

# *Polynesian Irrigation: Archaeological and Linguistic Evidence for Origins and Development*<sup>1</sup>



PATRICK V. KIRCH AND DANA LEPOFSKY

AMONG THE MOST ANTHROPOLOGICALLY significant aspects of traditional Polynesian agriculture were several kinds of irrigation and water-control technologies for the intensive cultivation of taro (*Colocasia esculenta*). Most of the high volcanic islands of tropical and subtropical Polynesia exhibit landscape modifications such as terracing or ditching, or both, resulting from prehistoric Polynesian irrigation, and in many cases traditional irrigation techniques continued to be practiced into the present century. The pondfield irrigation systems of the Hawaiian Islands are doubtless the best known of these indigenous Polynesian irrigation works (Earle 1978, 1980; Kirch 1977; Kirch and Sahlins 1992), but similar terraced pondfield systems are recorded for Futuna (Barrau 1963; Kirch 1975), Rarotonga and Mangaia (Allen 1971; Buck 1934, 1944), the Marquesas (Handy 1923), the Society Islands (Lepofsky, in prep.), Mangareva (Buck 1938), Tubuai (Aitken 1930), and Rapa (Stokes [1930]). In addition to pondfield irrigation, the Polynesians also practiced intensive swamp cultivation of taro in systems of raised beds with intervening reticulate drainage/irrigation ditches (Damm 1951). Such raised-bed systems are known from 'Uvea (Kirch 1978), Samoa (Buck 1930; Coulter 1941; Farrell and Ward 1962), Atiu and Mauke in the Cook Islands (Buck 1944), the Society Islands (Handy 1930), Tubuai (Aitken 1930), and Rurutu (Verin 1969).

Although Polynesian irrigation is for taro cultivation rather than for rice, it is technologically and hydraulically similar to the irrigated terrace systems used extensively throughout Southeast Asia for wet rice culture (e.g., Conklin 1967; Spencer and Hale 1961; van Breeman et al. 1970). Given that Polynesian origins—as well as the origins of most of the major crops cultivated by the Polynesians—are generally thought to lie to the west in the island or mainland Southeast Asian region, the question arises as to whether the Polynesian agronomic practices of pondfield irrigation and swamp cultivation trace their antiquity back to a “Proto-Austronesian” homeland in insular Southeast Asia. Were pondfield and raised-bed cultivation methods integral components of the early Oceanic “transported landscape” (Kirch 1984:135–139) that facilitated the colonization of the remote Pacific Islands?

Patrick V. Kirch is a professor and Dana Lepofsky is a doctoral candidate in the Department of Anthropology, University of California, Berkeley, California.

*Asian Perspectives*, Vol. 32, no. 2, © 1993 by University of Hawai'i Press. All rights reserved.

This is not a new question for Oceanic scholars, as a brief review of the literature will indicate. However, only with the development of direct archaeological approaches to agricultural prehistory in Oceania has sufficient evidence been adduced to address this question meaningfully. In this paper, we introduce two independent lines of evidence relevant to the origins and development of complex pondfield irrigation and raised-bed swamp cultivation of taro in Polynesia. The first consists of chronologically controlled archaeological evidence for agronomic modifications of Polynesian landscapes. Our second, independent line of argument draws upon historical linguistics, specifically the lexical domain of irrigation terminology found in Polynesian and related Oceanic languages. The congruence between both lines of evidence creates a compelling argument for relatively late—and *independent*—development of irrigation technology in separate areas within Polynesia.

#### ORIGINS OF POLYNESIAN IRRIGATION: ALTERNATIVE MODELS

Most anthropologists and ethnobotanists who have considered the origins of Polynesian irrigation fall into one of two main camps: (1) a “diffusionist” camp, which holds that irrigation technology developed in Southeast Asia (either for taro or rice) and was transferred into Oceania by Austronesian-speaking peoples; or (2) an “independent-development” camp, which argues for a later, independent invention of irrigation technology in response to demographic, social, or environmental pressures. Both positions have their current advocates.

Perhaps the classic statement of the diffusionist position is that of Spencer and Hale (1961), who reviewed the evidence for the origins and distribution of agricultural terracing on a world-wide scale. Their fundamental tenet was that “the basic concepts of terracing owe their origins to a relatively few regional developments, and that early concepts and technologies of terracing spread by diffusion to many of the parts of the world in which today the traditional systems of terracing are to be found” (1961:31). In Spencer and Hale’s cartographic depiction of terracing diffusion (1961: fig. 5), the Pacific Islands are shown at the terminus of a reticulate set of arrows spreading out from a “region of origin of wet field terracing,” located in South China and northern Indochina. However, in a footnote, Spencer and Hale expressed doubts as to the validity of their interpretations with regard to the Oceanic “taro pit-field,” admitting that “there are evolutionary and sequential problems around terracing in the Pacific not brought out in our discussion” (1961:37).

In the same year that Spencer and Hale published their diffusionist theory, Jacques Barrau succinctly posed an alternative model; although he was equivocal as to whether the actual origins of the technology were wholly independent within Oceania. Barrau argued that “the original agricultural systems” on the high islands of the Pacific were shifting cultivation with the use of burning to clear climax forest (1961: 18). In time, population growth and “the use of primitive agricultural techniques” led to deterioration of soils and vegetation.

With the decrease in land fertility it became necessary to employ semi-permanent forms of agriculture with artificial fertilization of the soil. It was this need, apparently, that led to the development of taro-growing on low-lying, hydromorphic soils

and on irrigated terraces in the valleys, techniques which may have been introduced by the migrations (1961:18).

Although Barrau's final line suggests that he was uncertain as to whether terracing technology may have been part of the initial Oceanic agricultural set, he clearly held that the use of terracing and irrigation did not play a major role in Polynesian agricultural systems until well after the period of early dispersal and colonization.<sup>2</sup>

As archaeological and ethnobotanical data on the distribution of Oceanic irrigation technology accumulated, it became evident that the widespread distribution of both pondfield and raised-bed agricultural technologies in Polynesia was not matched by an equally extensive distribution in Melanesia. Because the Austronesian-speaking dispersal is regarded as having spread through Melanesia to Polynesia, this extensive geographical gap in the distribution of terracing posed something of a conundrum to the diffusionist position. Although there are "pockets" of highly intensive taro pondfield irrigation in Melanesia (notably in the New Georgia group of the western Solomons, on Aneityum in Vanuatu [Spriggs 1981], and in New Caledonia [Barrau 1956]), on most of the intervening islands (including the large island of New Guinea) irrigation is absent. Brookfield and Hart, for example, commented in 1971 that "there is a wide gap between island Melanesia and the putative area of origin of irrigated terracing in southeast Asia, bridged only by scattered and ill-developed occurrences here and there in New Guinea" (1971:81-82). Yet Brookfield and Hart still inclined to a diffusionist interpretation.

Writing in 1973 just as Polynesian archaeologists were beginning to address directly questions of subsistence ecology and agricultural systems, Douglas Yen offered a series of propositions regarding the origins of Oceanic agricultural systems, reflecting the thesis that "the solely diffusionist explanation for variation is no more valid for agriculture than it is for culture" (1973:80). Among the hypotheses he put forward was that the Melanesian-Polynesian "border area" may have been "an independent centre for the development of irrigation technology, through which the idea of the spread of natural water resources for taro planting may have originated (or reoriginated?)" (1973:83). Yen apparently believed that such innovation occurred rather early in the prehistory of Polynesian expansion, however, because his speculative sequence for Hawaiian agricultural prehistory included the proposition that "irrigation agriculture was practiced early" (1973:81). Likewise, Kirch (1985:218-219; see also Kirch 1984:172) pointed to a putative Proto-East Polynesian lexical reconstruction of a term for pondfield (*roki* or *loki*) as evidence that the early Hawaiian colonists "brought irrigation technology with them," although he maintained that the major irrigation systems witnessed at European contact were developments of a "major episode of expansion in irrigation" in late prehistory. In contrast, Athens (1983) maintained that Hawaiian irrigation was a "density-dependent adaptation" that arose in response to demographic pressures occurring well after initial settlement of the archipelago.

In recent years, Spriggs (1982a, 1982b, 1990) has championed the diffusionist position that irrigation technology was part of the agricultural knowledge of early Oceanic peoples. Spriggs disagreed with Yen's Melanesian-Polynesian "border area" hypothesis of an independent center of irrigation technology development: "Certain irrigation techniques may well have developed independently in New Guinea or island Melanesia, but the similarity in pondfield morphology and tech-

niques between Oceania and island Southeast Asia suggests a common origin" (1982a:317). In another paper he reiterated this position, noting that "pondfield agriculture is nearly exclusively found among Oceanic Austronesian speakers in the Pacific and of course both language and technique point to links with island Southeast Asia" (1990:185).

