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Taro Irrigation and Primary State Formation in Hawai‘i

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World archaeology seeks to understand the origins of complex polities by looking comparatively at examples of the independent trajectories for development. This paper argues that the Hawaiian Islands represent a separate case for primary state formation, and so provide a critical case for state origins. Most importantly the Islands lack several recurring themes in state origins elsewhere, namely cereal agriculture, world-systems trade, markets, and urbanism. The root crop taro, like cereals, can provide the productivity needed to produce the surplus that supported state-like institutions, and the engineered landscapes of irrigation and intensive dryland farming provided the necessary control through the property system. Our search for particular factors allowing for state emergence should be reconfigured to evaluate the dynamic processes involved. I emphasize the political economy, its productivity, and its ability to be controlled at specific bottlenecks, represented here by irrigation.

1. INTRODUCTION

World archaeology tries to understand the origins of truly complex polities. Primary state formation is thought to have taken place independently in several world regions. The list of these pristine states typically includes Mesopotamia, Egypt, the Indus, China, Mesoamerica, and the Andes, although the autonomy of the Old World cases can be questioned because of trade, personal travels, and likely political relationships (Kristiansen and Larsson 2005). The subsistence economies of all these early states were based on intensive cereal cultivation, sufficiently productive to create the surplus needed to support complex institutions of governance, religion, and social stratification. Researchers studying primary state formation have focused on craft specialization (Childe 1951), irrigation (Wittfogel 1957), markets (Sanders and Price 1968), warfare (Carneiro 1970), and information processing (Wright and Johnson 1975) among other factors. Secondary states were linked directly or indirectly to primary states, which provided opportunities for local elites to amass wealth and power (Price 1978; Parkinson and Galaty 2007).

Discussions of state origins have waxed and waned, but there is now a consensus that primary states arose independently in different regions, under diverse circumstances and for diverse reasons (Wright 1977). Although the evolution of states was undoubtedly a complex, multivariate process, I believe that the driving force for both primary and secondary state formation was the same, the ability of emerging elites to control a political economy to mobilize surplus to finance institutional systems of control (Earle 1997, 2002). Although

many factors were involved in state formation, the minimum requirement for complex institutions must have been the ability to support them materially. Complex societies were not simply imagined; they involved the organization of human action that required the mobilization of substantial surplus. My focus is on common processes of the political economy that mobilized and distributed surplus to support the emergence and operation of chiefdoms and eventually states.

To understand the nature of political complexity requires a description of the currencies, channels, and conversions in the flows of goods used in finance and particularly a description of the bottlenecks whereby flows of currencies were interdicted and mobilized to support and institutionalize political power. The currencies of finance in chiefdoms and states were valuable foods including cereal staples and domestic animals, or alternatively objects of wealth such as metal display items, weapons, and money. The political economy of most pristine chiefdoms and primary states, however, relied heavily on staple finance, by which elites mobilized subsistence goods from commoners by asserting ownership over agricultural land (D'Altroy and Earle 1986). States can be seen as emerging out of chiefdoms along multiple parallel paths, each made possible by particular characteristics of the political economy (Johnson and Earle 2000; Earle 1991, 1997). The Hawaiian Islands late in prehistory provide an excellent example of how Polynesian chiefly organizations established state institutions by controlling staple finance reliant on root-crop agriculture. The mobilization of staples was then linked to wealth finance by incorporating the mobilization of specific materials (like feathers) for special items and by using staples to support craft specialists attached to the ruling elites (Earle 1987; Kirch 2010).

Unfortunately ignored in the general discussions of primary state origins, Hawai'i illustrates a rather distinctive pathway to state formation based on surplus from root crops rather than cereal grains. It also shows how population distribution in a state can be decidedly dispersed (non-urban) in its character. Here a highly intensified, engineered landscape using irrigation provided the surplus to support the emergence of pristine states. Hawai'i is a critical example of primary state formation that helps specify the dynamic interplay between institutional elaboration and an underlying political economy based on intensive, root-crop agriculture.

Before we proceed, I should discuss Yoffee's (1993) thoughtful and influential paper "Too many chiefs?" His work is well known to Pacific prehistorians and so I only summarize a few of his most important points. He joins a group that rightly criticizes the early reliance on typology to understand social evolution. In their undergraduate texts, both Service (1962) and Fried (1967) developed stair-step models for social evolution based on an earlier tradition of ideal types derived from historical and ethnographic examples. Yoffee argues that such schemes are totally inadequate. Focusing on variation in institutional forms, he and other processual archaeologists quite generally emphasize the variable pathways to and away from central power. He also points to a changed direction in evolutionary approaches to complexity that came to focus on chiefdoms and states as political organizations with increasingly institutional, central structure. Chiefdoms and states were highly variable according to the characteristics of: origin (pristine vs. secondary), institutional structure (networked vs. corporate; hegemonic vs. territorial), finance (staple vs. wealth), economy (degrees of commerciali-

zation), and certainly military strategies and religions as well. He implies that pristine state origins were somehow separate from the lines that created the ethnographic signatures of diverse chiefdoms.

