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The non-hierarchical development of complexity in the semitropics: water and cooperation

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Abstract Seasonality and unpredictable rainfall patterns in the tropics and semitropics make living in such regions challenging. Further, dispersed agricultural soils and critical resources result in low-density urbanism where people are blanketed across the landscape. As we show through a discussion of Amazonia, Bali, Angkor, Maya Lowlands, and West Africa, however, people adapt in a sustainable manner through constructing water management systems and developing specialized occupations. Specialized economies develop that take advantage of the varied resource niches that rely more on productive labor rather than technology per se. Cooperation and heterarchical networks are key; the former to build and maintain water systems, and the latter to provide the means to exchange information, goods, and knowledge from among the varied resources areas. Central nodes or urban centers also emerge to bring people together at set times for markets, ceremonies, and other activities that serve to socially integrate the dispersed and diverse groups. Over-exploitation is kept in check through myths that consecrate aspects of the landscape as sacred, especially those revolving around water.

Keywords Semitropics · Cooperation · Water management · Heterarchy · Low-density urbanism

The role of cooperation as an evolutionary strategy has occupied the biological sciences since Darwin (e.g., Boyd and Richerson 1992; Hammerstein 2003; Henrich and Henrich 2007; Patton 2009). Nevertheless, the principal force guiding method and theory in evolution comes from natural selection models emphasizing resource competition (e.g., Gintis

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et al. 2005). Although recent work is now giving greater attention to the complexity of social cooperation among organisms (e.g., Axelrod 1997; Sloan Wilson et al. 2004), a long and vibrant history of research exists within anthropology and sociology (e.g., Mead 1961[1937]). Resource concentrations are emblematic of human social complexity frequently associated with competition, conflict, and potential environmental overuse or degradation (Carneiro 1970; Hardin 1968; cf., Smith and Wishnie 2000). Recent assessments and studies, however, suggest that less hierarchically organized complex societies establish and maintain collective interdependencies by way of their institutions (Crumley 1995, 2003; Scarborough and Burnside 2010; cf., Beddoe et al. 2009; Ostrom 2009). Of special merit is the work of Ostrom (1990, 2009) in promoting the concept of "common-pool resource" (CPR) and arguing that many goods and services under several social–ecological circumstances are more equitably shared.

Water management is an especially attractive topic to address the issue of societal cooperation. Water is the most critical of all resources that humans can control, and unlike the primacy of air for all living things, water's availability is less predictable even when regulated by societies. Although much is made of the conflictual dimensions associated with water access and management between groups (Hunt and Hunt 1974, 1976; cf., Scarborough 2003), a recent survey indicates that of the 300 international water agreements over the past 60 years, only 37 have been so broken that some form of violence has ensued—and when it has resulted in serious conflict, it has been quickly quelled (Wolf 2007; cf., Nair 2011; Scarborough 2011). This is a highly significant assessment, one that requires considerably more attention concerning how and why water-related disputes are made resolvable and what these complicated and potentially incendiary situations can tell us about conflict resolution more generally. The division between too much as opposed to too little water has impacted human prehistory and history in pivotal ways, with a current focus emphasizing climate change, which is fundamentally water access change (see United Nations 2003). This paper examines the environmental and social parameters within settings that were/are either too dry or too wet and how these circumstances have influenced cooperative relationships.

From the origins of agriculture to the beginnings of the archaic state, semiarid and semitropical environmental settings have been the seats for major social transitions in human history. Temperate settings that are identified with several of today's most developed nation states generally are not the loci for the catalytic environmental and social conditions that precipitated the earliest experiments in social complexity—rather, this takes place in other "marginal," very dry or very wet settings (e.g., Kirch 1994). And between these two dichotomous ecologies, arid environments like the Near East are those that receive the greatest attention. The latter's marginality is implicitly associated with Toynbee's "challenge and response" proposition of the 1950s; it suggests that external forces such as climatic degradation in which animal and plant distribution shrank and concentrated around desert watering holes or "oases" (Childe 1951), population pressures promoting sedentism (Cohen 1977; Boserup 1965) or a combination of these and several other less well-understood variables converged to catalyze intensification and radically change a landscape. Agriculture and domestication were significant outcomes of these processes induced by such stressors as early as 10,000 years ago. Subsequent early and "first" experiments in urban social complexity are also well documented in the Near East, with the initial appearance of the city by about 5000 years ago (Yoffee 2005).

The juxtaposition of semiarid settings in immediate proximity to water has a well-established social history. Several of the great primary civilizations as well as the earlier principal foodstuffs on which we depend today were first established in these dry environments. Wheat and barley of the Near East (Miller 1992), and perhaps millet of north

China (Lee et al. 2007) and sorghum of East Africa (Harlan 1992), suggest the primacy of a desert with some seasonal access to rainfall. The early use of food animals also appears in the Near East with the domestication of goats and sheep, and the subsequent domestication of cattle (North Africa) and pigs (China; Yuan and Flad 2002). These food sources compose a large part of what humanity consumes globally today.

As populations did indeed increase, a growing need for more predictable water access positioned communities near perennial running sources—streams and rivers. Because of the seasonal rise and fall of these rivers, however, sedentary communities were not placed in proximity of floodplains and frequently depended on flows from much smaller distributaries. In the Near East near present-day Mandali, Iraq, our best reported early canalization efforts are found. The Choga Mami system is a diminutive artificial drainage designed to irrigate wheat and related grains by 5500 BC (Oates 1972, 1973; Oates and Oates 1976). Although the first canalization efforts surely have earlier antecedents, they do introduce a significant "technological breakthrough" within the built environs.