Yen (1990:263–264) continues to maintain an independent development of irrigation technology in the Pacific, observing that Spriggs's "rather bold claim . . . carries the burden of proof from future studies of prehistoric and contemporary Southeast Asian rice-growing systems." In his most recent statement, Yen opined that "the linguistic correlate of irrigators as Austronesian speakers" as argued by Spriggs is unconvincing, "unless it can be shown that most Austronesians under the same ecological conditions practice irrigation, or that there are *direct linguistic connections in the lexicon of water control*" (1991:81, emphasis added). Yen (1990) also contended (rightly so in our opinion) that it is through the expansion of archaeological efforts that a satisfactory resolution to the debate will ultimately be found, and it is on Yen's challenges that we proceed to a review of both the archaeological and linguistic evidence.

#### THE ARCHAEOLOGICAL EVIDENCE

Archaeological efforts to uncover material evidence of Oceanic prehistoric terracing and irrigation technology—and to date those remains radiometrically—began in 1969–1970 with several projects in the Hawaiian Islands. In the Mākaha Valley Project, Yen directed the investigation of an inland pondfield irrigation system (Yen et al. 1972). Those pioneering studies have been followed up by extensive excavations in several areas within Hawai'i and by more limited efforts in several other Polynesian Islands. We will not review this work exhaustively here; rather, our focus is on the chronometric and sequential evidence for pondfield terracing and raised-bed swamp taro systems in various Polynesian Islands. We begin in western Polynesia, the first region within the Polynesian triangle to have been colonized by humans, and proceed eastward.

#### *Futuna*

In western Polynesia, only the high volcanic island of Futuna exhibits extensive pondfield irrigation. Valley-bottom pondfield systems, confined largely to the western chiefdom of Sigave, rival those of the Hawaiian Islands in their technological sophistication and scale. Stratigraphic archaeology in Futuna and Alofi, as well as 'Uvea, was pioneered by Kirch (1975, 1976, 1981, in press), whose objectives were focused explicitly on the prehistory of the Islands' agricultural systems. Excavations were conducted in several extant and prehistoric pondfield terrace complexes, although datable charcoal was recovered in only one instance. An abandoned terrace system at Lotuma, near Nuku Village, yielded a radiocarbon age of  $185 \pm 80$  B.P. Calibration of this date suggests that the buried pondfield horizon dates to the period c. A.D. 1670–1798. On the whole, the stratigraphic and geomorphological evidence from the extensive Nuku pondfield system suggests a rather late construction, probably within the past few hundred years (Kirch, in press).

At Tavai, important stratigraphic data were uncovered for massive alluvial deposition on the narrow coastal plain that is the geomorphic environment upon which the pondfield terrace complexes were constructed. The site FU-11 excavations revealed a late Eastern Lapita village site dating to  $2120 \pm 80$  B.P., capped by 2.5 m of sediment derived from the steep slopes inland of the site (Kirch 1981). A probable agricultural horizon overlying the Lapita settlement was dated to  $1315 \pm 175$  B.P. (cal. A.D. 560–936). However, the lack of an oxidation-reduction soil profile indicates that this horizon was not irrigated. The depositional sequence at Tavai suggests that the Futunan coastal plain had undergone extensive alluvial deposition and progradation within the past two millennia, and that the extensive pondfield systems witnessed at European contact could only have developed once this alluviation sequence was fairly well advanced.

Remarkable corroboration of the Tavai sequence was obtained by Frimigacci and his associates from their excavations at Asipani, along the southern coast of Sigave, and within the “heart” of the Futunan irrigation territory. The Asipani excavations similarly yielded evidence for massive alluvial construction and progradation of the coastal plain subsequent to Lapita occupation, with some 3.2 m of deposition (di Piazza 1990; Frimigacci 1990; Frimigacci et al. 1988). Most important, the French team exposed a “fossil” irrigated pondfield planting surface (in bed 6) that had been buried suddenly by a flood event of the Asipani Stream. The exposed surface displays 68 taro planting depressions (the plants had probably just been harvested at the time of the flooding and burial of the field) and a shallow drain or ditch. Charcoal from the cultivation layer yielded a date of  $1120 \pm 70$  B.P. (cal. A.D. 791–992).

The Futunan evidence (reviewed in detail by Kirch [in press]) indicates that pondfield irrigation did not become a major part of the agricultural landscape until about the middle of the first millennium A.D. For the first 1500 years of the Futunan sequence, the Lapita-descended population probably practiced shifting cultivation, leading in part to the sequence of hillslope erosion and alluvial deposition that created the fertile coastal plains. Beginning by about A.D. 500, these plains became the setting for increasingly productive and extensive pondfield systems, which reached their maximum extent only after European contact and the introduction of steel tools. Although the Futunan sequence does not preclude the possibility that the first Lapita colonizers practiced some limited forms of wet taro cultivation, it does not support the notion that pondfield terracing was a major component of the early agricultural set introduced at first settlement. Rather, pondfield irrigation was largely a development of the last 1200 years, when local populations had reached substantial numbers.

### *Samoa*

Despite the topographic and hydrologic suitability of the Samoan high-island environment for irrigation, there is no evidence that classic pondfield irrigation was ever practiced by the Samoan people. The use of raised-bed swamp taro cultivations is, however, reported as a “rare” practice in the large islands of Upolu and Savai'i, one that was furthermore in decline by the early 1960s (Farrell and Ward 1962:218–219). Buck (1930:548) and Coulter (1941:26) indicated a greater importance of raised-bed taro cultivation on the smaller islands of Aunu'u, Ta'u, and

Olosega. In the Falefa Valley, Upolu Island, Ishizuki discovered a network of drainage ditches and intervening raised beds adjacent to a late prehistoric to early historic habitation terrace (the SU-Fo-1 site; Ishizuki 1974:49, figs. 30, 31). Ishizuki interpreted these features as agricultural plots. Although he cut trenches across the drainage ditches to expose stratigraphic sections, these features were not directly dated. The adjacent Folas-a-Lalo house site yielded radiocarbon dates of  $470 \pm 180$  and  $210 \pm 70$  B.P. (Ishizuki 1974:56), and the raised-bed garden features most likely date to this late prehistoric to early historic time span. A third radiocarbon date of  $1410 \pm 110$  B.P. came from disturbed soil with charcoal flecking underlying the SU-Fo-1 house floor, which the excavator associated with "activities associated with clearing the slopes of bush" (Ishizuki 1974:56), possibly from shifting cultivation. Although this may indicate agricultural activity on the Falefa Valley slopes as early as the middle of the first millennium A.D., it is doubtful that the well-preserved ditch-and-raised-bed features are this old. Further archaeological work on such prehistoric agricultural features in Samoa is clearly desirable.

### *Hawai'i*

More archaeological effort has been devoted to tracking the course of agricultural prehistory in Hawai'i than in any other Polynesian locality, with investigations of both irrigated and dryland field systems. Stratigraphic excavations have been carried out in pondfield irrigation complexes in the Pololū Valley, Hawai'i Island (Tuggle and Tomonari-Tuggle 1980), Hālawā Valley, Moloka'i (Riley 1975), Mākaha, Anahulu, and Luluku valleys, and at Fort Shafter and West Loch, O'ahu (Allen 1987, 1991, in press; Dicks et al. 1987; Kirch and Sahlins 1992; Watanabe 1986; Yen et al. 1972), and at Hā'ena and Hanalei on Kaua'i Island (Athens 1983; Schilt 1980). The geographic sample of sites thus extends the length of the archipelago and encompasses both windward and leeward valley systems.

At four sites, Oa-G5-85 at Luluku, O'ahu, Oa-G6-68 and -70 at Mauna-wili, O'ahu, and in the Hanalei Valley, Kaua'i, there are radiocarbon ages from pondfield cultivation soils that date to the Colonization (A.D. 300–600) and Developmental (A.D. 600–1100) Periods of the Hawaiian sequence (Allen 1991:124, 127–128; see Kirch 1985 for the Hawaiian sequence periods). However, at two of these sites the excavators recognize problems of interpretation, and two others have yet to be published in full. At Oa-G5-85, for example, two early dates of A.D. 235–620 and A.D. 440–910 from the early pondfield horizon (Layer VIII) were contradicted by a third date of A.D. 1405–1950 (Allen 1991:123). The argument that these dates represent irrigation is based primarily on sedimentary and pedological characteristics of the cultivation layers from which the samples derived, although at Luluku (Layer VIII) a stepped terrace feature is present. None of these sites has clear evidence, at this early time period, for such technological features as stone-faced embankments or irrigation canals typical of classic Hawaiian pondfield irrigation. Thus, although some form of inundated field cultivation does appear to have been practiced in the Colonization-Developmental Periods, the technology and scale of such water control remains to be resolved through further archaeological studies.

