulaka, Cyrtosperma chamissonis (Schott) Merr., all of whose natural habitats are “damp spots, near forest streams, or sometimes in open swamps” (Barrau 1965a:331). In naturally humid environments, such as the tropical forests in windward parts of high islands, Colocasia taro can be readily grown without special attention to water control. However, “for the Oceanian gardener in growing taro with irrigation outside the tropical rain forest area, and far from coastal or riverine fresh water swamps, the main and constant subject of concern is water supply” (Barrau 1965a:334).
Not surprisingly, water itself frequently became “worthy of a kind of religious veneration,” as in Hawaii where the word for water (wai) was extended semantically to mean wealth or prosperity (wairwai).

Contrasting with the cultivated aroids are the yams (family Dioscoreaceae), of which two main species were regularly planted in Polynesia: the Greater Yam (Dioscorea alata L.) and the Lesser Yam (Dioscorea esculenta L.). These plants were originally domesticated in the monsoon zone of southeastern Asia (Burkill 1954; Coursey 1967), where there is a regular seasonal variation between wet and dry. Yams are tropophytes, with a seven- to nine-month growth phase during the wet season and a dormant period during the dry season. “To cultivate this tropophyte far from its centre of origin in conditions often differing from those of its natural habitat, special horticultural methods were devised” (Barrau 1965a:337). These frequently involve some form of drainage technology, most simply cultivation on mounds, but sometimes more elaborate technology of ditches and drains.

Taro and yams, in their contrastive ecologies and agronomic requirements, provide different constraints and possibilities for the production of surplus. Yams yield their crop within a short period at the end of the wet season, and the tubers are naturally adapted to a period of storage, offering the potential for a magazine economy. This kind of storage economy based on yams is well exemplified by the contact-period Tongan chiefdom (Kirch 1984a). Taro, on the other hand, must be consumed soon after harvesting. The political economy of Hawaii, with its peripatetic movements of chiefs from district to district, was founded upon just this kind of aroid-dominated cropping system. However, the artificial cropping of taro under irrigation allows for nearly continual production.

Finally, the hierarchy of wet-dry contrasts can be extended from the realms of environment and crop to the fully cultural dimension of agricultural technology. In their application of particular technologies, the indigenous Polynesian cultivators were consciously aware of the controlling role of wet and dry environments. A Hawaiian gardener of the 19th century commenced his account of local agriculture with the phrase: “Elua ano a ka aina, he maloo a he wai . . . ; of two kinds is the land, the dry and the wet” (Fornander 1919:160). Depending upon local environmental constraints, and combined with the ecological templates of the preferred crops, specific technology was applied to convert naturally dry to wet conditions, and vice versa. These agronomic devices ranged from simple, temporary mounding to elaborate, permanent pondfield irrigation. The more elaborate and intensive of these technological devices will be reviewed in greater detail shortly.

Fundamentally, the significance of the wet and dry hierarchy lies in the
ways it directed or channeled (but never wholly determined) particular pathways of agricultural history on individual islands. On some islands irrigation was favored by the presence of alluvial soils and abundant stream flow, while on others the irrigation pathway to intensification was not possible. On most islands and certainly across the landscapes of entire archipelagoes, however, local conditions for agricultural development varied strikingly. Windward districts supported irrigation, while leeward regions favored the seasonal cropping of yams and other swidden crops. Thus, within particular Polynesian societies, the contrasts inherent in local agricultural landscapes set the stage for differential production regimes, and for a dynamic tension between competing polities whose production bases varied in their abilities to yield surplus and to respond to recurring hazards such as drought and cyclones. In the case of Futuna-Alofi, it is just such a contrast between two chiefdom polities—one based on irrigation and one on swidden cultivation—that channeled the long run of prehistory along its particular course.

**Intensification: Theoretical Issues**

The problem of agricultural intensification began to attract attention in the 1960s, developing out of various ecological studies of nonmechanized or traditional agro-ecosystems, stimulated by the debate issuing from Wittfogel’s (1957) hydraulic hypothesis. Geertz’s *Agricultural Involution* (1963) was perhaps the first major anthropological study to tackle the problem of intensification among tropical agriculturalists, specifically in the densely populated islands of Indonesia. Geertz examined the ecological contrasts between two fundamentally different systems of cultivation: swidden and *sawah* (irrigated rice). Geertz saw increasing population as the driving force behind intensification; the swidden and *sawah* systems responded to such growth in markedly different ways. Whereas overpopulation in a swidden environment led to reduction in fallow and subsequently to environmental degradation (1963:33), the irrigated *sawah* exhibited a marked tendency to respond to increasing population through intensification by absorbing increased numbers of cultivators on a unit of cultivated land (1963:32). Over time there was an “involution” of the system, an ingrowing process “in which smaller and smaller pieces are ever more closely fitted together in a squeezed-down shared poverty” (Brookfield 1972:33). In short, Geertz’s model stressed the differential elasticity or response of contrastive agro-ecosystems to a fundamental Malthusian process.