The subsequent rise of truly complex society by 3000 BC has been described for the Near East in detail for well over a century (e.g., Adams 1966). The catalyst for the "urban revolution" was neither singular nor clearly predictable, though perhaps inevitable given a similar set of primary civilizations—states—developed within a thousand years of this Near Eastern city-scape florescence. An early explanation for the origins of the state was Karl Wittfogel's Hydraulic Hypothesis (Wittfogel 1957), the first nomothetic approach for addressing statecraft as a comparative worldwide phenomenon of pivotal significance in human history. Wittfogel posited that developed irrigation systems and the bureaucracy necessary to control and coordinate water allocation and access were responsible for the archaic state. Although now dismissed as deterministic and limited in its explanatory power, the theory did precipitate the several other "prime movers" subsequently incorporated for the rise of the state—warfare, trade, population pressure or a set of societal processes dependent on historical precedent. Today, most scholars assess the appearance of the earliest states as a highly nonlinear process (Scarborough 2003; Scarborough and Burnside 2010; Yoffee 2005). Nevertheless, Wittfogel's early emphasis on (1) a terrain associated with limited rainfall, (2) a population identified by sedentary agriculturalists, and (3) a heavily canalized landscape, which then rapidly catalyzed the earliest states, may be an important explanatory component in some situations—though clearly formulaic (cf., Marcus and Stanish 2006). While Wittfogel overstated its absolute primacy, water management cannot be easily dismissed as a significant variable in state-level development (Isaac 1993; Scarborough 2003).

In many semiarid states, monumental investments in water management reflect aspects of conspicuous consumption (Veblen 1934) by a state manifested in highly visible aqueducts, siphons, pleasure gardens, baths, and fountains. Perhaps especially powerful when built in desert settings, these grand material statements indicate to a sustaining population the influence and control by a governing elite. Water is frequently a highly limited resource and lavishly displaying it in this manner—subject to immediate evaporation and less functional economic use—only accentuated the hegemonic force of some states (Scarborough 2003, 2011).

The semitropics

Semitropical ecologies are identified by marked seasonality of rainfall and warm to hot temperatures, and occupy latitudes between 5 and 10 and 23½° North and South of the equator (Hutterer 1985). They are considered by most western societies as marginal settings for implementing or developing productive land- and water-use technologies, and much of what is understood as the "underdeveloped world" occupies these environments today. Nevertheless, they were/are no more "marginal" than the reclaimed deserts of the Near East or the US Southwest of either antiquity or the present. Perhaps because the environmentally temperate West has subsumed portions of these semiarid settings due to that other subsurface liquid—oil—or invested in sophisticated water technologies with long histories of invention to reclaim these environments, we are less apt to view them as foreign landscapes. The less attractive aspects of semitropical settings are likely a worldview based on the challenges of making a living from an environment in which our technological breakthroughs designed to harness and concentrate its resources remain poorly developed, and in many cases simply inapplicable (e.g., the Green Revolution in Bali; Lansing 1991).

Semitropical and tropical environments are identifiable by a grand abundance in plant and animal diversity (Willig et al. 2003); the abundance of the former offsets much of the carbon footprint from those more temperate and technologically advanced states today, thus allowing significant carbon sequestering. The extremely high diversity index is possible, in part, because of low specific species richness from within any microenvironment or patch (Erwin 1988; Hubbell 1979; Janzen 1970). Human populations mimic aspects of this dispersed distribution, with lower population densities—though frequently sizable regional populations overall—when compared with more semiarid or contemporary temperate settings (Scarborough 2003). This translates as a lack of resource concentrations or their collective centralization by a society (Scarborough 2005; Scarborough and Burnside 2010), an attribute associated with one of the hallmarks of complex society as identified by the earliest cities in the semiarid Near East and maintained into our own Western history. But we do have several geographically dispersed examples where social complexity arose in these demanding settings. These early complex societies were not imported or forced into these settings from some other "more attractive" region (contra Meggers 1954), as they represent indigenous trajectories stimulated by the abundances and challenges of the natural surroundings.

What were the principal shared constraints as well as advantages that facilitated complex society in semitropical settings? One major challenge was in organic storage, in that high humidity and temperature conspire to accelerate decay. Several strategies were used to offset this condition, inclusive of harvesting resources quickly and consuming them soon thereafter. This was both a production and distributional issue affecting the manner in which the landscape was engineered and the scheduling of consumption practices. In concert with evolving methods of harvesting plants and animals through advances in cultivation and domestication, effective ways to further concentrate and refine the use value of these organics were established that significantly ameliorated storage concerns—such as leaving mature root crops in the ground for extended seasons or immediately dehydrating a catch of fish through salting. Landscaping efforts might invest more in constructing and maintaining ponds or reservoirs of freshwater for fish and mollusks, while cultivating agricultural tracts to best accommodate root crops in combination with other more perishable harvests like maize or squash.

Such strategies fall under the purview of labortasking techniques, whereby relatively high densities of semitropical farmers rely on each other, not only to maintain water and agricultural systems but also to exchange goods not available in their immediate vicinity (Scarborough 2003, 2007, 2008, 2009). A high degree of labor and resource interdependency within and between groups associated with rapid labor and resource substitutions when necessary identifies significant aspects of these semitropical societies (Scarborough and Burnside 2010; Scarborough and Valdez 2003, 2009). Consequently, there is less need for top-down or centralized management to deal with everyday needs such as local trade or the maintenance of agricultural systems; instead, heterarchical principles hold sway, where "each element possesses the potential of being unranked (relative to other elements) or ranked in a number of different ways" (Crumley 1979:144, 1995). The diverse, dispersed, and fragile semitropical setting demands varying and flexible modes of subsistence when compared to some other environmental venues.