What is evident from the excavated and dated pondfield sample in the Hawaiian Islands is a rapid development of irrigated pondfields beginning in the Expansion Period, from A.D. 1100 to 1650, and continuing on in some cases into the early

decades after European contact (see Allen [in press] for a thorough review of radiocarbon dates from Hawaiian agricultural sites). Most dates from the Luluku (O'ahu) terraces range from the thirteenth century A.D. to European contact (Allen 1991:128, table 2), closely matching the sequence from inland Mākaha on the island's leeward side (Yen et al. 1972). In the Anahulu Valley of O'ahu, irrigation systems in the valley interior were not constructed until after the military occupation of the island by the paramount chief Kamehameha I in A.D. 1804, several decades after European contact (Kirch and Sahlins 1992, vol. 2). In the Hālawā Valley, Moloka'i, no direct  $^{14}\text{C}$  dates were obtained from pondfield horizons, but on the strength of settlement pattern associations with dated residential sites, Riley (1975) ascribed these systems to the Expansion and Proto-Historic Periods. Finally, in the Pololū Valley in Kohala, Hawai'i, the valley floor was not brought under irrigation until late in the prehistoric sequence, in the Proto-Historic Period (Tuggle and Tomonari-Tuggle 1980).

Several authors have explored the complex relationships between population growth, anthropogenic impacts on the environment, agricultural intensification, and the rise of sociopolitical complexity in the Hawaiian Islands (e.g., Allen 1991, in press; Hommon 1986; Kirch 1984, 1985, 1990). The issues are complex and extend beyond the scope of this paper. It is clear, however, that the development of the "classic" Hawaiian pondfield irrigation technology, including what Allen (1991) referred to as "standardized" terrace facings, extensive and multiple irrigation canal complexes, and flood-control devices, is a phenomenon of the mid-to-late Expansion Period (c. A.D. 1400–1650), which went hand in glove with major population increases and with the rise of a hierarchical and surplus-exploiting sociopolitical formation.

That Hawaiian pondfield irrigation in its classic expression was a later prehistoric development has key implications for the diffusionist model of Oceanic irrigation terracing, because it is the Hawaiian case that is most frequently cited as exemplifying the technological parallels with Southeast Asian rice pondfield technology (e.g., Yen 1990:263). If the specific hydraulic and agronomic details of classic Hawaiian irrigation (which are so interesting in comparison with the Southeast Asian systems) are late prehistoric innovations, then the diffusionist case for Polynesian irrigation is weakened. Recent archaeological evidence does suggest some form of simple inundated cultivation of taro in the Colonization-Developmental Periods of Hawaiian prehistory. But the classic form of Hawaiian valley pondfield irrigation is a distinctly later phenomenon of the Expansion and Proto-Historic Periods.

### *Society Islands*

The few references to pondfield irrigation in the ethnohistoric and ethnographic accounts of Tahiti are suggestive of the prior importance of wet taro cultivation (Beaglehole 1969:773; Forster 1777:341–342; Forster 1778:52; Handy 1930:9, 20, pl. II). The evidence for pondfield irrigation is considerably strengthened, however, by archaeological surveys that revealed stone terrace systems in valleys on Tahiti, Mo'orea, and Raiatea islands (Green and Descantes 1989; Handy 1930; Lepofsky, in prep.). Pondfield systems that employ formal canal networks were not observed, and recent surveys by Lepofsky indicated that the predominant form

of irrigation seems to have been simple “barrage systems,” in which stone retaining walls were constructed directly across intermittent stream channels (see Kirch 1977; Riley 1975:87; and Spencer and Hale 1961:5–6 regarding barrage systems).

These simple pondfield irrigation systems are a major component of the surface archaeological landscape in most valleys and clearly played a significant role in prehistoric subsistence production. Radiocarbon dates for these agricultural remains are pending; however, based on associations with megalithic architecture characteristic of the late period of Tahitian prehistory, the terraces likely date to that later time. Co-occurring with these remains is an extremely high density of habitation sites likely reflecting large populations. As in Hawai'i, intensive wet cultivation of taro, high population density, and an increase in sociopolitical complexity seem to coincide in late Tahitian prehistory and protohistory.

### *Marquesas Islands*

Pondfield irrigation of taro was a decidedly secondary aspect of the Contact-period agricultural production system, which in the Marquesas revolved around breadfruit arboriculture (Handy 1923). Nonetheless, archaeological surveys have revealed the widespread distribution of small stone-faced terrace sets throughout Marquesan valleys (Bellwood 1972; Kellum-Ottino 1971; Ottino 1985). Unfortunately, there have as yet been no efforts to excavate or directly date any of these archaeological terrace complexes. The integration of the mapped terrace complexes in the Hane, Hanatekua, and Haka'ohoka valleys with typical megalithic residential architecture of the Expansion and Classic Periods suggests that the agricultural remains are themselves of relatively late date, but this remains to be confirmed through excavation, which should be a high priority for future work in the archipelago.

### *Mangaia*

Within the southern Cook Islands, Rarotonga and Mangaia islands both exhibit traditional agricultural systems heavily dependent upon pondfield irrigation and raised-bed swamp systems (the latter most extensive on Rarotonga). The Rarotonga systems have yet to be archaeologically studied, but recent work on Mangaia (Ellison in press; Kirch et al. 1992) has yielded some evidence on the probable antiquity of the island's pondfield irrigation. As a result of a combination of the outer ring of largely infertile, karst *makatea* and the interior volcanic cone that has been heavily eroded and vegetatively degraded, traditional subsistence practices on Mangaia emphasize pondfield irrigation of taro in the narrow valley bottoms and swampy basins below the inner *makatea* cliff. These environments were intensively investigated through stratigraphic coring, radiocarbon dating, and pollen analysis as a part of the 1989–1991 Mangaia Project directed by P.V.K. The results of that work, published at length elsewhere (Ellison in press; Kirch et al. 1991; Kirch et al. 1992), revealed sustained anthropogenic impacts on the island's environment commencing about 2500 B.P. and continuing until the historic period.<sup>3</sup> These changes are interpreted as resulting from forest clearing associated with shifting cultivation on the then-forested volcanic interior. Removal of forest cover and exposure of the thin soil resulted in a major phase of slope erosion, creation of a terminal fernland



community on the hillslopes, and deposition of thick clay wedges in the valley bottoms (which had formerly been covered in shallow freshwater lakes). In the Veitatei basin, for example, the deposition of massive alluvial clays increased after about 600 B.P.

As in Futuna, the intensive pondfield systems that cover the Mangaian valley bottoms cannot have been constructed until after the process of clay infilling was well advanced. Based on a comprehensive series of dated cores from all major Mangaian drainage basins, this process must date to the last five or six centuries of the prehistoric period.

### *Archaeological Evidence from Melanesia*

Although our main purpose in this paper is to focus on the evidence for *Polynesian* irrigation, we will also briefly review the archaeological evidence for pondfield irrigation from Melanesia. This is necessary because Spriggs (1982a, 1982b, 1990) and others have pointed to scattered instances of Melanesian pondfield irrigation as critical connectors along a putative path of irrigated terracing diffusion from Southeast Asia to Polynesia.

Certainly the most technically complex pondfield irrigation within Melanesia is that of New Caledonia (Barrau 1956), which, indeed, is unique within Oceania in its utilization of steep hillslopes as opposed to valley bottoms and in the inter-drainage basin integration of the canal networks. However, we are not aware of any archaeological attempts to excavate or date the extensive remains of such terrace systems. The antiquity of the New Caledonian terracing technology thus remains wholly enigmatic (not unlike other aspects of the island's prehistory!).

In Vanuatu, pondfield irrigation has been reported from a number of islands (Spriggs 1990, table 1), but has been archaeologically investigated only on Aneityum, by Spriggs (1981, 1986). Initial human occupation on the island can be dated to about  $2890 \pm 60$  B.P., presumably by Lapita populations whose agricultural clearance activities are reflected in the coastal pollen sequence at Anauwau Swamp. Continued forest clearance over the next 1000 years led to a sequence of erosion and coastal alluvial deposition similar to that in Futuna. "The first direct evidence for the use of the valley mouths and plains for agriculture . . . comes from within the last 1000 years" (Spriggs 1986:11). The large-scale canal-fed irrigation systems of the valley flats all appear to have been constructed over an even shorter time span, within the period since about 500–600 B.P. Thus in Aneityum, if not elsewhere in Vanuatu, complex pondfield irrigation is best understood as a late development in a local sequence involving land use changes, population growth, and sociopolitical transformation. The late prehistoric pondfield systems of Aneityum can hardly be adduced as evidence along an early dispersal route of irrigating Lapita cultivators.

A third center of complex valley-bottom pondfield irrigation lies in the New Georgia group of the western Solomon Islands, especially on Kolombangara and New Georgia islands. In 1971, Doug Yen, Paul Rosendahl, and P.V.K. investigated several irrigation complexes along with associated fortified hilltop settlements in the Ndughore Valley of Kolombangara, in a study that remains unpublished. Stratigraphic excavations in one of the irrigation complexes yielded a radiocarbon date of A.D.  $1720 \pm 90$ . The associated habitation sites all contained

early European-contact materials along with indigenous artifacts, and the entire settlement pattern dates to the eighteenth–nineteenth centuries. The intensification of pondfield agriculture in Kolombangara was closely tied to a phase of sociopolitical transformation involving slave raiding and escalating mortuary exchanges. Again, the New Georgia irrigation systems appear to be of terminal prehistoric to early historic age and are best interpreted as local developments.