Yoffee appears to have got himself caught in the same mousetrap of typology that he criticized so effectively. This paper may help liberate him from the snare. The solution to his problem may be to focus on the *processes* of chiefdoms and states as essentially political, based on developing political economies. By looking at the root-crop-based political economy of the Hawaiian Islands, I hope to demonstrate that the emergence of their exceptional complexity exemplifies how the 'classic' Polynesian chiefdoms could develop into pristine states, without external influences.

The development of social stratification across Polynesia and its climax in state formation in Hawai'i provide a critical new case for primary state formation. In his doctoral dissertation, Rob Hommon (1976, 1986) argued that by AD 1600 the Hawaiian chiefdoms developed a state political structure. Kirch presents the convincing case that "with the development of class stratification, land alienation from commoners and a territorial systems of administrative control, a monopoly of force and endemic conquest warfare, and, most importantly divine kingship legitimated by state cults with a formal priesthood (including human sacrifice), [Hawai'i] should be regarded as a set of archaic states at time of first contact with the West" (2010: 27). The paramount lords of the largest islands were backed increasingly by force of arms, expanding areas of control by conquest. Governance was institutionalized not on kinship, but on territorial divisions ruled by hierarchies of political and religious officers designated by the paramount. Hommon (1986) pointed to the importance of the local, *ahupua'a* community, a specially marked land area in which kinship of commoners was truncated and rule established by an overlord, who received the estate from the ruling paramount. This territorial (as opposed to kinship) base of power is often thought of as distinguishing states. Kirch (2010) emphasizes the divine kingship as a special example of ideological power typically associated with states. The high lords were considered gods on earth, dressed with feather cloak and helmet rich in symbols of divine presence (Earle 1987). Although previously I considered Hawaiian polities as complex chiefdoms, the classification itself has little meaning, because the development of primary states out of chiefdoms was continuous and highly varied, and I believe that typological borders hamper our ability to look at the responsible processes (Earle 1978). Polynesian chiefdoms contained the key processes of state formation, constrained only by the physical limits of islands.

Prior to conquest, paramount rulers or kings of the two largest islands of Hawai'i were locked in wars of inter-island conquest. With the rapid adoption of European military technology, especially the big European sailing ships, King Kamehameha was able to conquer most of the islands to form the Hawaiian state (Saxe 1978), but had the complex chiefdoms of Hawai'i become small states prior to European conquest? Along with Hommon (1976) and Kirch (2010), I now believe that Hawaiian chiefs did indeed transform themselves into kings late in prehistory; certainly these polities would be called states if, for example, they had existed in Medieval Europe. The question that I address here is the necessary condition for the formation of pristine Hawaiian states: how was newly instituted complexity financed?

Polynesian prehistory presents a laboratory for social evolution, because of high degrees

of isolation among the main island groups that resulted in fairly independent developments on each major island group (Sahlins 1958; Kirch 2007). Hawai'i should become central to discussions of state development, because it contradicts the belief that cereal cultivation and urbanization were essential to state formation. From each main island of the chain, paramounts, newly formulated as kings, mobilized surpluses that were reinvested in the three main sources of power (economic, military, and ideological) to develop the institutions of states. Manipulating the positive feedback charter of a political economy, they expanded and institutionalized their power. How was this possible? I focus on the extensive and highly productive irrigation systems and the linked developments of engineered landscapes. Because of its isolation, the Hawaiian case allows us to focus on exactly why irrigation was so important in the dramatic development of social complexity. Irrigation itself was not the critical factor, but irrigation along with other forms of engineered landscapes (fishponds and dryland complexes) provided controllable productive facilities over which the new kings could assert ownership, the key bottleneck in a political economy.

2. ENGINEERED LANDSCAPES IN PRIMARY STATE FORMATION

A compelling lesson from archaeology is that humans have extensively modified their environments (Earle and Doyle 2008). All environments are more or less 'landscaped' and the extent of this landscaping has increased dramatically across human history. Ten thousand years ago, much of the world was heavily forested. Since adopting agriculture and even in some non-agricultural societies, humans have purposefully transformed the land to increase its productivity and use for economic and socio-political objectives. Humans have cleared forests for animals and crops, channelled rivers, terraced hills, and drained swamps. They planted trees and bushes to mark land divisions, and they constructed houses, walls, roads, and monuments. These constructed landscapes were human artefacts, over which systems of land ownership could be asserted. The creation of a built landscape had a durability that undoubtedly became linked to new systems of land tenure that offered possible bottlenecks for an emerging political economy (Earle 2002).