The role of calendrics in all complex societies was emphasized, frequently as a method of costly signaling or conspicuous symbolic displays by an elite to promote the illusion of predictive control over natural rhythms like seasonality or the abundance implied by just enough rainfall or the absence of disease vectors. A less clear but fundamental aspect of calendrics was their more immediate and mundane influence over scheduling routine and quotidian activities. Because of the legacy of tropical ecosystems identified by tremendous biological diversity (Willig et al. 2003), but limited numbers of any one species in any specific patch or microenvironment (Erwin 1988; Hubbell 1979; Janzen 1970), usable human resources were frequently dispersed across the natural landscape. Although societies were creative in attempting to concentrate biophysical resources and refine their edible or otherwise usable ends, frequently it was necessary to organize the timing of labor for the most productive extraction, distribution, and consumption of these resources. Additionally, given the dispersed character of tropical niches, temporal monitoring required spatial linkages to accommodate the allocation and consumption of rapidly harvested resources. Human populations tended to mimic the greater biological distributions, though community concentrations are highly indicative of any complex society. Network pathways were developed around roadways and occasionally incorporated the use of tractable animals, at least in the Old World semitropics (cf., ancient Sri Lanka [Scarborough 2003] or Cambodia—see below).

The occupants of the "wet" followed by the "dry" in semitropical settings tended to invest in water reservoirs, unless surface drainages were significant with permanent watersheds some distance away. A reservoir landscaping adaptation permitted degrees of centralization or resource concentration within a set of societies with otherwise dispersed settlement patterns. Nevertheless, problems with waterborne disease (Graham 1999; Miksic 1999) spiked with such sedentary attachments again requiring creative methods to curb infections such as significant fish cultivation (and associated insect removal) (Erickson 2003, 2006, 2011), frequent dredging (Scarborough 1993), or postulated sand filtering systems (cf., Fairley 2003). Within these contexts, wetlands take on a potential little appreciated even today.

The role of wetlands, broadly defined from within semitropical settings, is of special merit (Scarborough 2007, 2009). Early complex societies frequently modified, expanded, and refined their production attributions naturally available to humans. Wetlands were no more "marginal" than the reclaimed arid lands of both antiquity and today and, by way of a very different investment in the engineered landscape, are responsible for some of the most creative and sustainable built environments recorded. In the remainder of this paper, we briefly examine five case studies and introduce the productivity of these semitropical environments and the non-hierarchical complex societies that emerged (Fig. 1): Amazonia, Bali, Angkor, Maya Lowlands, and West Africa. They differ in historical precedent but share similar population dispersion patterns with urban-like centers concentrating no more that 600–700 people per square kilometer, perhaps a full order of magnitude less dense than cities identifiable in the earliest states of more semiarid environments—clearly a very different social trajectory (Fletcher 2009). Moreover, hinterland distributions of population

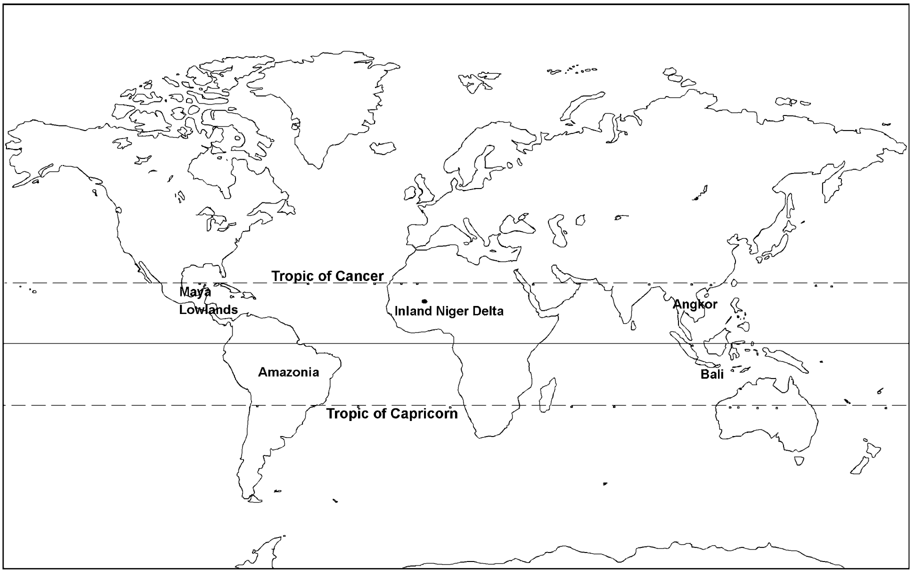

Fig. 1 Map with tropical regions noted

did not decrease or "drop off" as dramatically as noted in other more semiarid environments. We posit that these different societies established in semitropical environments share common social structural features unlike many other environmental settings (Coe 1957, 1961).

Amazonia

Recent "breakthroughs" in our understanding of the Amazon are radically changing our views of the past and the significant degree to which the landscape was modified. Between 500 BC and AD 500 sedentism was well-established and significant populations were residing on plateau edges overlooking highly productive but seasonally inundated floodplains (Denevan 2001; Erickson 2003). Deep deposits of "terra preta" soils, or rich organics likely concentrated by the settlers themselves from their own food remains and related wastes, greatly enhanced the fertility of the otherwise poor quality of local soils. By at least AD 1000, sizable populations of townspeople invested in mound building activities producing a highly domesticated landscape in a setting today considered uninhabitable by Western standards (e.g., Roosevelt 1999). Ethnohistory and ethnography have emphasized the tribal nomadic movements of these groups, with ethnographic analogies strongly arguing for a similar lifeway in the distant past (Holmberg 1950; cf., Chagnon 1968). However, both the introduction of European diseases (Borah and Cook 1969; Dobyns 1966, 1983; McNeill 1976) and the steel axe (machete) (Denevan 1992) have conspired in allowing highly reduced populations since the "Conquest," resulting in dispersed and mobile activities in harvesting jungle resources. Archeology now reveals a noticeably different set of past landscapes and adaptations principally focused on expanding the "marginal" wetlands.