In short, the evidence from Aneityum and New Georgia do not support a case for an early diffusion of pondfield irrigation through Melanesia and into Polynesia. Rather, the evidence best fits a model of rather late, local innovations, although perhaps utilizing widespread Oceanic agronomic concepts of planting *Colocasia* in wet edaphic media (see Yen 1973).

Finally, in Melanesia we cannot ignore the critical evidence from the Kuk site in the New Guinea Highlands, excavated over many years by Golson and associates (Bayliss-Smith and Golson 1992; Golson 1977). The complex sequence of six phases of artificial modifications of the Kuk swamp, beginning with Phase 1 at about 9000 B.P. and ending with Phase 6 at 250–100 B.P., is pregnant with implications for the history of horticulture in Oceania. Yen has characterized the Kuk sequence as “the only *in situ* example in Pacific archaeology of a sequence of production intensification that might be labeled as evolutionary” (1990:262).<sup>4</sup> It is generally presumed that the Kuk drainage systems were “founded on taro” (Yen 1990:263) and evidence an increasing sophistication in the technical abilities to manipulate soil and water. The Kuk site, however, exemplifies an evolutionary sequence leading to raised-bed, drainage cultivation and not terraced, pondfield irrigation. Kuk demonstrates that the concepts of water control for taro culture were very early innovations within Melanesia itself, without doubt predating Lapita and the Austronesian expansion. We will return to the possible significance of these early Melanesian innovations in the conclusion.

#### THE LINGUISTIC EVIDENCE

We turn now to our second body of independent evidence, the corpus of terms related to irrigation in various Oceanic languages. The use of comparative and historical linguistic methods to derive paleoethnobotanical inferences has a long tradition in the Pacific (e.g., Barrau 1963; Chowning 1963; Rensch 1991). As knowledge of the subgrouping or genetic classification of Austronesian languages has increased over the past few decades, it has become possible to reconstruct specific lexical domains for various proto-language stages within the Austronesian tree. The most comprehensive effort to date is French-Wright’s (1983) extensive reconstruction of the Proto-Oceanic (POC) lexical set associated with horticulture. French-Wright was able to reconstruct a large set of POC terms relating to food production practices (site preparation, garden types, seedlings, cuttings, weeding, harvesting terms), food processing, and crops/cultigens (Table 1). On the basis of that study, it is certain that the POC speakers (who probably included at least some of the Lapita pottery-using peoples) worked with a wide range of crops including taro, yams, breadfruit, bananas, coconut, a wide range of nut- and fruit-bearing trees, kava, and other plants. French-Wright also concluded that “the evidence points to a slash and burn style of gardening” (1983:191).

From the point of view of irrigation or swamp cultivation of taro, French-

TABLE I. SOME PROTO-OCEANIC LEXICAL RECONSTRUCTIONS RELATING TO HORTICULTURE

TERM	GLOSS	TERM	GLOSS
* <i>poki</i>	to clear a garden	* <i>talu</i>	fallow, weeds
* <i>kokoda</i>	to prepare a garden	* <i>mena</i>	ripe
* <i>nsada</i>	to clear	*( <i>pu</i> ) <i>put-i</i>	harvest tubers
* <i>quma</i>	a garden (swidden)	* <i>punti</i>	banana
* <i>wa(a)so</i>	digging stick	* <i>kuluR</i>	breadfruit
* <i>ko(n)so</i>	digging/husking stick	* <i>niu(R)</i>	coconut
* <i>koti</i>	cut taro tops for planting	* <i>talo</i>	taro
* <i>upe</i>	taro top	*( <i>m</i> ) <i>pulaka</i>	<i>Cyrtosperma</i>
*( <i>m</i> ) <i>pula(m)pula</i>	seed yams	* <i>qupi</i>	yams
* <i>pa(n)si</i>	to plant	*( <i>q</i> ) <i>uRi</i>	<i>Spondias dulcis</i>
*( <i>n</i> ) <i>suki</i>	to transplant	* <i>tawan</i>	<i>Pometia pinnata</i>
* <i>ta(m)puki</i>	yam mound	* <i>natu</i>	<i>Burckella obovata</i>
* <i>papo</i>	to weed	* <i>kangaRi</i>	<i>Canarium</i> spp.
* <i>iopa</i>	cultivated land	* <i>qipi</i>	<i>Inocarpus fagifer</i>

Source: French-Wright (1983).

Wright's study is remarkable in the total absence of any valid POC reconstructions for such semantic glosses as 'pondfield', 'irrigated terrace', 'irrigation ditch', or indeed any terms associated with water control and taro cultivation.<sup>5</sup> That there is no evidence for any POC lexical set associated with pondfield irrigation or swamp/raised-bed cultivation of taro is, in our view, significant negative evidence. If either or both of these technologies were truly ancient in the Pacific, then it is reasonable to expect that at least a few basic terms (such as 'pondfield') would be reflected by shared cognates in a number of related Austronesian languages, as indeed is the case for shifting cultivations, dryland gardening techniques, and the root-tuber/tree crop complex.

To explore the possibility that a set of cognate reflexes for irrigation may in fact exist but simply have been overlooked, we carried out a review of ethnographic, ethnobotanical, and dictionary sources for all Polynesian societies known to have practiced some form of pondfield irrigation or raised-bed swamp cultivation of taro. In some cases, we also were able to augment the published literature through our own fieldwork (Kirch in Futuna and Mangaia; Lepofsky in the Society Islands). The lexical data are provided in Table 2, which also notes the documentary sources utilized. A perusal of the terms listed in Table 2 quickly reveals that the languages represented fall into two geographic (and linguistic) groups: (1) a group of western Polynesian-Outlier and Fijian languages; and (2) a group of eastern Polynesian languages. Within each of these two groups there are one or more obvious cognate terms, but no evident cognates shared between the two groups. We will discuss each group in turn.

Within the Fijian-western Polynesian region (and also including the Polynesian Outliers of Rennell-Bellona, which are linguistically part of the Samoic-Outlier linguistic subgroup), there is a single cognate set of reflexes, represented by Bauan *vuci*, 'pondfield', Moalan *vucivuci*, East Futunan *vusiga*<sup>6</sup>, 'pondfield', East 'Uvean *fuhi*, 'raised bed', and Samoan *fusi*, 'raised bed'.<sup>7</sup> The linguistic rules for reconstruction of a term to a proto-language stage require that the term be represented by cognates in languages derived from the primary branches of the proto-language

TABLE 2. FIJIAN AND POLYNESIAN IRRIGATION TERMS

LANGUAGE	PONDFIELD	RAISED BED	IRRIGATION CANAL	IRRIGATION COMPLEX	OTHER TERM
Bauan	<i>vuci</i>		<i>mata-ki-laua</i>		<i>qete</i> , 'taro bed'
Moalan	<i>vucivuci</i>				
Lauan				<i>solove</i>	
East Futunan	<i>vusiga</i>	<i>fakasakesake</i>	<i>mata'ilava</i> <i>maga a vai</i>	<i>telega</i>	<i>saliga a vai</i> , 'inlet to pondfield'
East 'Uvean	—	<i>fuhi</i>	<i>kauano</i>	<i>to'oga</i>	
Samoan	—	<i>fusi</i>	<i>vai ta'i</i> <i>alavai</i>		
Mangaian	<i>repo taro</i>	<i>taro pa'i</i>	<i>aravai</i>		<i>puna</i> , 'wet taro lands'
Rarotongan	—	<i>motu repo</i>	<i>kauvai</i> <i>aravai</i>		<i>matavai</i> , 'dam'
Rapan	<i>roki</i>	—	<i>uvai</i>		
Rurutuan	<i>repo taro</i>	<i>pa'i taro</i>	<i>utuwai</i>	<i>vihī taro</i>	
Tubuai	<i>repo taro</i>	<i>pa'i taro</i>			
Mangarevan	<i>repo taro</i> <i>rua taro</i>		<i>tairua</i> ('main') <i>ka'iraga-vai</i>		<i>kato</i> , 'retaining wall'
Hawaiian	<i>lo'i</i>	—	<i>'auwai</i>	—	

Sources: Bauan, Capell 1973; Moalan, Sahlins 1962; Lauan, Hocart 1929; E. Futunan, Kirch field notes, 1975, Burrows 1936, Grézel 1878; E. 'Uvean, Kirch field notes, 1975, Bataillon 1932, Burrows 1937; Samoan, T. Maiava, pers. comm., Neffgen 1918, Pratt 1862, Buck 1930; Mangaian, Kirch field notes, 1991, Allen 1971, Buck 1944; Rarotongan, Buck 1944; Rapan, Stokes [1930]; Rurutu, Verin 1969, Panoff 1970; Tubuai, Panoff 1970; Mangarevan, Buck 1938; Hawaiian, Pukui and Elbert 1965, Andrews 1922; Mosblech 1843.

node. In the case of the languages represented here, Bauan and Moalan represent a primary branch descended from Proto-Fijic (PFJ), and East Futunan, East 'Uvean, and Samoan all represent the branch descended from Proto-Polynesian (PPN). Thus, in theory, it would be possible on this data set to reconstruct a term for the proto-language that split into PPN and PFJ; that is, Proto-Central-Pacific (PCP). In fact, it has been suggested elsewhere (French-Wright 1983:72) that just such a term, PCP \**pusi*, with a semantic value of 'taro bed' or 'taro swamp', can be reconstructed.