The long-standing Malthusian model was challenged by Boserup’s pro-
In the Hawaiian Islands agriculture was conducted differently on lands where there were streams of water and on dry lands. On lands supplied with running water agriculture was easy and could be carried on at all times. . . .

On the kula lands, farming was a laborious occupation and called for great patience, being attended with many drawbacks.

Malo, ca. 1840 (1951:204)

Among the most isolated lands on earth, the eight major Hawaiian islands (fig. 101) were colonized by Polynesians sometime early in the first millennium a.d. (Kirch 1985a, 1990b). The time scale for cultural change and sociopolitical development in Hawai‘i is therefore only about half as long as for Futuna. Yet in the approximately fifteen hundred years between initial discovery and the arrival of Europeans in the late 18th century, there emerged in this large and resource-rich archipelago what are universally recognized by anthropologists as Polynesia’s most highly stratified, intensely competitive chiefdoms (Sahlins 1958; Goldman 1970; Pebbles and Kus 1977; Earle 1978, 1987). Sahlins, who more than anyone has advanced our knowledge of Hawaiian ethnography, opines that, in Hawaii, Polynesian society discovered the structural limits of chieftainship (1972:144): “The great disadvantage of the Hawaiian organization was its primitiveness: it was not a state. . . . If Hawaiian society discovered limits to its ability to augment production and polity, this threshold which it had reached but could not cross was the boundary of primitive society itself” (1972:148). It is telling that in his discussion of Hawaiian sociopolitical development, Sahlins stresses the efforts of ruling chiefs to augment production, especially irrigation and other forms of intensive agriculture. Thus, we might anticipate the possibility of discovering in Hawaii how the
relations between irrigation, intensification, and chiefship were played out when both geographic and demographic scales are increased by an order of magnitude from the Futunan case. Indeed, it is precisely these expanded geographic, demographic, and sociopolitical scales—in contrast with those in Futuna—that give Hawaii its analytical significance for our understanding of the differential pathways to intensification.

**Production Systems: The Wet and the Dry**

Mirroring the complexity of its sociopolitical systems, indigenous Hawaiian production achieved an apogee of technological development and intensity within Polynesia, if not the whole of Oceania. Hawaiian taro irrigation systems were certainly the largest and infrastructurally most complex (matched only by the New Caledonian systems [Barrau 1956b]). Less well known but equally impressive were the vast intensive dryland field systems reported by early European visitors (e.g., Beaglehole 1969; Men-
zies 1920) and recently the subject of much archaeological research (Kirch 1984a:181–92). Technological developments were not restricted to agriculture, and late prehistoric Hawaiians invented true fishpond aquaculture (Kikuchi 1976).

Hawaiian agriculture, and especially irrigation, has a respectable tradition of ethnographic study (e.g., Nakuina 1894; Handy 1940; Handy and Handy 1972). Since the late 1960s, this study has been augmented by a spate of archaeological investigations of prehistoric agricultural landscapes (e.g., Yen et al. 1972; Riley 1975; Rosendahl 1972; Earle 1978, 1980; Kirch 1977; Kirch and Sahlins 1992; Tuggle and Tomonari-Tuggle 1980; Schilt 1984; Allen 1987, 1991). These have expanded our knowledge of traditional agronomic practice and provided a framework for understanding agricultural change over time.

Despite all this work, one fundamental aspect of Hawaiian production systems has consistently been ignored or downplayed. This is the striking geographic contrast between the agricultural systems of the geologically older, western islands (Kaua‘i to Moloka‘i and west Maui) and the younger, eastern islands (east Maui and Hawai‘i). Most anthropologists who have tackled the problem of Hawaiian political development (e.g., Sahlins 1958, 1972; Earle 1978; Pebbles and Kus 1977; Cordy 1974a, b) stress the importance of intensive production to the chiefship, yet fail to fully recognize the radical differences between the eastern and western chiefdoms. Earle (1978), for example, applied a model of chiefly investment in taro irrigation—developed wholly through research on Kaua‘i—to the Hawaiian Islands at large, as though local production was everywhere essentially identical. Even the ethnographer Handy (1940; Handy and Handy 1972), who painstakingly recorded cultivation systems locality by locality on all islands, failed to grasp the significance of his own data on geographic differentiation in Hawaiian production systems.