Erickson (2003, 2006) and Heckenberger (2006; Heckenberger et al. 2007, 2008) each demonstrate independently the impact of the human-shaped environs. Today's fire-prone savannahs covering extensive reaches of the Amazon and providing only limited biodiversity were ditched and flooded in the past. Hundreds of kilometers of raised fields were built and hundreds to thousands of kilometers of headwater terraces were established by the first century AD. Waterways were filled with fish and mollusks and kept clean by way of cultivating water hyacinths and other water-cleansing plants. Uninterrupted canoe navigation was possible across 170 km of present-day savannah in a culture area without wheels, sails, or metal tools (Erickson 2011). The utility of the raised-field system came in several forms. First, elevated fields in wetland settings can absorb at least a quarter-million cubic meters of water during seasonal deluges and associated runoff, with a slow release during the dry season. Second, squash, manioc, and sweet potato thrive on these raised-field surfaces as opposed to the abuses wreaked by slash-and-burn agriculture currently practiced. The two root crops noted characterize a "natural food storage" when left in the ground even beyond their annual seasonality, a major advantage in hot and humid surroundings that accelerate decomposition upon harvesting. The indigenous domestication process indicates that not only were manioc and sweet potato first cultivated in tropical regimes, but also maize (Piperno and Pearsall 1998; Pohl et al. 1996). And third, swamp-like settings more generally are conjectured to have been the seats of the earliest experiments in Near Eastern grain domestication because such "oases" had naturally elevated water tables at their margins, a suggestion first made by Sherratt (1980) and now confirmed at the temporally prodigious Anatolian center of Catalhoyuk (Hodder 2006).

From the Amazonian data sets, we can project several factors that counter conventional assessments of how and where early social complexity developed. Although the highly patterned raised-field layout might appear carefully orchestrated by an overarching and commanding political body, this is not the case. The field systems "self organize" (Lansing 1991, 2006; McIntosh 2005) within the confines of immediate environmental constraints and the communities responsible for their construction and use. They do not demand considerable upfront planning drawing from controlled access implementation of elaborate technologies, but rather the coordinated efforts of village-level and cooperative community labor and information exchange. Because of the fragility of the raised-field platforms constantly requiring the shoring of their canal margins and dredging of the nutrient-rich muck in annually "raising" the field surfaces, maintenance costs are extreme. Highly decentralized and governed by heterarchical relationships, these expanding and sustainable water and land-use systems challenge the notion of a "Tragedy of the Commons" so prevalent in discussions of capitalistic land-use models, a condition to which we will allude in the conclusions.

Bali

The most complex of wetland reclamations are the rice paddy systems of Southeast Asia. These highly engineered surfaces frequently hanging from dizzying stair-stepped slopes on the volcanic island of Bali capture in microcosm several zones of this greater region. The Indonesian island chain experiences a profound seasonality of precipitation dichotomized, in part, by Geertz (1963) as the "wet and the dry," resulting in significant socioeconomic organizational patterning. The Balinese rice paddy and *subak* land- and water-use system appears well-established by AD 1100 and continues to reflect the highly intensified wetland reclamation and extended use of these carefully controlled landscapes (Scarborough et al. 1999, 2000). Although not as expansive as the Amazonia reclamation examples, the effort invested in intensification is second to none—a condition that has led to the notion of "agricultural involution" among those populations that can no longer intensify their return on yields given the maximum use of a highly scheduled labor pool and the limits to which the

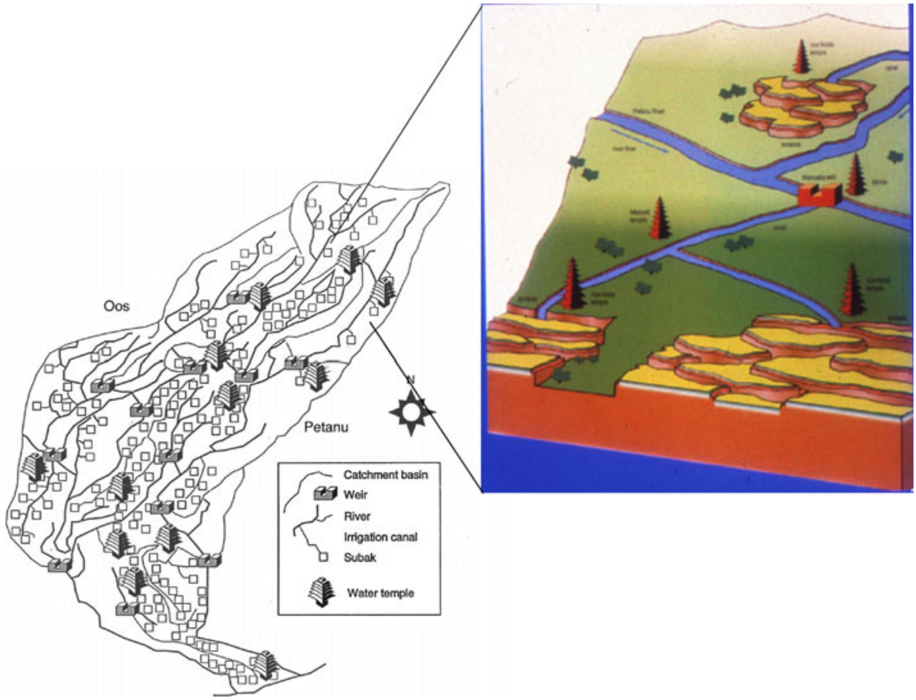

Fig. 2 Schematic of Balinese water temple, water system distribution. Courtesy of Stephen Lansing