Brookfield describes environmental improvements as *landesque capital*, meaning that human labour manufactured special soils and built facilities like drainage ditches, terraces, and irrigation canals that substantially increase the productivity of the land (Brookfield 1984; Blaikie and Brookfield 1987; Kirch 2004, 2007). Brookfield's prime example for *landesque capital* was the intensive root-crop agriculture in Highland New Guinea. With proper maintenance, such improvements continue for generations to raise productivity of the land, and as such the improvements represented substantial fixed capital, the ownership, transfer, and inheritance of which became of social and political concern. Landscaping increased the consequence of property systems, giving rights to some against others. At the same time, marking the land with permanent facilities helped associate the land with groups or families who built them. Stone (1994) talks of the 'perimetrics' of landscapes, meaning the marking by walls, fields, plants, monuments and the like that define ownership patterns. With the emergence of the political force of a warrior elite, agricultural lands developed by farmers could be seized and held by chiefs and eventual kings. Corporate lands, so characteristic of

tribal societies, created opportunities for chiefs and lords to dominate land-tenure systems operating as a bottleneck in staple production, thus allowing mobilization of surplus. The creation of a political economy and its investment of surplus in power strategies comprised the engine for the expansion of institutional control and state formation. The creation of states may reflect the extent to which highly productive lands can be developed and ownership asserted. In my analysis, the emergence of states from chiefdoms required surpluses that could be mobilized to finance state institutions.

Landscapes have also been subjected to massive unintended consequences that create the opportunities both for agricultural development and potential disaster (Kirch 2007). Forest clearing, for example, can increase erosion, flooding, desertification, and species extinctions. Many have argued that population growth and required intensification are unsustainable, because of environmental degradation. In some situations, environmental change can actually open up unexpected opportunities. For example, the erosion induced by swidden cultivation of upland soils in the Pacific may have increased alluvial deposition in the valley bottoms, thus creating conditions ideally suited to irrigation agriculture (Spriggs 1985, 1986). The effects of long-term intensification were highly variable, and devastating environmental losses were neither inevitable nor uniform across the globe. As illustrated by Asian irrigated rice agriculture, farmers could develop specialized skills for cultivating and maintaining highly intensive agriculture (Bray 1986). In an *American Anthropologist* special section, archaeologists describe how human population growth, socio-political organization, and environmental degradation interacted to create particular landscapes (Fisher and Feinman 2005). They argue that the banking of labour as landesque capital buffered production systems against degradation, because careful maintenance of soils, terraces, embankments, and canals created the infrastructure for sustainable agriculture. Regarding the relationships between landscape and economy, we can conclude that environmental disaster and environmental stability have been to a large measure both products of human action.

An extreme example of Brookfield's landesque capital that supported state development is the *engineered landscape* of the Balinese states (Lansing 1991). Engineered landscapes were built up across generations to contain facilities, including fields, terraces, canals, dams, and reservoirs for agriculture and walls, roads, buildings, monuments, villages and eventually cities, all of which had degrees of permanent marking of the landscape on which land-tenure systems could be materialized and stabilized. They were notable in the extent and variety of change to the physical appearance and sustained productivity of the landscape. An engineered landscape has some of the characteristics of an urban world, in which many aspects are "man made" and maintained. Angkor, for example, illustrates intensive, irrigated agricultural systems, low-density urbanism, and large-scale ceremonial architecture creating the engineered landscape of a tropical state (Fletcher *et al.* 2003). Although environmental engineering was partially effective for stabilizing agricultural production, it was critical for the reliable production of surpluses, on which chiefdoms, early states and empires depended.

To measure engineering across time requires an estimation of the labour invested in the construction and modification of improved facilities. By determining the uses of the engineering, archaeologists can describe how the human goals of landscaping may have changed through time (Kolb 1997). Across generations, building on the land created a palimpsest that

met the shifting needs and expectations of its people. Importantly, such building created a 'permanency' in social order and economic access that provided the foundations for social complexity (Earle 2004).

Heavily engineered landscapes, such as the Balinese or Angkor countrysides, were topographically altered in impressive and permanent ways that changed production functions and social uses. Most important perhaps is how the creation of an engineered landscape played into the building of complex societies. Although complex societies arose for many and complicated reasons, each must have developed means to finance their newly created political institutions. Typically this finance requires the mobilization of resources that could be used to support special events and personnel associated with new ruling institutions. My thesis is that engineered landscapes, especially those with irrigation, were both highly productive *and* controllable, and were thus used to generate reliable surpluses that financed many (perhaps most) precapitalist chiefdoms and non-mercantile states. On the Hawaiian Islands, irrigated and dryland root-crop facilities and fishponds provided the intensified infrastructure, over which ownership could be asserted to mobilize the surplus to finance new state polities.