Rather than being monolithic agriculturally—as the received anthropological literature would imply—the chiefdoms of the Hawaiian archipelago differed quite radically in their dominant production systems. In the westerly islands (Kaua‘i, O‘ahu, Moloka‘i, and west Maui), the emphasis was on taro irrigation, with shifting cultivation and other forms of dryland gardening providing a distinctly secondary role. In the east (east Maui and Hawai‘i), irrigation was only a minor contributor to subsistence production and highly labor-intensive, short-fallow dryland field systems predominated. This contrast was dictated, as in Futuna, primarily by environmental conditions. The western islands, geologically older and hence more heavily weathered, offered the requisite conditions of permanent stream flow and valley alluvium upon which irrigation could be developed. In the
east, most of the arable terrain is volcanically youthful and undissected, lacking stream flow, and prohibited the development of extensive irrigation works. Thus, irrigation systems in east Maui and Hawai‘i, while present in restricted areas, contributed in only minor ways to the support of these chiefdoms.⁴

In short, the Hawaiian archipelago presents precisely the same contrast between “wet” and “dry” chiefdoms that we have seen in Futuna. Here, however, the contrast lies not at the level of individual islands but across the scale of an entire archipelago.⁵ Just as in Futuna, where Sigave is the “wet” chiefdom of taro and irrigation and Alo the “dry” chiefdom of yams and shifting cultivation, so in Hawaii the chiefdoms of Kaua‘i, O‘ahu, and Moloka‘i were “wet” and those of Maui and Hawai‘i “dry.” The fundamental sociopolitical significance of this contrast will become evident shortly.

It is unnecessary to review in detail the technical aspects of Hawaiian agricultural systems, as these have been treated exhaustively elsewhere (for overviews, see Earle 1980; Kirch 1985a:215–36; Kirch and Sahlins 1992, vol. 2). A brief summary of essential characteristics will suffice. In scale and complexity, the largest Hawaiian irrigation systems exceeded those in any other Polynesian islands. For example, a field complex mapped by Earle (1978:67–69) at Wai‘oli on Kaua‘i extended over 54 hectares, an area some five times larger than the Nuku telega described in chapter 7. In the well-watered western Hawaiian Islands, most of the broad alluvial floodplains had been modified for pondfield irrigation by the time of European contact. Lt. King of Cook’s 1778 expedition expressed his admiration for the pondfields of Waimea, Kaua‘i, thus:

The inhabitants far surpass all the neighboring islanders in the management of their plantations. . . . These plantations were divided by deep and regular ditches; the fences were made with a neatness approaching to elegance, and the roads through them were thrown up and finished in a manner that would have done credit to any European engineer (quoted in Handy and Handy 1972:406).

In addition to these extensive valley bottom systems, the smaller valleys and gulches in interior reaches of the islands also exhibit archaeological remains of more modest pondfield complexes, in the range of 1–18 hectares (plans of several of these systems are illustrated in Kirch 1985a:218–27, figs. 191–96). In infrastructural detail, the Hawaiian pondfield systems are similar to those of Futuna. Technical descriptions are provided by Handy (1940; Handy and Handy 1972), Earle (1978), Kirch (1977), and others. Various classifications of Hawaiian irrigation systems have been proposed, all based on arrangements of the hydraulic infrastructure (Riley 1975; Kirch 1977; Allen 1987).
Although they were encountered and described by some of the first European explorers of Hawaii (e.g., Beaglehole 1969; Menzies 1920:75), the intensified dryland field systems of the eastern islands were abandoned relatively quickly as the effects of depopulation gripped the islands. Unlike the irrigation systems, these dryland field complexes have not been well described in the ethnographic literature, and the discovery of their extent and importance has been one achievement of Hawaiian archaeology since the 1970s. Most of this archaeological work has concentrated on the western side of the island of Hawai’i, where three vast dryland field systems are situated. While it is clear that east Maui had similar extensive field systems, these remain virtually unexplored.

The western Hawai’i dryland field systems differ somewhat in technical details, but all share certain common features (see Kirch 1984a:181–92 for a more extensive description). Chief among these is a closely spaced grid of stone field borders defining permanent plot boundaries. In some areas, the stone borders run along the contours, while in others they run perpendicularly to the slope. Integrated with the stone borders are a wide range of agronomic modifications, such as stone mounds and heaps, windbreaks, planting circles, clearings, simple terraces, and various animal enclosures (for pigs or dogs, presumably), as well as both temporary and permanent residential sites. Exhaustive archaeological studies of these systems are presented by Rosendahl (1972), Tuggle and Griffin (1973), Clark and Kirch (1983), Soehren and Newman (1968), Schilt (1984), and Kelly (1983).

These dryland field systems represent an endpoint in the process of short-fallow intensification of shifting cultivation, resulting in a formalized system of permanently defined fields. According to early ethnohistoric descriptions, fallow was reduced to a short herbaceous growth of perhaps one to three years (Menzies 1920:75–76), with a regular rotation of dryland taro, sweet potato, and bananas between fallow periods. This cropping regime was maintained only through a high labor input, particularly in weeding and mulching, which were essential to the maintenance of soil fertility. The Hawaiian scholar Kepelino, who was born about 1830 in the Kona area of the island of Hawai’i, describes these labor-intensive cultivation methods, including careful mulching, weeding, and tending, in his account of dryland farming (Beckwith 1932:152–56). While the early sources indicate that agricultural work was an exclusively male activity in the westerly islands, both men and women shared the burdens of agricultural labor in Maui and Hawai’i (Kamakau 1961:239). This is not surprising, in view of the expanded labor inputs required of intensified dryland field systems.
Time, Intensification, and Population

Unlike Futuna, where our knowledge of prehistory is still embryonic, we have a firm grasp on the prehistoric sequence in Hawaii, thanks to more than four decades of vigorous research under the auspices of the Bernice P. Bishop Museum, the University of Hawaii, and other organizations. In a synthesis of Hawaiian archaeology, I proposed a division of the prehistoric sequence into four cultural periods (Kirch 1985a:284–308, 1990b). These periods are shown in figure 102, where they are graphed against some of the major trends evident in the prehistoric record.