We strongly question the validity of this putative PCP reconstruction, however, on several grounds. First, three of the cognate reflexes appear in a single, relatively low-level branch of Polynesian, the Samoic-Outlier subgroup.<sup>8</sup> Second, there are no reflexes of the putative PCP \**pusi* in any of the Polynesian languages outside the geographic region of Fiji-western Polynesia. These facts point to an alternative hypothesis that the term may be a more recent innovation of one of the languages in the western Polynesian-Fijian region that has subsequently been borrowed into the others. A plausible hypothesis is that the term is a Proto-Samoic-Outlier innovation that was subsequently borrowed into Bauan Fijian as *vuci*, after expectable sound shifts. Borrowing in the other direction, however, from Bauan into the Samoic-Outlier languages, is not inconceivable. There are strong ethnographic and archaeological reasons why such borrowing within the Fiji-western Polynesian region is expectable. At the time of early European contact, these archipelagoes were all closely integrated through a complex system of long-distance exchange and chiefly marriage alliances (Kaepler 1978; Kirch 1984:232-242). Archaeological ex-

cavations have yielded evidence for interarchipelago transport of such durable goods as obsidian, basalt adzes, and pottery over the three-millennia-long prehistory of this region. Given this documented history of regular contact and cultural interchange, we prefer the hypothesis that the shared reflexes for pondfield and raised bed in this region represent borrowing, and reject the putative POC reconstruction of *\*pusi*.

Turning to the languages of eastern Polynesia (which are all members of the low-level subgroup derived from Proto-Eastern-Polynesian, PEP), there are three sets of cognate reflexes. The first, a term meaning 'pondfield' or 'taro garden', is represented by Rapan *roki* and Hawaiian *lo'i*. Both languages are members of Green's (1966) Marquesic subgroup of Eastern Polynesian, presumably derived from the breakup of the Proto-Marquesic (PMQ) subgroup. Given the vast distances separating these Islands and the consequent implausibility of borrowing, we could propose a PMQ reconstruction of *\*roki*, with a gloss of 'pondfield', or 'wet taro field'. However, several cognate reflexes appear in other eastern Polynesian languages, in every case with a semantic gloss of 'bed' or 'couch': Mangaian *roki*, Mangarevan *roki*, Marquesan *'oki*, and Tuamotuan *roki*. The presence of these reflexes strengthens the case for the reconstruction of a slightly higher level, Proto-Eastern-Polynesian (PEP) (rather than PMQ) reconstruction *\*roki*, but complicates the matter of semantic interpretation. What seems possible is that a PEP term *\*roki* originally meant 'bed', and that by a process of semantic extension identical to the use of the English term 'bed' to mean 'planting area' (e.g., 'a rose bed'), *\*roki* came to refer to wet or irrigated taro fields within the PMQ communalect.<sup>9</sup> Because of this semantic complication, we are hesitant to suggest that PMQ *\*roki* meant anything more specific than a taro field, probably in some cases inundated. It would be an over-interpretation to suggest a PMQ gloss of 'terraced pondfield' for the term.

A second possible set of shared reflexes are those relating either to an artificial irrigation canal or to a stream that is tapped or diverted for irrigation purposes: Rarotongan *kauvai*, Rapan *uvai*, and Hawaiian *'auwai*. These reflexes might be judged sufficient to support a PEP reconstruction of *\*kauvai*, for 'stream' or 'irrigation canal'. The reconstruction is problematic, however, because it is a compound term, deriving from the widespread Polynesian terms *kau*, a classifier indicating linearity, and *vai*, the term for fresh water. A descriptive term such as *kauvai* or *'auwai* could readily arise independently in conjunction with technological innovation. Thus, we recommend caution in the acceptance of this second putative PEP reconstruction.

The third set of cognate reflexes is found among a group of southeastern Polynesian languages focused on the chain of islands connecting Mangaia in the southern Cooks, through the Austral chain, to Mangareva. In Mangaian, Rurutuan, Tubuaian, and Mangarevan, the term for irrigated pondfield is *repo taro*, a compound construction from the words *repo*, 'earth or mud', and *taro*. These islands were known to have been in regular contact with each other at the time of European discovery, and this innovation presumably arose in one island and was borrowed into the others. Likewise, in Mangaian, Rurutuan, and Tubuaian, the term for raised beds (usually thrown up within inundated fields) is *taro pa'i*. Given the proximity and contacts between these islands, both sets of compound terms can be regarded as borrowed, late innovations; there is no basis for reconstructing either term to Proto-Eastern-Polynesian.

Finally, although our focus is on Polynesia, we also consulted available sources on terminology associated with irrigation and swamp cultivation from Melanesia, to determine whether there were any cognates to the Polynesian terms that could support higher-level reconstructions to, for example, POC. The available terms from Melanesia are listed in Table 3. Although many of the New Caledonian language terms are clearly cognate, we are unable to detect interarchipelago cognate correspondences in this set, a finding that further strengthens the argument we have been making on the basis of the Polynesian lexical evidence.

What are we to make of these linguistic data? First, there is not a single term associated with irrigation or swamp cultivation of *Colocasia* that could be reconstructed to POC. This is in stark contrast with the numerous terms of shifting cultivation gardens, planting procedures, harvesting methods, and crop plants that French-Wright (1983) has reconstructed for POC. If irrigation had been an integral part of the agricultural repertoire of the POC speakers, it would be surprising that not a single term related to this complex technology could be lexically reconstructed.

Second, there is some evidence within Polynesia itself for two geographic sets of terms: one in the Fiji–western Polynesian region and one in eastern Polynesia. Because we reject the putative PCP *\*pusi* reconstruction, there is no evidence for a lexical domain related to irrigation or wet taro cultivation in PCP or its descendant stage of PPN. Only after the breakup of PPN do we have evidence for the innovation of terms for ‘pondfield’ or ‘wet taro field’, a possible Proto-Samoic-Outlier term *\*fusi* in the western Polynesian region, and a Proto-Marquesic term *\*roki* in eastern Polynesia. Such a pattern is consonant with a hypothesis of the independent innovation or development of complex pondfield irrigation or raised-bed cultivation in these two regions. We believe this also fits well with the archaeological evidence reviewed earlier.

In sum, the linguistic evidence from Oceania cannot support the diffusionist model of pondfield irrigation or complex raised-bed cultivation of taro being a technological transfer out of Southeast Asia by the Austronesian-speaking peoples. Rather, the evidence is strongly suggestive of several centers of independent development of such agronomic technology, in several parts of Melanesia, in the Fiji–western Polynesian region, and in eastern Polynesia.

#### CONCLUSIONS

The congruence between the two independent lines of evidence that we have considered—archaeological remains of irrigation structures and historical linguistic reconstructions of irrigation/water control terminology—is quite remarkable. Neither body of evidence lends support to the first of the alternative models for the origins of Polynesian irrigation technology, that of a direct transfer or diffusion from Southeast Asia via the migrations of Austronesian-speaking peoples. Rather, all of the evidence suggests that there have been multiple local sequences of innovation and development of complex irrigation or swamp drainage technology, or both, for *Colocasia* taro cultivation within eastern Melanesia and Polynesia. Within Polynesia itself, separate developments of complex pondfield irrigation can be posited for the Fiji–western Polynesian region and for eastern Polynesia.

Although the complex forms of irrigation and swamp cultivation witnessed in

TABLE 3. MELANESIAN IRRIGATION TERMS

LANGUAGE	PONDFIELD	IRRIGATION CANAL	SLUICE	EXTERNAL EMBANKMENT	WATER INLET	IRRIGATION SYSTEM
New Caledonia						
Ajie	<i>nejawa</i>	<i>weduru</i>	<i>vavo</i>	<i>rhë</i>	<i>weoxè</i>	
Arhâ	<i>newe xè</i>	<i>pu wi</i>	<i>boara i de</i>	<i>kora xiri</i>	<i>mesa i de</i>	
Boewe	<i>boerhawere</i>	<i>newâ rhuru</i>	<i>pepu rhã ne</i>	<i>boewesai i negawa</i>	<i>weoxë</i>	
Sirhë	<i>abarhi</i>	<i>xuruñi ne rhë</i>	<i>ajamuru</i>	<i>aso axi</i>	<i>ajone rhë</i>	
Ciri	<i>ni'nëu</i>	<i>o'nëu</i>	<i>rhoxoro</i>	<i>rho n'ëu</i>	<i>fo'nëu</i>	
Pinje	<i>gala</i>	<i>pue we</i>	<i>padi we</i>	<i>degala</i>		
Wamoang	<i>boala</i>	<i>danoë</i>	<i>moa we</i>	<i>dici boala</i>	<i>xapethewe</i>	
Ñua	<i>boala</i>	<i>de we</i>	<i>tô we</i>	<i>didì</i>	<i>we tobo</i>	
Poapoâ	<i>t'amen g<sup>w</sup>ala</i>	<i>danewe</i>	<i>moa we</i>	<i>detin g<sup>w</sup>ala</i>	<i>kapetaboim</i>	
'Moaekè	<i>boale</i>	<i>boa fuki we</i>	<i>vani we</i>	<i>di'i boale</i>		
Aneityum	<i>nacynitei</i>	<i>neucsinwai</i>		<i>nathat</i>		<i>incauwai</i>
Maewo	<i>mata</i>			<i>vonda</i>		
Kolombangara	<i>lologha</i>	<i>matagana</i>		<i>hara</i>		<i>ovulologha</i>