engineered landscape has been altered within the parameters of the grain utilized, principally rice. Contemporary observations indicate that in portions of Southeast Asia, farmers deliberately exhaust elevated slash-and-burn slopes to obtain a short-term return on a suite of crops with the expectation that accelerated erosion will relocate productive and aerated soils to low-lying paddy fields (Padoch et al. 1998). Such intentional denudation accents the productivity of paddy fields and the lengths taken in a highly "involuted" system.

In the Balinese case, society is organized in a heterarchical manner as outlined in the Amazonian example (Scarborough and Burnside 2010). Agricultural involution was not a factor until perhaps the introduction of the World Bank and its attempts to increase rice production by way of massive amounts of phosphate fertilizer and highly growth-controlled varieties of foreign strains of rice (Lansing 1991). Prior to these practices—which have been considerably curbed, though continuing today—the agricultural base was organized around a series of water temples established and maintained by the crosscutting corporate unit of the *subak* or rice cooperative. Having self organized by way of both the landscape changes within the narrow and highly incised valleys and the evolving interplay between the local farmers and their socioeconomic, sociopolitical and ideological institutions, the Balinese represent another way of assessing complexity.

Although less apparent in the ethnographically "understood" Amazonian case, the Balinese are organized into "districts" determined in part by the diminutive, steep-sided drainages and valleys dissecting the island. These water districts tend to operate relatively independently of one another, but are highly interdependent within a district with the coordination of production, distribution, maintenance, and aspects of consumption assumed by the water temple loci (Fig. 2) (Lansing 2006). Ritualized and routinized labortasking allows the continued promotion of incremental adjustments to the sustained success of the ever changing human-nature co-evolution.

In contrast to the city of Angkor described below, "there are no grand capitals with monuments representing the cosmic mountain [Mount Meru]. Instead the island is dominated by several large active volcanoes…. According to Balinese legend, these symmetrical peaks are fragments of the cosmic mountain that were brought to the island by Hindu gods" (Lansing 2006:24). This dispersed symbolism is also reflected in the distribution of natural reservoirs (crater lakes at volcano summits).

Angkor

The monumental city of Angkor (AD 800–1200) represents one of the largest preindustrial cities known, with a dispersed population extending over 1000 km^2 (Evans et al. 2007; Fletcher et al. 2008). Much of the entire island of Bali would have been enclosed by the city's somewhat ill-defined limits. Population estimates are difficult, but they appear to approach 750,000 within the expansive Khmer Empire of several million people (Coe 2003, 2008). Certain "districts" are suggested throughout the urban-scape by an apparent standard temple complex design of several hundred shrines associated with a "moat/mound with rectangular east-oriented reservoir" layout. These "districts" are surrounded by open fields and resemble the appearance of Balinese water temples, though they likely have a residential function, indicating that the shared community-level interdependencies noted for these early complex societies are repeated across the landscape.

Angkor Thom, a palace and temple complex within the city of Angkor, serves as an example of these locally organized features. Its 3-km-long walls on each of its four sides encompass 900 hectares and over 90 km of roads, canals, and waterways. Within its walls are over 2600 artificial ponds for domestic use in accommodating its approximately 40,000 inhabitants. Zhou Daguan, a thirteenth century Chinese traveler who visited Angkor, reported that "every family has a pond—or at times, several families own one in common" (cited in Coe 2003:192).

Although biodiversity remains considerable, much of the terrain is less severe in topographic relief than that of Indonesia or Bali; it is perhaps more similar to a well-drained Amazonia, but with sandy soils instead of the "dark earth." In addition to the extensive road system frequently elevated and acting as a shunting system in diverting runoff and related drainage are the truly huge tanks or rectilinear reservoirs called *baray* (Penny et al. 2006). On the east and west flanks of the urban core are two *baray* measuring approximately 2 km wide by 8 km in length (ca. 2 m deep), sizable enough to contain the entirety of the largest central precincts of the Classic Maya of Central America (e.g., the regional capital of Tikal is 6% the size of Angkor; Coe 2008:723). The centripetal forces allowing the scale—both in terms of aggregate populations and the enormity of the water management systems—and social complexity require explanation in light of the centrifugal forces otherwise dispersing biophysical resources in a tropical setting. The effects of Old World domesticates and technologies are suggested, both likely introduced from the technotasking societies of China and points westward where they relied more on technology than specialized labor pools. Clearly, root crops were part of the package—yams have a long history of domestication in this tropical setting; but it was the monoculture of rice and its unique water and labor demands that permitted such population concentrations (but still dispersed by Western notions of urbanism), which Fletcher (2009) has defined as low-density agrarian urbanism. Domestication came in a variety of forms inclusive of chicken, ducks, and pigs, to say nothing about the complementary relief to human burden bearers of elephants, water buffaloes, and horses (e.g., Coe 2003, 2008; Higham 1989).