The first eight centuries of the Hawaiian sequence are subsumed within the Colonization and Developmental Periods. As in Futuna, it is clear that the initial colonizers were horticulturists who brought with them planting stocks of most, if not all, of the Hawaiian crop plants, as well as domestic pigs, dogs, and fowl. Shifting cultivation was presumably the primary mode of cultivation for these early settlers. That some kind of pondfield irrigation may have been practiced, however, is hinted at by tenuous linguistic evidence for a Proto-Marquesian term for pondfield, *roki, which has modern reflexes in Hawaiian and Rapan (see Kirch and Lepofsky 1993). But direct archaeological evidence for pondfield cultivation during either the Colonization or the Developmental Period has been scanty and controversial (e.g., Allen 1987; see discussion further below).

During the Colonization and Developmental Periods, settlement was confined for the most part to the windward valley regions, with their more favorable ecological conditions (ample stream flow, higher rainfall, extensive alluvial soils). Toward the end of the Developmental Period, by about A.D. 1100, there commenced a phase of major expansion into leeward regions throughout the archipelago. The initial stages of this expansion focused on leeward valleys or around bays with rich marine resources. By the middle of the Expansion Period, about A.D. 1400, settlements were intruding into increasingly marginal environments, including the interiors of leeward valleys and the higher elevation slopes of the easterly islands. This Expansion Period has been termed by Hommon (1976, 1986) a phase of "inland expansion." It was a period of tremendous significance in Hawaiian prehistory since, during this time, (1) the population underwent a geometric rate of increase; (2) virtually all habitable and arable lands were occupied and territorially claimed; (3) the territorial pattern of chiefdom (moku) and subchiefdom units (ahupua'a) appears to have been established; and (4) toward the end of this period the Hawaiian sociopolitical system was transformed from a simple, ancestral Polynesian chiefdom to a highly stra-
Figure 102 Diagrammatic summary of the Hawaiian prehistoric sequence (from Kirch 1985a).
tified society with virtual class differentiation between chiefs and commoners (Cordy 1974a, b; Hommon 1986; Kirch 1984a, 1985a, 1990b).

The Expansion Period witnessed significant agricultural developments in both irrigation and dryland field systems, and in fishpond aquaculture. J. Allen (1987:242–54, fig. 104) recently summarized the archaeological evidence (including radiocarbon dates) for the construction of various kinds of irrigation systems. While some pondfield complexes were being constructed in valley interiors as early as A.D. 1200–1300 (e.g., in Makaha [Yen et al. 1972]), a major phase of irrigation construction occurred during the latter half of the Expansion Period, between about A.D. 1400 and 1600. Allen opines that

these dates from sites associated with internally coordinated and complex agricultural sites in core inland areas on three islands support Hommon’s model [1986] for Phase II population growth, inland expansion, coordination of agricultural production, and the development of a strong socioeconomic base along a coastal-inland axis, replacing the earlier, primarily coastal networks. These coastal-inland developments ultimately produced the abupua’a system (1987:249).

The construction of irrigation works did not cease at the end of the Expansion Period but continued on into the Proto-Historic Period and, indeed, even after European contact. At the Luluku site on O’ahu investigated by Allen, this final prehistoric period witnessed the elaboration of pondfield terraces to a level of infrastructural complexity not evidenced in earlier periods:

At Site G5–85, increased political control and integration within a socioeconomic system involving an area larger than the local valley are strongly suggested by the evidence for well-coordinated construction of large numbers of terraces, effective control over landslides and floods, cooperation in terms of water rights and maintenance of patent irrigation ditches, and cultivation of taro in quantities large enough to suggest production for a consumer group larger than the local population (1987:250–51).

In the easterly islands, during the Expansion and Proto-Historic Periods, parallel developments occurred within the dryland field systems. The best temporally controlled archaeological data come from the western region of the island of Hawai‘i. The Kohala field system, studied by Rosendahl (1972) and others at Lapakahi, developed over about a 350-year period, from A.D. 1450 to 1800, and was followed by rapid collapse and abandonment after European contact. During these three and one-half centuries, the field complex was increasingly intensified, evidenced by a pattern of successive division of originally large fields into increasingly diminutive
plots (fig. 103). The Lapakahi cultivations began around A.D. 1450 as an integral swidden system, becoming increasingly modified through shortened fallow length and definition of ever-smaller permanent plot boundaries (Rosendahl 1972). During this sequence, occupation sites in the inland agricultural zone also changed from temporary shelters to permanent residences, a further index of increasingly dense population.