Sources: New Caledonia: Leenhardt 1946, Moysè-Fauric and Néchéro-Jorédié 1986, Rivierre 1983; Aneityum: Spriggs 1981; Maewo: Bonnemaïson 1974; Kolombangara: Yen field notes, 1971.

the ethnographic record appear to have resulted from several independent developmental trajectories, it is still reasonable to suppose that these systems were founded upon a base of common agronomic knowledge or lore that can be traced back to the early Proto-Oceanic-speaking peoples of the southwestern Pacific. We draw attention here to Yen's important remark regarding the transport of agricultural systems:

Subsistence systems may be seldom transported in toto, and cultural methods [e.g., irrigation technology] may or may not be transferable without immediate modification; however, *the concepts that underlie method are a part of the cultural armoury transferred*. Such basic ideas as that taro requires a wet edaphic medium and yam requires a dry are as permanent as the species occupying roles in subsistence plant patterns. They remain a part of what has been variously described as the underlying lore or the ethnoscientific basis of so-called primitive agricultures (1973:70, emphasis added).

We will go farther and suggest that the Proto-Oceanic speakers not only understood the edaphic and hydrologic templates of *Colocasia* quite intimately, but that they were accustomed to using—and even manipulating in subtle ways—naturally hydromorphic terrain for taro culture. Golson's important work at the Kuk site demonstrates that simple ditching and mounding techniques for the modification of swampy ground were well established at least in parts of New Guinea by the time of the Lapita expansion. The Lapita people, who were the founding colonists of eastern Melanesia and Polynesia, exhibited a highly characteristic settlement pattern of siting their villages on beach ridges or terraces. From both geomorphological and agronomic perspectives, such settlements were situated in key *interfacial* environments, lying between the accretionary coastal terraces and beach ridges, and the steeper volcanic ridges and hillslopes that were a primary source of sediment deposited in valley bottoms. Although the proximity of Lapita sites to reef and lagoon resources has often been stressed (e.g., Green 1979), equal or greater attention appears to have been given to proximity to arable land and fresh water, as Lepofsky's catchment analysis of 28 Lapita sites revealed (Lepofsky 1988). Kirch and Yen (1982:17–18) pointed to the agronomic significance of such coastal interfacial environments based on the Tikopian archaeological record, which commences with Lapita colonization c. 900 B.C. The naturally swampy terrain often found immediately inland of or adjacent to beach ridges would have provided precisely the sorts of microenvironments suited to minor drainage and mounding modifications for *Colocasia esculenta* (and *Cyrtosperma chamissonis*) cultivation. We suggest that it was this kind of relatively simple (in a landscape modification sense) water control and edaphic manipulation that was an integral part of the early Oceanic horticultural set, and which was carried by the colonizing groups into eastern Melanesia and Polynesia. Only later in the prehistoric sequences of particular island groups, and in response to a variety of stimuli and pressures (including population growth and political competition), was this underlying knowledge of taro's hydrophytic template applied in the development of more complex irrigation technologies.

We have tested two alternative hypotheses regarding Polynesian irrigation, only to end by advancing another hypothesis of our own: the putative use of naturally hydromorphic coastal microenvironments by the Lapita people. This is a hypothesis that has yet to be subjected to direct archaeological testing. The archaeological signatures of aroid cultivation<sup>10</sup> in such naturally swampy terrain lying inland of



Lapita beach-ridge settlements are likely to be subtle and will require the application of sensitive field techniques. We urge field archaeologists investigating Lapita and other early Oceanic sites to include likely geomorphic environments in the vicinity of such sites within the purview of their research designs. Detailed stratigraphic coring of such interfacial swampy zones, combined with geochemical and pollen analyses, may permit us to determine whether wet-land aroid cultivation was a significant or regular part of the subsistence base of these early Pacific colonists. We hope that this paper may stimulate such research in the near future.

#### ACKNOWLEDGMENTS

We are grateful to Jane Allen for her critical comments on an early draft of this paper and for sharing with us the results of recent and as yet unpublished data on prehistoric Hawaiian irrigation systems. Michael Graves and an anonymous reviewer also made useful suggestions.

#### NOTES

1. We respectfully dedicate this paper to Douglas E. Yen on the occasion of his receiving the Distinguished Economic Botanist Award of the Society for Economic Botany. The senior author, especially, thanks Doug for his stimulating and enjoyable collegiality over more than two decades.
2. In later writings, Barrau seems to have modified his position. In a 1972 paper, for example, he suggested that irrigated terraces in the Indo-Oceanic humid tropics may have first developed for wet taro cultivation, with rice originating as weeds in the taro fields: "le transfert du taro *Colocasia* hors de la forêt humide tropicale conduit—il sans doute à la mise au point de terrasses irriguées. Ces dernières, en Indo-Océanie, servirent plus tard à la culture de riz, l'*Oryza sativa* L., descendance domestiquée de mauvaises herbes des jardins humide à taro" (1972:309).
3. Direct archaeological evidence for the initial stages of Mangaian prehistory has not as yet been discovered, but charcoal particle and pollen analyses of sediment cores from Veitatei and Tamarua valleys both indicate initial anthropogenic vegetation modifications by about 2500 B.P. (Ellison in press).
4. A point, however, that depends very much on one's concept of "evolution," a matter Yen and P. V. K. have been fond of arguing over for some years!
5. French-Wright made a single reference to terms for irrigation, as follows: "Low level reconstructions such as PCP \**pusi* "taro swamp" and PNM \**pwel(a)* "taro patch, taro swamp" were noted, but the glosses do not make clear whether or not the taro referred to was tended in any way or whether it was wild" (1983:72). We will deal with these putative PCP and PNM reconstructions below.
6. The suffix *-ga* in the East Futunan case is a place indicator.
7. Buck (1930:547) gave the term *loiloi* for 'wet planting in swampy lands', and the term *fuinu'u* for plots divided by 'cut drains and pathways'. However, Buck's terms are not confirmed by the primary Samoan dictionary sources (Neffgen 1918; Pratt 1862). Indeed, Pratt provided a gloss of 'to dip in a sauce' for *loiloi* and did not list *fuinu'u*. Both Pratt and Neffgen gave *fusi* for 'swamp cultivation'. Although Buck's term *loiloi* initially intrigued us as a possible cognate reflex of Hawaiian *lo'i* and Rapan *roki*, the absence of the glottal was apparently intentional on Buck's part, and the terms therefore cannot be cognate. Furthermore, Pratt gave Samoan *lo'i* as 'a shed built to the side of the house, or a pig sty'. Because Buck's *loiloi* cannot be confirmed and, in any event, clearly cannot be cognate to the Hawaiian or Rapan terms, we have omitted it from Table 2.
8. East Futunan and Samoan are clearly Samoic-Outlier languages (Pawley 1967), but East 'Uvean is a Samoic-Outlier language that has been heavily modified through extensive borrowing from Tongan in relatively recent times.
9. It is also conceivable that this semantic extension occurred independently in both Rapan and Hawaiian, which would invalidate the hypothesis of a Proto-Marquesic term \**roki* meaning 'wet taro field'.
10. We purposefully use the more general term "aroid" here, because early forms of swamp cultivation in Melanesia or western Polynesia may have included the large "swamp taro" species *Cyrtosperma chamissonis*, as well as *Colocasia esculenta*. Indeed, carbonized remains of *Cyrtosperma* have recently been identified from the basal zones of the Tangatatau rockshelter site on Mangaia Island in the southern Cooks (Jon Hather, pers. comm., 1992).

*chamissonis*, as well as *Colocasia esculenta*. Indeed, carbonized remains of *Cyrtosperma* have recently been identified from the basal zones of the Tangatatau rockshelter site on Mangaia Island in the southern Cooks (Jon Hather, pers. comm., 1992).