3. DOES IRRIGATION MATTER IN ITS NEED FOR CENTRAL MANAGEMENT?

Anthropologists know that human labour transforms a region's look and its productivity, and we have often discussed the organization of the labour involved and whether engineering large-scale irrigation or massive pyramidal mounds required central management. Interest in the organization of labour is, of course, rooted in the writings of Karl Marx, and, for pre-industrial economies, Karl Wittfogel (1957) argued that irrigation required central management in ways analogous to capital technologies. Management of irrigation continues to generate considerable interest, and a consensus has emerged that irrigation systems, even of large scale, can be managed in alternative ways.

The focus on irrigation's managerial requirements derives from Wittfogel's (1955, 1957) influential book *Oriental Despotism* and earlier writings. Although Marx (Hobsbawm 1964) had believed that village-based irrigation farming created a conservative, modular, and non-dynamic economy ("the Asiatic Mode of Production"), Wittfogel argued that irrigation's complicated and large-scale technology required central management to construct and reconstruct its impressive dams, levees, branching canals networks, terraces, and drainage ditches. He argued that a need for central management in these activities was the organizing function responsible for forming state bureaucracies. His theory quickly gained favour, providing the basis for a comparative study of state origins (Steward 1955). But, as quickly as Wittfogel's hydraulic hypothesis gained support, anthropologists began to assemble case material to show its inadequacies. For the primary states of Mesopotamia and Mesoamerica, the construction of large-scale irrigation followed the development of states and so could not have been their cause (Adams 1966). Ethnographies of irrigation in traditional societies showed that irrigation could be managed quite locally in various ways depending on local organizational structures (Fernea 1970; Hunt 1986; Hunt and Hunt 1976; Lansing 1991; Leach 1961; Lees 1973; Mitchell 1991; Mitchell and Guillet 1993; Sahlins 1962; Scarborough

2003; Spooner 1974).

As a graduate student at the University of Michigan, I became involved in this debate, when Marshall Sahlins asked me to join his Hawaiian project (Earle 1978). In his treatise, Wittfogel (1957: 241–243) had used the Hawaiian Islands to support his empirical generalization that irrigation and agrarian states were closely linked. At contact, Hawaiian polities were the most complex in Polynesia, and they depended heavily on intensive irrigation-based taro farming, especially on the western islands. Wittfogel focused on the role of the *konohiki*, a low-level chief, who administered the local economy of an *ahupua'a* for its chiefly owner. He argued that these managers were required by the complexity of the irrigation, and thus caused the exceptional development of Hawaiian political structures. Sahlins (1958) had taken a different tack in his dissertation, explaining the complexity of Hawaiian society as based on the gross productivity of its intensive agriculture, not on its irrigation systems' needs for central management. Wittfogel, a member of Sahlins' doctoral committee, aggressively questioned Sahlins' interpretation, and later, when Sahlins was setting up his historical project to study Hawaiian society, he remembered that attack and recruited me to demonstrate that Wittfogel's interpretation was mistaken.

Showing that Wittfogel was mistaken for Kaua'i, where I chose to work because of its extensive irrigation complexes, proved to be quite easy. Although much of the Hawaiian landscape had been extensively engineered to create irrigated agriculture and aquaculture, nothing about those facilities suggested a need for central management for either construction or maintenance (Earle 1978, 1980; Kirch 1977). Hawaiian irrigation systems were very small scale. Dams were simple rock diversions, ditches were short, earthen channels, and fields were low, ponded terraces. All but a few irrigation systems were less than 10 ha, servicing a handful of farmers living along the ditch or in a neighbouring household cluster. Virtually all irrigation was restricted to single *ahupua'a*, and each community contained multiple, separate systems. Those sharing an irrigation ditch could comfortably have managed construction and maintenance requirements. After the 19th century change in property law that gave farmers individual subsistence plots (*kuleana*), neighbouring farmers provided all management themselves for their irrigation. As expressed in the 19th century legal testimony by a native farmer, "everybody, now that he has a *kuleana*, is his own *konohiki*" (Earle 1978: 137). Considering other well-documented ethnographic cases of small-scale irrigation shows that management was highly variable (local farmers, community officials, or chiefly managers), corresponding not to the needs of irrigation management but to the overarching political structure within which irrigation was embedded. In simplest terms, the political superstructure, not the requirements of such modest irrigation, determined the managerial style of such small-scale irrigation.

Considerable research has refined our understanding of the scale, chronology, and organization of Hawaiian irrigation (Allen 1987; Green 1980; Kirch and Sahlins 1992; Riley 1975; Tuggle and Tomonari-Tuggle 1980; McElroy 2007). The descriptions of individual irrigation systems emphasize their small scale. Kirch and Sahlins (1992) show how irrigation mapped on the local social structure, which would have provide the local organization for construction and maintenance. Allen (1992) compiled a radiocarbon chronology for the history of Hawaiian farming that sketches out the linkage between the expansion in irrigation

and the development of complex political systems. The bulk of radiometric dates for irrigated agriculture were after AD 1200, corresponding with population expansion and the formative process of chiefdoms. After AD 1400, state authority apparently intervened to maximize surplus production (Allen 1991), and a new system of staple finance was instituted (Earle 1998). By this later period, which provided the foundation for Hawaiian states, these irrigation systems were built with social labour centrally managed by chiefs, but the small scale of these systems reinforces the point that central management was simply not necessary.