South of Kohala, the vast dryland agricultural zone of western Hawai‘i bends inland across the fertile plains of the Waimea region, on the saddle between the Kohala and Mauna Kea mountains. The archaeological field systems here were investigated during a major highway salvage-archaeology project (Clark and Kirch 1983). While in many respects similar to the Lapakahi fields, the Waimea systems incorporated intermittent irrigation from two seasonally flowing streams. The radiocarbon chronology for this region again indicates rapid expansion and intensification of production after about A.D. 1500, in the later Expansion Period. Reeve

**Figure 103** Successive stages in the development of agricultural field borders and trails in a segment of the Kohala dryland field system at Lapakahi on the island of Hawai‘i. Note how fields that were originally large become successively divided into smaller plots over time (from Kirch 1984a).
(1983) demonstrated that marginal sectors of the Waimea agricultural system were developed after European contact, under the direct aegis of the paramount chief Kamehameha while he and his retinue of warriors were resident on the coast at Kawaihae preparing for their conquest of the westerly islands.

Sites in the Kona region of western Hawai‘i, seat of the powerful ruling chiefs descended from Liloa and locus of some of the largest war temples and nucleated settlements on the island (Kirch 1985a:161–67; Stokes 1991), are also informative. A vast inland field complex is archaeologically attested by a grid of permanent stone-walled field boundaries, as well as a plethora of minor agricultural features (terraces, mounds, planting circles, etc.). Schilt (1984), who directed archaeological studies in a marginal sector of this system, has provided the best chronological data. Her results indicate an initial phase of garden development occurring between A.D. 1400 and 1600, followed by an “intensive gardening” phase from A.D. 1600 to 1779. The Kona dryland field complex differed from those of Kohala or Waimea in the presence of an arboricultural zone dominated by breadfruit (Kelly 1983).

The Kohala, Waimea, and Kona inland dryland field complexes in western Hawai‘i all reveal a chronology of increasing core intensification, matched by progressive expansion into marginal environments at their peripheries, over the period from about A.D. 1400 to European contact. Archaeological estimates of prehistoric population growth during this same period (Hommon 1976; Cordy 1981; Kirch 1984a; Clark 1988) all concur that this was also a major phase of population explosion following a “logistic” or sigmoidal curve. There can be little doubt that the intensification and expansion of both pondfield irrigation and short-fallow dryland field systems in Hawaii were intimately linked with a phase of explosive population growth during the Expansion Period (Kirch 1985a:303–6). Hommon concluded that “the need for additional food for a continually growing population appears to be the simplest explanation for the inland expansion initiated about A.D. 1400” (1986:64). The empirical demonstration that population increase and agricultural expansion-intensification were contemporaneous processes does not permit assignment of any causal priority either to population pressure or to technological development. Indeed, it seems both an empirical red herring and a theoretically circular exercise to attempt to resolve the causality issue by assigning a prime mover status to either side of the equation. Even if population pressure were demonstrated at time \( t \) to have spurred agricultural expansion, the problem could be put back to time \( t - 1 \), when the opposite situation could have prevailed, leading to an endless regression in the search for first causes. It seems more productive simply to recognize that population
growth and agricultural expansion-intensification in prehistoric Hawaii were fundamentally linked processes; each was a necessary condition of the other.

**Intensification and Political Competition**

The *Annales* historians recognized the dynamic cycle encapsulated by Le Roy Ladurie as *structure-event-structure* (1979:111–31); structures inspire actions, with sometimes unintended consequences, which in turn may alter the way in which we conceptualize the world. In chiefdom societies such as protohistoric Hawaii, with their “heroic” polities, events often replicated the actions of great mythic heroes, a process Sahlins has termed *mytho-praxis* (1981, 1983). So it was with the famous paramount chief Kamemehameha I, the usurping junior sibling and heir to the war god Kuka'ilimoku, who reenacted the history of his ancestor 'Umi-a-Liloa. The 'Umi myth is revelatory not only for what it reveals of Hawaiian political cycles but for the prominence it gives to control over a small but symbolically essential area of irrigated lands: the Waipi'o Valley on the windward side of the island of Hawai'i.6 This valley, with its broad, flat alluvial floodplain, contains the only substantial area of irrigated pondfields on that island and, not surprisingly, therefore, was the traditional seat of the paramount chiefs. 'Umi, offspring of the high chief Liloa by a chiefess of low rank who rears him in the countryside, comes to his aging father residing in Waipi'o and is given control of the war god Kuka'ilimoku, while his half-brother Hakau succeeds to the paramountship on Liloa's death. Hakau, jealous of 'Umi, drives the latter out of Waipi'o into the hinterlands of Hamakua and Puna. While in exile in the dry tablelands, 'Umi becomes a renowned cultivator and husbander of animals (Valeri 1985b:82). With the support of a disaffected populace, whom he feeds, 'Umi eventually usurps Hakau's title and power. He reclaims the valley of Waipi'o with its irrigated fields and its temple of Honua'ula, where he offers up the slain bodies of Hakau and his followers as sacrifices.