The urban core is surrounded by waterworks built by the Khmer between the ninth and thirteenth centuries that completely transformed the landscape. Like Bali today, it is difficult to distinguish what is "natural" from what is not (Fletcher et al. 2008). "The immense water tanks and moats of Angkor were nodes in a profoundly ritualized, elaborate system of hydraulic engineering" (Fletcher et al. 2008:669). The hundreds of kilometers of canals were fed from several rivers (e.g., the Pouk, Roluos, and Siem Reap), many of which filtered through or immediately around the baray (Stone 2009:50) (Fig. 3). Although a highly sophisticated water system, 90% of the yearly precipitation occurs between May and October—a seasonality akin to most of the case studies presented—which means that water access was entirely rainfall-dependent, though riverine catchments could permit flow to a limited degree into the dry season. State temples reflected Hindu mythology (e.g., Angkor Wat), "centering on a stepped pyramid that symbolized holy Mount Meru, abode of the gods in the distant Himalayas" (Coe 2008:715). Mount Meru and its five peaks are represented by five towers surrounded by the ocean of milk (moat).

It is important to note that Angkor invested significantly in the implementation of technologies inclusive of wheeled vehicles, metal tools—both bronze and iron—and the sail. Under these historical conditions empire was not only possible, it was realized. Nevertheless, several of the social underpinnings affecting any semitropical society remained (i.e., small community based). A worldview dependent on elaborately ritualized costly signaling (conspicuous material symbols, especially architecture) continued to coordinate and unite the dispersed community "districts" and cultivated the interdependencies of an embedded heterarchy.

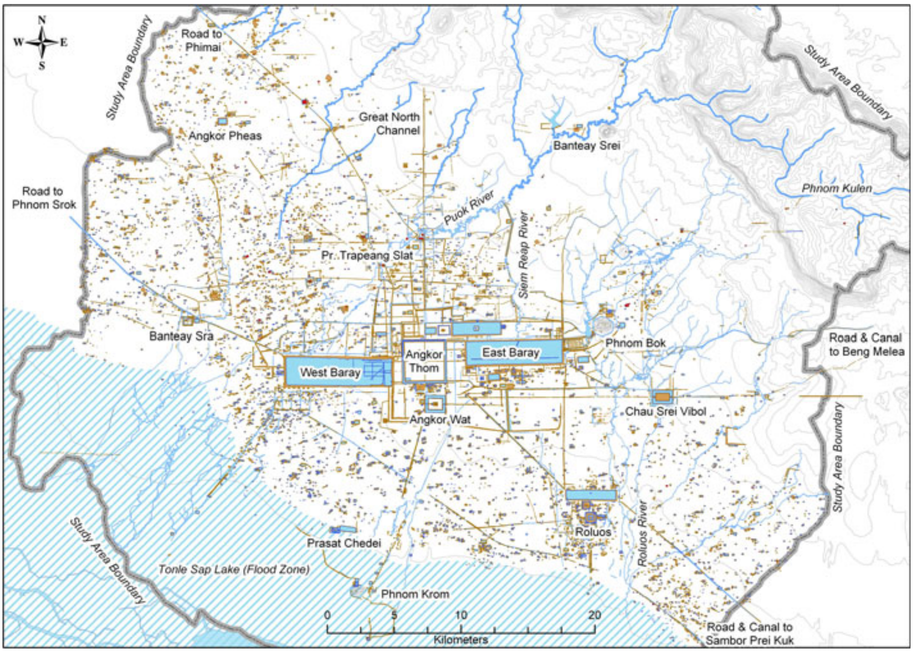

Fig. 3 Angkor water systems. Courtesy of Damian Evans and Christophe Pottier

Maya Lowlands

The Maya Lowlands cover an area of 250,000 km^2, comparable to the entirety of the United Kingdom, with the ancient Maya reflecting longevity of well over 1500 years and conservatively spanning a time from 600 BC to AD 900 without metal tools, the wheel, or beasts of burden. Although several periods were more turbulent than others with the rise and fall of urban-like states, a sophisticated and shared set of socioeconomic and sociopolitical tenets tethered to a deeply embedded worldview underpinned this evolving cultural and regional trajectory of social complexity. The environment was shaped by a karstic topography with dispersed pockets of fertile soils (Fedick 1996; Sanders 1977) and a classic semitropical rainfall regime, the latter suggesting considerable stream development. Nevertheless, the landscape remains characterized by an extremely limited water supply as a consequence of poor lateral surface drainage and the near immediate loss of the volumes of water that percolate into the porous and jointed limestone bedrock—not extractable given the stone-age technologies then available.

Perhaps 40–60% of any given area of the Lowlands is associated with seasonal wetlands, or *bajos* (Dunning et al. 2006), but it remains a moot point concerning the amount of engineering that was actually performed across these surfaces by the Maya (Scarborough and Burnside 2010). We do know that by the Late Preclassic Period (400 BC–AD 200), striking amounts of erosional sedimentation occurred on the flanks of sizable depressions in proximity to early towns and city-like communities. This degradation was induced by highly successful Late Preclassic agricultural populations by way of harvesting the bajo margins and perhaps elsewhere. What precipitated this infilling was what Scarborough has coined "concave microwatersheds," a landscape adaptation that developed when these early sedentism gravitated toward naturally ponded seasonal water sources and the organic resources they afforded (Scarborough 1993, 1996).

To significantly enhance these settings, the Maya built their communities in immediate proximity to these sources, and by quarrying and unearthing tanks and short canal segments they produced a year-round, water-accessible built environment with the excavated fill used to construct their acropolises and pyramids. With time and population growth, forest clearance associated with some form of short-fallow intensive slash-and-burn resulted in significant slope erosion. At this Late Preclassic to Early Classic (AD 200–550) period transition, the first clear evidence for landscape terracing occurs, an obvious reaction to soil loss. Furthermore, the rapidity of the infilling appears to have not only buried the farming margins of the wetlands, but it also interrupted the otherwise elevated water table highly influencing the recharge and containment of many of the usable depressions that held water year-round (Dunning et al. 2003).