Both archaeological and ethnographic cases provide good examples of how state management of irrigation was unnecessary; this consensus is well supported by Hunt's (1988) cross-cultural study of 15 ethnographic cases in which state societies use larger-scale irrigation. While small-scale systems, like those on the Hawaiian Islands, could be managed informally, many activities on larger irrigation systems (water allocation, head dam construction, ditch cleaning and the like) require considerable social coordination. Such coordination, however, could be provided in alternative ways, classed roughly into self-organizing irrigation community and national government management. In Hunt's analysis, scale of irrigation and the tasks of its management do *not* apparently require centralized decision-making. Ranking the cases by the size of irrigation systems shows a largely random mix of state versus local management options (Hunt 1988: Table 1). Even large-scale systems are often managed cooperatively by irrigation communities (Scarborough 2003). Management does not require state bureaucratic oversight, and so it could not have required the evolution of a state superstructure. So where are we?

3.1 Why Irrigation Does Matter

Wittfogel's hypothesis seems fatally flawed, except for the nagging fact that most (but not all) primary states relied heavily on irrigated agriculture. Wittfogel's observation of an empirical association between states and irrigation seems valid, although his emphasis on management became a red herring allowing critics to discount the causal basis for the relationship between irrigation and complex political forms. Attention was drawn away from the ways in which irrigation supported states by a political economy based on staple finance. I believe that irrigation was often a major factor for the emergence of state societies, because it created an engineered landscape with irrigation, terracing, and/or drainage (see Scarborough and Isaac 1993). Operation of this system became a bottleneck that could be controlled to mobilize the production of surpluses to support state institutions.

Political complexity in other situations could be financed by controlling other bottlenecks. For example, around agrarian states, secondary chiefdoms and states emerged by interdicting and controlling the movement of materials into the core states. For primary state formation, the engineering of landscapes for irrigation realized particularly high and relatively sustainable levels of production. Whoever could claim responsibility for the engineering could also claim ownership and control over the mobilization of surplus. The high productivity of irrigated agriculture simply made possible the substantial surpluses that chiefdoms and states mobilized (Hunt 2000). Most importantly, surplus production from irrigated landscapes could be controlled. Based on attached warriors, Hawaiian elites asserted ownership over the productive land, both irrigated and dry, that produced the surplus to finance their political expansion and

transformation. I argue for the basic significance of the irrigated landscape as it became linked to further intensification of dryland systems.

3.2 High and Sustainable Productivity

The first requirement for the evolution of complex societies was to fashion a political economy to finance emergent institutions of order and control. The vast majority of chiefdoms and early states depended on agriculture, and their political development required highly productive and sustained agricultural intensification. Note that taro pondfield agriculture provides exceptionally high productivity that could have created the same surplus derived from cereal grains. Although many chiefdoms and a few primary states exploit other bottlenecks, or control point, the engineering of irrigation is very frequently used and is particularly important. Many developing chiefdoms and states intensified agriculture with irrigation, progressively changing water flows with canals, soils with embanked terrace walls, thus keeping the nutrient cycles closely managed, and augmenting them. Unlike other forms of intensification, irrigation appears to have increased substantially the productivity of labour on its fields compared to neighbouring, non-irrigated lands (Bray 1986; compare Boserup 1965). The contrast was most dramatic in the deserts of Peru or Mesopotamia, where the canals marked a line in the sand between the fertile and the sterile. But the irrigation landscapes of tropical ecosystems provided a similar concentrated and highly productive agricultural landscape that could be owned and controlled by ruling elites.

The Hawaiian case illustrates the highly productive and concentrated nature of irrigated farming of taro (Ladefoged *et al.* 2009; Earle 1980). Almost wherever adequate water and other needed conditions co-existed, irrigation agriculture was developed here in prehistory, creating large patches of highly productive land limited to the lower valleys with major streams. Based on yield estimates from traditional Polynesian farming systems, the production from these would have been several times greater per hectare than for traditional dryland cropping and their potential for surplus production would have been much higher.

Irrigation systems seem to have an almost infinite potential for intensification, and remarkably high population densities can be sustained (Bray 1986). Geertz (1963) describes how labouring on Balinese irrigation is an 'agricultural involution.' The individual farmer could always work just a little harder—control water flow more carefully, weed another time, use more fertilizer, transplant seedlings, and the like. Each new input increased the farmer's output, allowing families to subsist on smaller plots and to provide 'surplus' to the landlord or the taxman. The harder and more carefully a farmer worked, the better they could live and the more that elites could demand from them. In irrigation, the potential for self-exploitation and class-exploitation seems almost inexhaustible.