The roles of Waipi'o and of the Hamakua-Puna hinterlands in this epic tale are paradigmatic of the relationship between irrigation and dryland cultivation in Hawaii. Waipi'o and several much smaller valleys in the windward Kohala mountains are the only areas on the island of Hawai'i where taro pondfield irrigation is possible. While these valleys make up a mere fraction of the island's agricultural lands, they hold a cultural and symbolic significance far exceeding their actual contribution to production. In ancient Hawaii, taro was the most valued crop and irrigation was the preferred mode of cultivation. Thus, Liloa had established his seat in
Waipi’o and constructed his war temple there. When ‘Umi is forced to flee, it is to the labor-intensive dryland agricultural regions where, among the oppressed people of the countryside, he finds the popular support that enables him to realize his political aspirations of succession to the chiefship. Like his father before him, ‘Umi reclaims his ancestral seat in the fertile, irrigated lands of Waipi’o. Generations later, ‘Umi’s descendant Kamehameha I would reenact this history, with one difference: his aspirations now encompassed not just the island of Hawai‘i but the entire archipelago. For Kamehameha, the irrigation-rich islands of Kaua‘i and O‘ahu lured him just as Waipi’o had beckoned to ‘Umi during his exile in the uplands of Hamakua. 17

At first European contact in A.D. 1778, the Hawaiian archipelago was politically segmented into four independent and frequently warring chiefdoms. From west to east, these polities were geographically focused on the islands of Kaua‘i, O‘ahu, Maui, and Hawai‘i. The smaller island of Moloka‘i was under the hegemonic control of O‘ahu, while Lana‘i and Kaho‘olawe were subject to Maui. East Maui, however, had been conquered by the Hawai‘i island chiefdom and was temporarily under the domination of its paramount chief, Kalaniopu‘u. This situation, moreover, was hardly stable, and an analysis of the political history of these chiefdoms in the decades both preceding and immediately following the 1778–79 Cook expedition reveals a regular pattern of cyclic territorial conquest and expansion, reconquest, and contraction. 18 Thus, a few years later the Maui paramount Kahekili not only recaptured his core lands of east Maui but extended his hegemony to include Moloka‘i and O‘ahu. Ultimately (in 1794–95), Kalaniopu‘u’s successor on the island of Hawai‘i, the famous Kamehameha I, would extend by conquest the control of the Hawai‘i line over all of the islands except Kaua‘i.

Sahlins has discussed this protohistoric Hawaiian pattern of cyclical expansion and contraction of chiefdom polities, a tendency for chiefly domains to enlarge and contract, extended at times by conquest only to be partitioned later by rebellion:

Conscious, it seems, of the logistic burdens they were obliged to impose, the Hawaiian chiefs conceived several means to relieve the pressure, notably including a career of conquest with a view toward enlarging the tributary base. In the successful event, however, with the realm now stretched over distant and lately subdued hinterlands, the bureaucratic costs of rule apparently rose higher than the increases in revenue, so that the victorious chief merely succeeded in adding enemies abroad to a worse unrest at home. The cycles of centralization and exaction are now at their zenith (Sahlins 1972:145).
A phase of rebellion and usurpation of power (frequently by junior kinsmen of the paramount) would ensue. This was not, however, a revolution. “The chieftainship if overthrown was replaced by a chieftainship. Delivering itself of oppressive rulers, the system did not consequently rid itself of basic contradictions, transcend and transform itself, but continued instead to cycle within the confines of existing institutions” (Sahlins 1972:146). This cycle, moreover, had an economic base. The competitions between powerful chiefs and their people were “transposed forms” of the more essential struggle over household livelihood, over “whether it was to be more modestly employed in household livelihood or more intensively deployed to political organization” (Sahlins 1972:146–47). A point not sufficiently stressed by Sahlins, however, is that these classic cycles of territorial expansion and contraction were geographically focused (or at least most intensely developed) on the easterly islands, especially Maui and Hawai’i, and that their particular economic base was the distinctive, intensive dryland agriculture described earlier.

There were other differences in the political, and religious, structure of the eastern and western chiefdoms, typically glossed over or ignored in the standard works on Hawaiian ethnography (see Kirch 1990a). In particular, the elaborate makabiki, or wet-season harvest ritual, as well as the emphasis accorded the cult of the war god Ku with its associated luakini temple ritual, was especially developed on Hawai’i and Maui, less so on the westerly islands of O’ahu and Kaua’i (Valeri 1985a:184–85). Even the distinctive iconographic style of temple images, referred to by Cox and Davenport (1974) as the “Kona style,” reflects a particular emphasis in the Hawai’i island chiefdom on the Ku cult and its objectives of territorial conquest.