The subsequent engineered landscape adaptation was one to higher ground. The movement was from a "concave microwatershed" to a "convex microwatershed," the latter identified with the largest Classic period centers located at the summits of hillocks and ridges near and above the earlier Late Preclassic settlements in proximity to the grand wetland bajos (Scarborough 1993, 2003). The landscape investment was again directed towards the quarrying of stone and earth for the construction of the largest pyramids or palaces, as well as ballcourts, paved plazas, courtyards, and market places. By sealing these quarry scars to retain seasonal precipitation and plastering the many surfaces identifying an "uptown" urban center, the Maya engineered the landscape to divert rainfall and its tremendous quantities of runoff to fill these tanks and reservoirs with water (Fig. 4). During the wet season, rainfall filled these elevated depressions, and access nearly everywhere was overabundant. Nevertheless, during the extended 4–6 months of seasonal

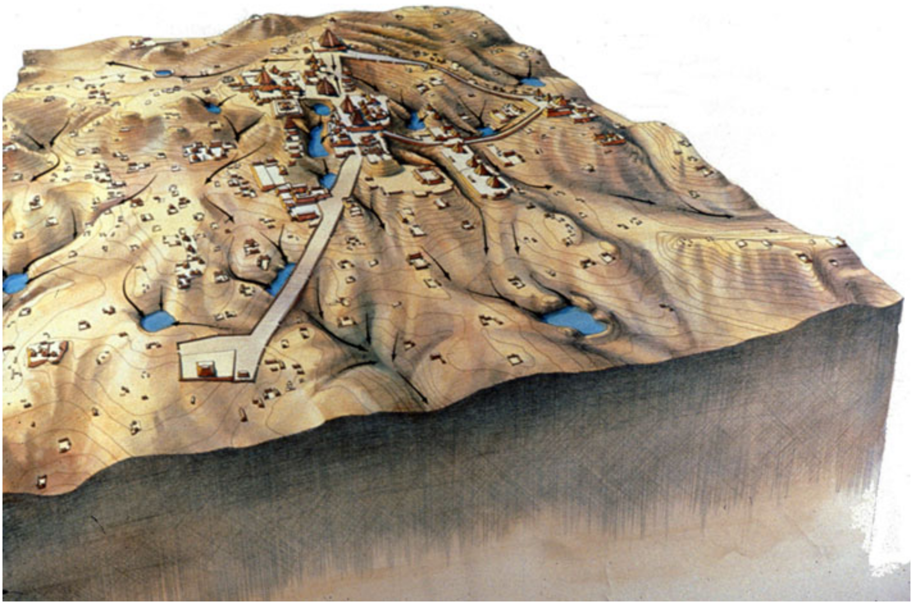

Fig. 4 Tikal reservoirs and drainage systems. Courtesy of Vernon Scarborough

drought, water was secured in the many elevated tanks—several of them of significant scale and capacity (Scarborough and Gallopin 1991). The Maya also had to maintain water quality, which they did through applying the "natural" principles of the wetland biosphere (Lucero 1999, 2011). Because of their elevation, gravity release of their contents during the driest portions of the year supplied much of the core area of an elevated community. The potable source was used to recharge smaller low-lying basins as well as to permit immediate consumption, but once a flow passed through a community it was still harvestable as gray water for agricultural purposes. We have examples where sizable but low-lying reservoirs were positioned to capture and contain these fouled waters and yet further released into adjacent field settings.

Little evidence supports wide-scale, intensive agricultural systems for the ancient Maya. Local ecological conditions, population densities, and water availability impacted the kinds of agricultural strategies used. Maya farmers emphasized diverse strategies depending on local settings, an adaptation conducive to cooperative strategies revolving around wetland cultivation, orchards, house gardens, swiddens, terracing, and forest management (Houston and Inomata 2009:233–237; cf., Berry and McAnany 2007; Lentz 2000; Scarborough 2009). Storage of the major staples of maize, beans, and squash (Atran 1993) would have been problematic in the humid setting, but "Year-around food access likely emphasized rapid food production associated with complex networks of immediate exchange as opposed to centralized and long-term storage" (Scarborough 2008:27).

Of significance is the role of "water districts" as noted in several of the previous examples from semitropical settings. At the site of Tikal, for instance, we have identified six catchment areas enclosing the distribution of runoff during the wet season (Fig. 5). Although only in microcosm, they reveal an organizational parameter posited to have been replicated to varying scales at many sites in the Maya Lowlands. The role of a heterarchical