## REFERENCES

- AITKEN, R.  
1930 *Ethnology of Tubuai*. B. P. Bishop Museum Bulletin 70.
- ALLEN, B.  
1971 Wet-field taro terraces on Mangaia, Cook Islands. *Journal of the Polynesian Society* 80:371–378.
- ALLEN, J.  
1987 *Five Upland 'Ili: Archaeological and Historical Investigations in the Kane'ohē Interchange, Interstate Highway H-3, Island of O'ahu*. Department of Anthropology Report 87-1. Honolulu: Bishop Museum.  
1991 The role of agriculture in the evolution of the pre-contact Hawaiian state. *Asian Perspectives* 30:117–132.  
in press Farming in Hawai'i from colonisation to contact: Radiocarbon chronology and implications for cultural change. *New Zealand Journal of Archaeology* 14.
- ANDREWS, L.  
1922 *A Dictionary of the Hawaiian Language*. B. P. Bishop Museum Special Publication 8. Honolulu: Bishop Museum.
- ATHENS, J. S.  
1983 Prehistoric pondfield agriculture in Hawai'i: Archaeological investigations at the Hanalei National Wildlife Refuge, Kaua'i. Typescript report in Department of Anthropology, Bernice P. Bishop Museum, Honolulu.
- BARRAU, J.  
1956 *L'Agriculture Vivrière Autochtone de la Nouvelle-Calédonie*. Noumea: Commission du Pacifique Sud.  
1961 *Subsistence Agriculture in Polynesia and Micronesia*. B. P. Bishop Museum Bulletin 219.  
1963 Introduction, in *Plants and the Migrations of Pacific Peoples: A Symposium*: 1–6, ed. J. Barrau. Honolulu: Bishop Museum Press.  
1972 Origines de l'agriculture, domestication des végétaux et milieux contrastés, in *Langues et Technique Nature et Sociétés*, vol. 2:305–310, ed. J. M. C. Thomas and L. Bernot. Paris.
- BATTAILLON, MGR.  
1932 *Langue d'Uvea (Wallis)*. Paris: Librairie Orientaliste Paul Geuthner.
- BAYLISS-SMITH, T., AND J. GOLSON  
1992 A Colocasian revolution in the New Guinea Highlands? Insights from Phase 4 at Kuk. *Archaeology in Oceania* 27:1–21.
- BEAGLEHOLE, J. C., ED.  
1969 *The Journals of Captain James Cook on his Voyages of Discovery: The Voyage of the Resolution and Adventure, 1772–1775*. Hakluyt Society Extra Series No. XXXV. Cambridge: Cambridge University Press.
- BELLWOOD, P.  
1972 *Settlement Pattern Survey, Hanatekua Valley, Hiva Oa, Marquesas Islands*. Pacific Anthropological Records 17. Honolulu: Bishop Museum.
- BONNEMAISON, J.  
1974 Espaces et paysages agraires dans le nord des Nouvelles-Hébrides. *Journal de la Société des Océanistes* 44:163–232.
- BREEMAN, N. VAN, L. R. OLDEMAN, W. J. PLANTINGA, AND W. G. WIELMAKER  
1970 The Ifugao rice terraces, in *Aspects of Rice Growing in Asia and the Americas*: 38–73, ed. N. van Breeman. Wageningen: H. Veenman and Sons.
- BROOKFIELD, H. C., WITH D. HART  
1971 *Melanesia: A Geographical Interpretation of an Island World*. London: Methuen.

- BUCK, P. H. (TE RANGI HIROA)  
 1930 *Samoa Material Culture*. B. P. Bishop Museum Bulletin 75.  
 1934 *Mangaian Society*. B. P. Bishop Museum Bulletin 122.  
 1938 *Ethnology of Mangareva*. B. P. Bishop Museum Bulletin 157.  
 1944 *Arts and Crafts of the Cook Islands*. B. P. Bishop Museum Bulletin 179.
- BURROWS, E. G.  
 1936 *Ethnology of Futuna*. B. P. Bishop Museum Bulletin 138.  
 1937 *Ethnology of Uvea (Wallis Is.)*. B. P. Bishop Museum Bulletin 145.
- CAPELL, A.  
 1973 *A New Fijian Dictionary*. Sydney: Australasian Medical Publishing Co. Ltd.
- CHOWNING, A.  
 1963 Proto-Melanesian plant names, in *Plants and the Migrations of Pacific Peoples: A Symposium*: 39-44, ed. J. Barrau. Honolulu: Bishop Museum Press.
- CONKLIN, H. C.  
 1967 Some aspects of ethnographic research in Ifugao. *Transactions of the New York Academy of Sciences, Series II*, 30:99-121.
- COULTER, J. W.  
 1941 *Land Utilization in American Samoa*. B. P. Bishop Museum Bulletin 170.
- DAMM, H.  
 1951 Methoden der Feldbewässerung in Ozeanien, in *South Seas Studies in Memory of Felix Speiser*: 204-234. Basel: Museum für Volker-Kunde.
- DICKS, A. M., A. E. HAUN, AND P. H. ROSENDAHL  
 1987 Archaeological reconnaissance survey for environmental impact statement, West Loch Estates golf course and parks, land of Honouliuli, Ewa District, Island of Oahu. Ms. on file, Hawaii State Historic Preservation Division, Honolulu.
- DI PIAZZA, A.  
 1990 Les jardins enfouis de Futuna: une ethno-archéologie de l'horticulture. *Journal de la Société des Océanistes* 91:151-162.
- EARLE, T.  
 1978 *Economic and Social Organization of a Complex Chiefdom: The Halelea District, Kaua'i, Hawaii*. Anthropological Papers 63. Ann Arbor: Museum of Anthropology, University of Michigan.  
 1980 Prehistoric irrigation in the Hawaiian Islands: An evaluation of evolutionary significance. *Archaeology and Physical Anthropology in Oceania* 15:1-28.
- ELLISON, J. C.  
 in press Paleo-lake and swamp stratigraphic records of Holocene vegetation and sea-level changes, Mangaia, Cook Islands. *Pacific Science*.
- FARRELL, B. H., AND R. G. WARD  
 1962 The village and its agriculture, in *Western Samoa: 177-238*, ed. J. W. Fox and K. B. Cumberland. Christchurch: Whitcombe and Tombs.
- FORSTER, J. G. A.  
 1777 *A Voyage Round the World in his Britannic Majesty's Sloop, Resolution . . . During the Years 1772, 3, 4, and 5*, 2 vols. London: White, Robson.
- FORSTER, J. R.  
 1778 *Observations Made During a Voyage Round the World*. London: Robinson.
- FRENCH-WRIGHT, R.  
 1983 Proto-Oceanic Horticultural Practices. Unpublished M.A. thesis. University of Auckland, New Zealand.
- FRIMIGACCI, D.  
 1990 *Aux Temps de la Terre Noire: Ethno-Archéologie des Îles Futuna et Alofi*. Langues et Cultures du Pacifique 7. Paris: Peeters.
- FRIMIGACCI, D., A. DI PIAZZA, C. SAND, B. VIENNE, AND J.-P. SIORAT  
 1988 *Etude Ethno-Archéologique et Ethnobotanique de l'Île de Futuna*. Rapports d'Activité, Sciences Sociales, Archéologie, 1. Noumea: ORSTOM.

- GOLSON, J.  
1977 No room at the top: Agricultural intensification in the New Guinea highlands, in *Sunda and Sahul*: 601–638, ed. J. Allen, J. Golson, and R. Jones. New York: Academic Press.
- GREEN, R. C.  
1966 Linguistic subgrouping within Polynesia: The implications for prehistoric settlement. *Journal of the Polynesian Society* 75:6–38.  
1979 Lapita, in *The Prehistory of Polynesia*: 27–60, ed. J. Jennings. Cambridge: Harvard University Press.
- GREEN, R. C. AND C. DESCANTES  
1989 *Site Records of the 'Opunohu Valley, Mo'orea*. Limited edition funded by The Green Foundation for Polynesian Research. Auckland.
- GRÉZEL, LE R. P.  
1878 *Dictionnaire Futunien-Français avec Notes Grammaticales*. Paris: Maisonneuve et Cie.
- HANDY, E. S. C.  
1923 *Native Culture in the Marquesas*. B. P. Bishop Museum Bulletin 9.  
1930 *History and Culture in the Society Islands*. B. P. Bishop Museum Bulletin 79.
- HOCART, A. M.  
1929 *Lau Islands, Fiji*. B. P. Bishop Museum Bulletin 62.
- HOMMON, R. J.  
1986 Social evolution in ancient Hawai'i, in *Island Societies: Archaeological Approaches to Evolution and Transformation*: 55–68, ed. P. V. Kirch. Cambridge: Cambridge University Press.
- ISHIZUKI, K.  
1974 Excavation of site Fu-Fo-1 at Folas-a-lalo, in *Archaeology in Western Samoa*, vol. II: 36–57, ed. R. C. Green and J. Davidson. Auckland Institute and Museum Bulletin 7.
- KAEPPLER, A.  
1978 Exchange patterns in goods and spouses: Fiji, Tonga, and Samoa. *Mankind* 11:246–252.
- KELLUM-OTTINO, M.  
1971 *Archéologie d'une Vallée des Îles Marquesas*. Publications de la Société des Océanistes 26. Paris.
- KIRCH, P. V.  
1975 *Cultural Adaptation and Ecology in Western Polynesia: An Ethnoarchaeological Study*. Ph.D. diss. Yale University, New Haven. Ann Arbor: University Microfilms.  
1976 Ethnoarchaeological investigations in Futuna and Uvea (Western Polynesia): A preliminary report. *Journal of the Polynesian Society* 85:27–69.  
1977 Valley agricultural systems in prehistoric Hawaii: An archaeological consideration. *Asian Perspectives* 20:246–280.  
1978 Indigenous agriculture on 'Uvea (Western Polynesia). *Economic Botany* 32:157–181.  
1981 Lapitoid settlements of Futuna and Alofi, Western Polynesia. *Archaeology in Oceania* 16:127–143.  
1984 *The Evolution of the Polynesian Chiefdoms*. Cambridge: Cambridge University Press.  
1985 *Feathered Gods and Fishhooks: An Introduction to Hawaiian Archaeology and Prehistory*. Honolulu: University of Hawaii Press.  
1990 The evolution of socio-political complexity in prehistoric Hawaii: An assessment of the archaeological evidence. *Journal of World Prehistory* 4:311–345.  
1991 Polynesian agricultural systems, in *Islands, Plants, and Polynesians: an Introduction to Polynesian Ethnobotany*: 113–133, ed. P. A. Cox and S. Banack. Portland: Dioscorides Press.  
in press *The Wet and the Dry: Irrigation and Agricultural Intensification in Polynesia*. Chicago: University of Chicago Press.
- KIRCH, P. V., J. FLENLEY, AND D. W. STEADMAN  
1991 A radiocarbon chronology for human-induced environmental change on Mangaia, southern Cook Islands, Polynesia. *Radiocarbon* 33:317–328.
- KIRCH, P. V., J. FLENLEY, D. W. STEADMAN, F. LAMONT, AND S. DAWSON  
1992 Ancient environmental degradation: Prehistoric human impacts on an island ecosystem, Mangaia, Central Polynesia. *Research and Exploration* 8:166–179.