Intensification by irrigation is also sustainable. Related to processes of degradation and resilience (Krech 2005), sustainability implies that agricultural production does not diminish long-term potential productivity. By what means and how much the environment is landscaped may mitigate to some degree its exposure to degradation. While all highly intensified landscapes are susceptible to loss, engineering and its regular maintenance reduce the susceptibility to disasters when compared to non-engineered landscapes. Better dams, larger reservoirs, deeper wells, better drainage, and more terracing help control water availability, erosion, and

salinization. As described earlier, initial expanding swidden agriculture on the Hawaiian Islands may have caused erosion that helped to create an opportunity to expand irrigation farming. The building of irrigation systems then provided an alternative, less risky, and highly-productive agriculture that sustained long-term intensification (Earle 1997). Ladefoged *et al.* (2009) emphasize that the risks of dryland farming in Hawai'i would have been substantially higher than for its irrigated fields. The irrigated pondfields of prehistoric Hawai'i would have been productive year-around and could be farmed almost continuously for many hundreds of years (Fig. 1).

Certainly irrigated agriculture has risks. Many scholars have mentioned the possibility that irrigation's design creates conditions susceptible to disruption by flooding and drought. In the Hawaiian Islands, for example, the removal of upland forests made flooding a major threat to lowland gardens, and their coastal locations made them vulnerable to tsunami (Earle 1978). Risks that do exist, however, tend to be borne differentially by some farmers, especially those at the edges of irrigation systems. In highland Peruvian communities, as an example, when water is abundant, farmers expand production by building new terraces, but, when annual rainfall decreases, those terraced fields at the margins are cut off from water and must be abandoned (Guillet 1987). Irrigation created a landscape that was fundamentally differentiated into better and worse land. Some soils became more productive and lower in risk, and ownership of these lands gave substantial long-term advantage to some over others. In the Hawaiian Islands, some parts of irrigation systems would have been less susceptible to flooding, but risks would have always been lower than on lands with dryland farming where droughts would have caused major hardship (Ladefoged *et al.* 2009).

The Hawaiian Islands did not share equally in lands suitable for major or even secondary irrigation districts (Earle 1980; Kirch 2007). Based on necessary conditions and tested with existing archaeological research, Ladefoged *et al.* (2009: Table 2) have modelled the amounts of irrigated vs. non-irrigated farming developed prehistorically across the Hawaiian Islands. The geologically younger islands (Maui and the Big Island) had limited areas suitable for irrigation and much larger areas suitable for dryland farming than did the geological older islands of Oahu and Kaua'i.

Turning Boserup (1965) on her head, Kirch (1994) argues that the most complex polities in Polynesia generally and, on the Hawaiian Islands specifically, did not develop primarily with intensive irrigated farming but with dryland farming for which intensification was severely limited and higher risk (see also Bollt, this volume). Take for example, the Island of Hawai'i where the largest polity in Polynesia developed. The early chiefdoms there were based on irrigated farming along the northern coast, but subsequent warfare and conquest created a massive, island-wide kingdom. These extensive chiefdoms then depended heavily on the intensified dryland farms along the island's west coast where no irrigation existed. The important point is that underlying environmental conditions and their realization through intensification channel the trajectories of political development quite differently. These political contrasts apparently rested on differences in the subsistence economy and linkage to types of finance. Furthermore, the extensive development of the dryland complexes on the Hawaiian Islands apparently exposed the emerging state to instability that would have created problems in guaranteeing the surplus production on which the expanding state depended



Figure 1 Extensive taro pondfields at Waimea, Kauai Island, Hawai'i, with dry hills above. In this valley, in the distant past, irrigation channels were built with closely-fitted stone blocks (photo by P.J. Matthews, 1998).

(Kirch 2007).

Each environment has distinct implications for intensification, and the long-term consequences vary significantly. On dryland landscapes, intensification may have increased erosion and decreased the fertility of soils, making high levels of production unsustainable. Although collapse was always a threat on engineered landscapes with irrigation, soil was conserved, productivity was less likely to decline, and intensification was more sustainable.

Some intensification may have been justified by family self-interest, but why would farmers be willing to produce further surplus to support ruling institutions? The answer seems self-evident: they had to.

4. CONTROL THROUGH ENFORCED PROPERTY RIGHTS

To finance emergent political systems of rule, surplus must have been mobilized through a political economy, and except for rather modest first-fruit gifts families did not willingly surrender that which they had produced by much toil. To gain access to land or facilities owned by a ruling elite, peasants relinquished surplus as tax or tribute; what Wolf (1966) calls a fund of rent. The origin of such hierarchical systems of property needs to be considered. Although intensification of agriculture increased the importance of ownership, individual farming families could still have owned their farms without increased stratification (Netting 1993). Irrigation systems, however, differentiate land based on productivity and inherent risk. Elites organized (or at least alleged to have organized) landscape engineering and thus laid plausible claims to surplus from farmers. The irrigation system built by an elite can thus be the bottleneck or control point with which to extract surplus, while use rights in actual fields and responsibilities for their management could still have been vested in commoner farmers. Even without irrigation, intensive farming practices and a warrior elite created the basis for the political economy of European feudalism (Johnson and Earle 2000). Because irrigation created lands of exceptionally high and concentrated productivity, a warrior retinue could easily have enforced demands for rent or tax. Monuments, buildings, and the agricultural facilities themselves marked these lands and persisted through time to materialize ownership and responsibilities within the political economy.