Unfortunately, most of the primary ethnohistoric sources on Hawaiian religion prior to the overthrow of the kapu system in 1819 derive from the island of Hawai’i. Yet sufficient evidence exists to suggest that there were major differences in ritual practice between the western and eastern parts of the archipelago. Of the four great Hawaiian gods, two—Lono and Kane—were both associated with agriculture. Most sources, with their Hawai’i island bias, usually place Lono in the primary role of agricultural god, and indeed, Lono was the key deity in the annual makabiki harvest festivals practiced in the Kona and Kohala districts of Hawai’i. It is clear, however, that Lono was specifically the god of dryland cultivation and that it was Kane who was associated with pondfield irrigation of taro. Valeri (1985a:15, table 1), who has synthesized a vast body of literature pertaining to Hawaiian theology, finds Lono to be associated with “clouds bearing rain,” thunder, the sweet potato (the primary dryland crop), the rise of Pleiades, and the rainy season. In contrast, Kane’s associations are with
running water (*wai*), springs, fishponds, male procreative powers, and irrigation. Kane’s close relation to taro, for example, is indicated in a taro-planting prayer recorded by Kamakau:

> Pause and receive thanks, O god,  
> O Kane, O Kane-of-life-giving-water;  
> Here is *lu‘au*, the first leaves of our taro;  
> Turn back and eat, O god . . .

(1976:35).

Handy and Pukui describe the mythic associations between Kane and taro, noting that “the family bowl of *poi* (starch staple made from taro) in the household was sacred to Haloa, who is Kane” (1972:34; see also Handy and Handy 1972:76, 79–83). In short, we have here two different sets of complex symbolic linkages, the one centered on Lono involving rainfall, sweet potato (and to a lesser extent dryland taro), and dryland cultivation, the other centered on Kane involving flowing waters, taro, and irrigation. This elaboration of Hawaiian theology and ritual, with its dual gods of agriculture corresponding to the wet and the dry modes of agricultural intensification, represents a significant transformation of ancestral Polynesian religious practice. It provides a fascinating point of contrast with Mangaia, to be discussed in the next chapter, where Rongo (Lono) merged the wet and dry symbolic associations into a single deity.

The political configurations and distinctive cycles of territorial expansion so characteristic of Hawaiian society on the eve of European contact display a clear-cut pattern of geographic distribution that corresponds closely to the fundamental differences in agricultural base. The aggressive, expansionist, Ku-cult centered chieftainships of Maui and Hawai‘i were precisely those polities most dependent upon intensified dryland field cultivation. The frequent objects of their aggression were the western islands of Moloka‘i, O‘ahu, and Kaua‘i, the resource-rich centers of irrigation agriculture and fishpond aquaculture. In these western islands, the possibilities for greater agricultural intensification remained substantial, despite high levels of population density, owing to the environmental conditions favoring irrigation. Our archaeological study of the Anahulu Valley, O‘ahu, demonstrated that the interior portions of this large stream valley were underutilized in late prehistory, in a low-intensity system of shifting cultivation. Only following the conquest of O‘ahu in 1794 and its occupation in 1805 by the considerable forces of Kamehameha from the island of Hawai‘i was this interior valley region brought under pondfield irrigation (Kirch 1990c; Kirch and Sahlins 1992).
On the island of Hawai‘i, especially in its leeward regions, which constituted the ancestral seat of the most powerful and aggressive chiefly line (that of Kalaniopu‘u and Kamehameha I), archaeological evidence reveals a significantly different level of agricultural intensification, one that had approached the limits of increased productivity even with significant labor inputs (including the addition of female labor in field cultivation). As Tuggle and Tomonari-Tuggle concluded on the basis of several years' study of the prehistoric agricultural systems of Hawai‘i, “The extent and intensity of the [dryland] complexes in Kohala lead to the conclusion that agricultural growth had reached its limits in the Kohala-Hamakua region, under the constraints of a simple irrigation technology and probably a comparable level of dry-field technology” (1980:311). These scholars further propose a key link between the limits to intensification and political developments on Hawai‘i:

There is some evidence that Hawai‘i was politically unified at an earlier date than the other islands and that it may have had a somewhat more complex political hierarchy. If so, it can be argued that demand for agricultural land, particularly irrigation land, increased competition among politics, thus acting as a variable in the process of political elaboration (1980:311).

Elsewhere (Kirch 1984a:181–92) I have reviewed the archaeological evidence for late prehistoric agricultural intensification in leeward Hawai‘i in the context of a production-function model of changing surplus production. The leeward Hawaiian field systems can be argued to have reached that sector of the production function in which surplus was diminishing relative to yield. Given the heavy demands that late prehistoric Hawaiian polity placed on the common people, what really counted was the constant pressure for surplus to be appropriated by the chiefship. Western Hawai‘i may have approached a situation where such demand exceeded the ability of the production base to supply it. This would have been politically intolerable, for chiefs were now accelerating demands on a surplus which was in absolute decline, leading precisely to the political cycle of expansion and subsequent rebellion so eloquently described by Sahlins (1972).¹⁹

Hommon (1986) rightly points out that the systems on the leeward side of Hawai‘i were also those most susceptible to environmental perturbations and to degradation:

With the expansion of population into marginal regions came an increase in the frequency and intensity of the adverse socio-political effects of crop failure and famine resulting from drought. . . . Irregu-
lar and unpredictable oscillations in the amount of goods available to chiefs increased in magnitude with the increase of agricultural lands that were susceptible to drought, soil exhaustion resulting from insufficient fallow periods, increased soil erosion, the effects of deforestation, and other factors that reduced the capacity of the land to produce (1986:66).