- KIRCH, P. V. AND M. D. SAHLINS  
1992 *Anahulu: The Anthropology of History in the Kingdom of Hawaii*, 2 vols. Chicago: University of Chicago Press.
- KIRCH, P. V. AND D. E. YEN  
1982 *Tikopia: The Prehistory and Ecology of a Polynesian Outlier*. B. P. Bishop Museum Bulletin 238.
- LEENHARDT, M.  
1946 *Langues et Dialectes de l'Austro-Mélanésie*. Travaux et Mémoires de l'Institut d'Ethnologie XLVI. Paris: Université de Paris.
- LEPOFSKY, D.  
1988 The environmental context of Lapita settlement locations, in *Archaeology of the Lapita Cultural Complex: A Critical Review*: 33–48, ed. P. V. Kirch and T. L. Hunt. Burke Museum Research Report 5. Seattle.  
in prep. Prehistoric Agriculture in the Society Islands. Ph.D. diss. University of California, Berkeley.
- MOSBLECH, B., ED.  
1843 *Vocabulaire Océanique-Français et Français-Océanien des Dialectes Parlés aux Îles Marquises, Sandwich, Gambier, etc.* Paris: Renouard.
- MOYSE-FAURIE, C., AND M.-A. NÉCHÉRO-JORADIÉ  
1986 *Dictionnaire Xârâcùò-Français (Nouvelle-Calédonie)*. EDIPOP. Paris: Les Editions Populaires.
- NEFFGEN, H.  
1918 *Grammar and Vocabulary of the Samoan Language*, trans. by A. B. Stock. London: Trubner.
- OTTINO, P.  
1985 *Archéologie des Îles Marquises: Contribution à la Connaissance de l'Île de Ua Pou*. Thèse de 3ème Cycle, Université de Paris 1, Panthéon-Sorbonne. Paris.
- PANOFF, M.  
1970 *La Terre et l'Organisation Sociale en Polynésie*. Paris: Payot.
- PAWLEY, A.  
1967 The relationships of the Polynesian Outlier languages. *Journal of the Polynesian Society* 76:259–296.
- PRATT, G.  
1862 *Grammar and Dictionary of the Samoan Language*. Malua (Samoa): London Missionary Society.
- PUKUI, M. K., AND S. H. ELBERT  
1965 *Hawaiian-English Dictionary*, 3rd ed. Honolulu: University of Hawaii Press.
- RENSCH, K. H.  
1991 Polynesian plant names: Linguistic analysis and ethnobotany, expectations and limitations, in *Islands, Plants, and Polynesians: An Introduction to Polynesian Ethnobotany*: 97–112, ed. P. A. Cox and S. Banack. Portland: Dioscorides Press.
- RILEY, T. J.  
1975 Survey and excavation of the aboriginal agricultural system, in *Prehistory and Human Ecology in a Windward Hawaiian Valley: Halawa Valley, Moloka'i*: 79–115, ed. P. V. Kirch and Marion Kelly. Pacific Anthropological Records 24. Honolulu: Bishop Museum.
- RIVIERRE, J.-C.  
1983 *Dictionnaire Paicî-Français Suivi d'un Lexique Français-Paicî*. Langues et Cultures du Pacifique 4. Paris: Société d'Etudes Linguistiques et Anthropologiques de France.
- SAHLINS, M. D.  
1962 *Moala: Culture and Nature on a Fijian Island*. Ann Arbor: University of Michigan Press.
- SCHILT, A.  
1980 Archaeological investigations in specified areas of the Hanalei Wildlife Refuge, Hanalei Valley, Kaua'i. Typescript report in Department of Anthropology, Bernice P. Bishop Museum, Honolulu.
- SPENCER, J. E., AND G. A. HALE  
1961 The origin, nature, and distribution of agricultural terracing. *Pacific Viewpoint* 2:1–40.
- SPRIGGS, M. J. T.  
1981 Vegetable Kingdoms: Taro Irrigation and Pacific Prehistory, Ph.D. diss. Australian Nation-

al University, Canberra.

- 1982a Irrigation in Melanesia: Formative adaptation and intensification, in *Melanesia: Beyond Diversity*, vol. I: 309–324, ed. R. J. May and H. Nelson. Canberra: Australian National University.
- 1982b Taro cropping systems in the Southeast Asian–Pacific region. *Archaeology in Oceania* 17:7–15.
- 1986 Landscape, land use and political transformation in southern Melanesia, in *Island Societies: Archaeological Approaches to Evolution and Transformation*: 10–19, ed. P. V. Kirch. Cambridge: Cambridge University Press.
- 1990 Why irrigation matters in Pacific prehistory, in *Pacific Production Systems*: 174–189, ed. D. E. Yen and J.M.J. Mummery. Occasional Papers in Prehistory 18. Canberra: Department of Prehistory, Australian National University.
- STOKES, J. F. G.  
[1930] Ethnology of Rapa, 5 vol. Manuscript in Library, Bernice P. Bishop Museum, Honolulu.
- TUGGLE, H. D., AND M. J. TOMONARI-TUGGLE  
1980 Prehistoric agriculture in Kohala, Hawaii. *Journal of Field Archaeology* 7:297–312.
- VERIN, P.  
1969 L'Antienne Civilisation de Rurutu. *Mémoires ORSTOM* 33. Paris.
- WATANABE, F. K.  
1986 Archaeological site survey and subsurface testing for the FY89 Chapel Center Facility and Daycare Center, Fort Shafter. Ms on file, U.S. Army Corps of Engineers, Ft. Shafter, Honolulu.
- YEN, D. E.  
1973 The origins of Oceanic agriculture. *Archaeology and Physical Anthropology in Oceania* 8:68–85.
- 1990 Environment, agriculture, and the colonisation of the Pacific, in *Pacific Production Systems*: 258–277, ed. D. E. Yen and J. M. J. Mummery. Occasional Papers in Prehistory 18. Canberra: Australian National University.
- 1991 Polynesian cultigens and cultivars: The questions of origin, in *Islands, Plants, and Polynesians: An Introduction to Polynesian Ethnobotany*: 67–96, ed. P. A. Cox and S. Banack. Portland: Dioscorides Press.
- YEN, D. E., P. V. KIRCH, P. ROSENDAHL, AND T. J. RILEY  
1972 Prehistoric agriculture in the upper Makaha Valley, O'ahu, in *Makaha Valley Historical Project: Interim Report No. 3*: 59–94, ed. D. E. Yen and E. Ladd. Pacific Anthropological Records 18. Honolulu: B. P. Bishop Museum.

#### ABSTRACT

Most tropical and subtropical Polynesian high islands exhibit landscape modifications such as terracing or ditching, or both, resulting from prehistoric irrigation of taro (*Colocasia esculenta*). Because of the technological and hydraulic similarities between such Polynesian taro irrigation and Southeast Asian rice irrigation, some prehistorians have traced Polynesian irrigation practices back to a Proto-Austronesian homeland region in Southeast Asia. Other scholars have advocated an independent development of pondfield irrigation in the Pacific Islands. In this paper we draw upon two independent lines of evidence to test these alternative hypotheses. Chronologically controlled archaeological evidence for irrigation indicates a relatively late development of irrigation works in those Islands investigated thus far. This evidence is corroborated by systematic comparison of the lexical terms associated with irrigation among speakers of Oceanic languages. The linguistic analysis yields no evidence for an early terminological set associated with pondfield agriculture, but distinct sets of western and eastern Polynesian cognate reflexes indicate independent development of irrigation in those regions. KEYWORDS: Oceania, Polynesia, prehistoric agriculture, irrigation, taro.