The landscape of a Hawaiian community embodied a dynamic interplay between natural topographies, vegetation, and human facilities. Before colonization, forests blanketed the islands, but the Hawaiian settlers cleared the land for dryland farming and eventually for extensive irrigation projects. Communities were literally built up over hundreds of years by human labour to create the palimpsest of landesque capital investment and physical markings. Kolb (1997) describes how year after year a local community constructed the facilities of an engineered landscape. Irrigation canals, in particular, were built wherever water was available to supply the pondfields that came to cover the valley floors. With constructions, the community's topography became progressively developed and associated with narratives of gods, chiefs, and commoners and with rights and obligations in the political economy.

A typical *ahupua'a* community in the older islands was a valley defined by mountainous cliffs, waterfalls, and knife-edge ridges. The valleys are often deeply entrenched and narrow, broadening out as they enter the coastal plain. Here irrigation systems were constructed as part of an engineered environment that was both highly productive and owned by chiefs. This ownership, reinforced by warriors, might transform the kin-based community and political structure typical of Polynesian chiefdoms. When a new paramount came to power, usually through a war of succession, he assigned an *ahupua'a* to an individual high-ranking chief or military supporter, who then assigned his or her *konoiki* to manage production as an income estate and as tax to the paramount. The *konoiki* allocated pondfields, house lots, and other

resources to commoners, who used these for their subsistence and housing. A commoner's right to his subsistence lands, however, was predicated on his corvée responsibilities to farm special agricultural plots (*ko'ele*) that supported the chiefs and their special projects such as digging canals, making fishponds, and building shrines. The Hawaiian polities became a classic example of the political economy that sustained many early states based on corvée labour and staple finance (Earle 1978, 1980). But the management of that economy by the *konoiki* was in no sense required by the simple irrigation technology.

Hierarchical property relationships that structured chiefly rights to surplus from the engineered landscape were often maintained by coercive force, an ability to restrict others from using landesque capital and by making those who used it pay for that right. Farmers on irrigated land were easy marks, and they were reluctant to abandon long-term investments (Gilman 1981). Typically, only a small portion of the land was irrigated, and so these highly productive zones could be carefully monitored and controlled by a warrior elite. Michael Mann (1986) talks of these peasant farmers as being 'caged' by irrigation, because they could not escape central control without losing use rights to the improved land. Farmers were locked into their engineered landscape of intensive, sustainable production.

The coercive superstructure is well illustrated by Hawai'i. Attached to the ruling chiefs was a retinue of trained and gifted fighters (Earle 1997). These warriors helped the chiefs gain power and enforce their rule. If the farmer did not undertake corvée responsibilities, he would be turned off his plots and denied subsistence use. During the annual ceremony of tribute collection, warriors accompanied the god-chief around the island territory (Malo 1951[1898]: 141–159). They would stop at the boundary of an *ahupua'a* to collect tribute, and, if the 'gifts' offered to the god-chief were considered paltry, more would be demanded, and warriors could ransack the community to obtain any shortfall.

The social nature of engineered landscapes also reinforced the hierarchical property relationships of irrigation. Lansing (1991; see also Mitchell 1991) describes how the daily operations and routine maintenance of irrigation were embedded within local ceremonial cycles. The irrigation communities of Bali were articulated with water temples, the priests of which helped manage patterns of cropping and water use. Participation was based on self-interest in water allocation, crop rotation, and pest management. Although they operated without state direction, the irrigation systems in Bali, as elsewhere in Asia (Morrison and Lycett 1994), displayed memorial inscriptions that recorded their history, or purported history, of construction by Balinese kings (Schoenfelder 2003). Rights to surplus rested on the organized events of construction that were used to co-opt a proportion of surplus production.

The role of the lord was formally recognized as the builder, because he financed the construction, and his managers put the people to work. The result was an overarching ownership that legitimized his rights to surplus extraction. On the Hawaiian Islands, labour crews were organized by the community's *konoiki* to construct and maintain irrigation systems and fishponds. In legal documents, farmers would describe a construction event with the name of the *konoiki*, who organized it, and of his chief, who was said to have built it. These construction events were elaborate, with special foods and dress to make them memorable. In an annual festival that reinforced the chiefs' role in maintaining farming productivity, all in the community worked together to prepare the pondfields for planting. In

a special ceremony, the paramount even went waist deep into the water of a ceremonial pondfield, beginning the arduous treading of its floor to make it watertight (I'i 1959: 68). By supporting the ceremonial events of construction and routine maintenance, the actions of the overlord became infused into the most visible events of production cycle.