Hommon relates these agro-ecological conditions to the cyclical political history of the island of Hawai‘i, suggesting that the rivalry between leeward and windward chiefs was rooted in two disparate economic histories (1986:67). In particular, this rivalry may have involved competition between an alliance of windward polities whose wealth and power were founded on a long-established stable productive economy supported in part by valley irrigation (in the Kohala and Hamakua areas) and the upstart nouveaux riches leeward districts with their rapidly growing but somewhat unstable economies based on the dryland field complexes.

Schilt, in her intensive study of the Kona district of Hawai‘i, points to the direct archaeological evidence for overt competition and warfare in the final few centuries prior to European contact, in the form of caves modified for refuge and defense. The conversion of these caves to refuges, between about A.D. 1500 and 1600, coincides with the traditional accounts of late precontact political rivalry in Kona and with the contemporaneous intensification of leeward field systems (Schilt 1984:294). Schilt opines that because the island of Hawai‘i “presented less total, sustainable production potential than the older [western] islands, where irrigation was the characteristic mode of taro production,” it was also “possibly the first place where a disjunction between an expanding population and the limits of agricultural development, within a politically competitive cultural system, was realized” (1984:292).

## Intensification and Hawaiian Protohistory

The archaeological and ethnohistoric evidence from the Hawaiian Islands reveals a structurally parallel case to Futuna and Alofi, in which fundamental wet-dry agro-ecological contrasts led to a significant sociopolitical tension. In Hawaii, this tension was played out at the scale of an entire archipelago rather than within two small islands. But the fundamental processes of short-fallow, high-labor intensification in dryland systems leading to territorial expansion and cycles of political conquest are remarkably similar between the leeward Hawai‘i island chieftainship and that of Alo-
Asoa on Futuna. By the same token, the “involution” of irrigation development on Kaua’i and O’ahu (and to some extent east Moloka’i) closely parallels that of Sigave.

In *Islands of History*, Sahlins explicitly remarks upon the dynamic tension that divided eastern and western sectors of the Hawaiian Islands:

As a general rule, the oldest and most senior lines are in the western islands, Kaua’i and O’ahu, whence originate also the highest tabus. But then, the historical dynamism of the system is in the east, among Maui and Hawai’i chiefs, who are able to differentiate themselves from local competitors, or even from their own dynastic predecessors, by appropriating ancestry from the ancient western sources of legitimacy (1985:20).

The “historical dynamism” of Maui and Hawai’i owes much to its agricultural production base. The pathway of labor-intensive, short-fallow, dryland field agricultural development followed in most of Hawai’i and east Maui yielded dramatic social and political consequences, as Sahlins has detected. Recognition that the contrastive pathways of agricultural intensification followed in Kaua’i and O’ahu—landesque capital intensification with pondfield irrigation—as opposed to the pathways followed in Hawai’i and Maui greatly influenced the respective sociopolitical structures of these chiefdoms does not necessitate adherence to some outdated theory of environmental determinism. The particular cultural, symbolic structures that emerged in each region, such as the elaborated Ku and Lono cult cycle of Hawai’i island, were in no way “determined” by the nature of the agro-ecosystem. But it would be equally facile to suggest that the different modes of agricultural production in western and eastern parts of the archipelago were without impact on the course of Hawaiian sociopolitical change. In each region, chiefs and their followers seized such opportunities for development and enhancement of the production apparatus as were at hand, at the same time that they were constrained in their abilities to make alternative choices. Whereas the Kaua’i and O’ahu chiefs benefited from a landscape favoring valley pondfield irrigation and fishpond aquaculture, the Hawai’i and east Maui chiefs operated under severe limits to irrigation or aquacultural expansion. The dryland agricultural regimes of these eastern islands—as they became increasingly intensified through short-fallow and labor-intensive methods in late prehistory—put increasing pressure on the political elite for territorial expansion. It is an accident of history that Kamehameha I found himself in a position to use the “structure of the conjuncture” (Sahlins 1985) between Hawaii and the expanding World System of the late 18th century to extend his hegemony over the
entire archipelago. That he should harbor such ambitions, that his greatest desire should have been the conquest and subjugation of the irrigation-based western polities, however, is bound up in a “mytho-praxis” which can be traced at least as far back in time as his ancestor 'Umi-a-Liloa, who after conquering all of the island of Hawai‘i established his residence and principal temple in the coveted Waipi‘o Valley, the only major location of irrigation works on the island (Kamakau 1961).\textsuperscript{21}