Irrigation facilities also provided the permanent physical markings of water flow and farmed plots that helped define property rights. We are familiar with how property is defined and transferred within a literate state; such transactions are recorded on deeds, contracts of sale, and wills that are held by the state or other legal representatives. But in non-literate societies, an important device for determining property units was the perimeters of the land (Stone 1994). The built landscape of plants, irrigation fields, walls, houses and monuments in the *ahupua'a* materialized the memory of their construction, the pattern of their assignment and use, and the property system upon which they were based (Earle 1998, 2000, 2004).

The facilities of an engineered landscape were built to be permanent, and their walls and banks marked the imbedded units of production and ownership across generations. Ownership rights in irrigation were carefully measured and watched, as each square metre of land and litre of water matters for a farmer's total yield. Their physical divisions and connections were also all but impossible to alter surreptitiously, and their group construction and maintenance made them accepted inter-subjectively. The physicality of an engineered landscape is well illustrated by the Hawaiian case (Earle 1998). The floor and lower slopes of each valley were a checkerboard of fields, each a pond surrounded by earthen bunds. In the 1850s, the property system was changed to a new system of private property modelled after the British. To receive ownership of fields and house lots, each commoner had to come before the courts and describe his land allocation (*kuleana*) and its history of allocation and use. The farmer would testify to the physical elements that marked the borders of the *kuleana*: the neighbour's pondfields, the chiefly plots, canals, and walls. A property's reality was the social memory of those involved in construction and allocation, and the everyday activities of the marked space (Earle 2000).

The engineered landscape of Hawaiian communities included the irrigated ditches and fields, patchworks of planted trees, earth and stonewalls, shrines, and paths that marked property, labour and tribute responsibilities, and ceremonial cycles. Hawaiian polities and many other chiefdoms and agrarian states existed in such artificial landscapes that materialized the rights and obligations in their political economies (D'Altroy and Earle 1986). Irrigation systems both large and small formed the basis for staple finance, not because of any need for management, but because the intensified and engineered landscape provided the permanent structure for political domination.

Where the potential for irrigated agriculture was limited, as on the Island of Hawai'i, an initial core area of irrigation probably provided an easily controlled surplus production that supported a warrior cadre, which would then have seized other large areas. To maximize surplus with the backing of warriors, the chiefs would then have been able to oversee the development of the dryland complexes that provided, at admittedly higher costs, the surplus needed to support the emergent state superstructure. Because of the greater instability of the dryland system, however, warfare was expansionistic and ultimately oriented westward where the developing state sought to conquer the highly productive irrigated areas (Kirch 2010).

Plausibly, the political economy that supported the emergence of states on Hawai'i was based on irrigated agriculture but, in areas without major irrigation potential, had to expand to generate sufficient surplus. In his prescient analysis, Sahlins (1958) appears to have correctly identified the combination of island size and productivity as underlying conditions that explain variation in political development across Polynesia.

5. CONCLUSIONS

The history of human economies and landscapes involves long-term intensification and innovation to support both higher population densities and more complex social institutions (Kirch 1994). Although the forms of intensification varied, it invariably involved the engineering of landscapes to increase and stabilize production and created land tenure systems that set rights of use and transfer across generations. The lands of irrigation, dryland farming and fishponds in Hawai'i provide magnificent examples of how engineered landscapes supported pristine state formation. Irrigation and the other facilities were critical, because they provided the productive and sustainable base for surplus extraction that financed complex chiefdoms and eventual states. Highly intensified landscapes of water management created an artificial world that could be controlled by elites to generate the surplus that fuelled political ambitions. The landesque capital helped structure patterns of everyday and long-term activities that made possible the imposition of new hierarchies of property ownership. Irrigation provided opportunities for control through property rights encoded in ritual practice and the built landscape. That a farming family held subsistence rights in a permanently marked plot effectively tethered that family to the land and made them an easy target for emergent elites in search of reliable incomes.

To understand the role of irrigation in the emergence of primary states, we should look again at prehistoric and historic cases of chiefdoms to study processes of political transformation and breakdown. The elaboration of chiefdoms in the Pacific based on irrigated and non-irrigated agriculture presents independent cases to study pristine state formation. Following Sahlins (1958), the potential for surplus production and, as I add, for its control explains to a large measure the variation in political evolution. Where island sizes were large and intensive agriculture developed, complex chiefdoms formed on several island groups and pristine states at least on the Hawaiian Islands. We need to push the importance of the Pacific in comparative studies of World prehistory, because of its independent developments and unusual characteristics, including the dependence on root-crop agriculture, provide key insights into common processes and alternative trajectories for social evolution.

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