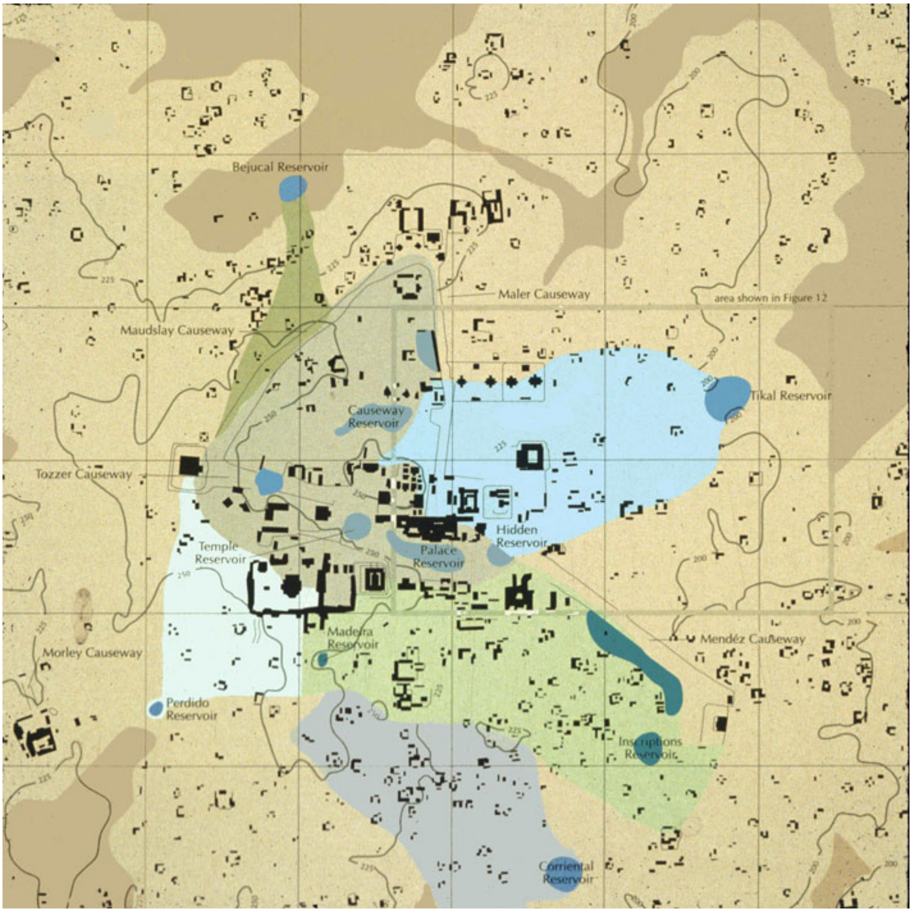

Fig. 5 Potential 'water districts' at Tikal. Courtesy of Vernon Scarborough

order associated with water's limited availability complements Carole Crumley's definition cited above (e.g., Scarborough and Valdez 2003, 2009).

Much has been said about the highly ritualized dimensions of Maya society, with water control and management significantly influenced by these worldviews (Lucero 2003, 2006; Scarborough 1998). Of particular influence is the notion of a "water mountain" that appears with some regularity in discussions of a Mesoamerican ideological concept. In the case of the ancient Maya, it was physically manifested, a place where water source creation was established by way of a "convex microwatershed"—not just metaphorically. Interestingly, centralization of resources does remain a significant concern for any society, and especially for semitropical complex societies affected by a highly dispersed set of biological resources. If a water source might be carved from a karstic landscape by way of creating source, a degree of centralization was established. This metaphor was materialized, perhaps not unlike Mount Meru on the island of Bali and the plains of Cambodia at Angkor.

West Africa

The socioecological processes identified along the Middle Niger inform our discussion of the semitropical case studies. Although located at a latitude comparable to both the Angkor Empire and the Maya Lowlands, the Middle Niger drainage basins of present-day Mali abut the southern reaches of the Sahara Desert—a semiarid setting unlike the other examples treated, with 350–450 mm of annual rainfall. Nevertheless, the meandering course of the Niger River, associated with deltaic deposition up to over 100 km wide, unpredictable flooding and significant environmental risk, precipitated a less studied group of complex societies recently highlighted by the work of Roderick and Susan McIntosh (McIntosh 2005, 2011; McIntosh 1999). Although with a clear focus on the sizable urban-like community of Jenne-jeno, the McIntoshes and their teams indicate that several communities of perhaps 20,000 souls each emerged. Such communities were dispersed along the river's extensive margins due to the presence and concentration of levees for wet season cattle pasturage, rice soils, and basins for dry season fodder foraging, each of which were unevenly distributed. Well-understood population density assessments are unavailable, but the vagaries of the riverine life-support system determined the character of these heterarchically organized communities from 400 BC to AD 1000—a span comparable to that of the ancient Maya prior to their great political fragmentation or collapse. The largest of these settlements, Jenne-jeno, was located in an area with a relatively substantial amount of fertile soils and year-round pasture land.

R. McIntosh makes a compelling argument for the emergence of complex society based on the self-organizing social system acting in concert with the chaotic fluctuations of available land and water. Drawing heavily on climatic and topographic associations through time, a "pulse model" of external forcings—chiefly climate change—is argued to have catalyzed a set of self-organizing principles that proved both resilient and sustainable. Although the McIntoshes seems to play down the fundamental institution of water management by way of dismissing any evidence for large-scale "instillations" (contra Wittfogel 1957), the role of smaller-scale water diversion features cannot be overlooked. R. McIntosh cites Wilkinson's experience from the Near East in noting that channels were not created anew, but were the "result of channel management in which key points such a nodes of avulsion…were the subject of focused teams that cleaned…only those points that required attention (2003:95)" (2005:215). But as mentioned in the Amazonian case, such investments likely changed the environmental parameters for the social system to an extent that communities evolved in novel and complex ways. Of special merit is the role of specialized groups in identifying a greater community and urban-like complexity.

Like most of the case studies developed here—with the clear exception of the Khmer Empire—these ancient, heterarchically organized, West African societies (likely inclusive of the little studied Yoruba area at a comparable period to Jenne-jeno; see Trigger 2003) lacked a sophisticated military apparatus or a steep, pyramidally pitched, hierarchical bureaucracy. Their ethnographic successors are ethnically differentiated and separated by ecological niche specializations, yet integrated through a shared generalized economy of cooperative local and long-distance exchange (e.g., copper and iron are not locally mined). Each group also has a role in an aspect of ritual authority; for example, the first founders, the Bozo, "made the first enduring agreements with the local water spirits…." (McIntosh 2005:112). It is they who maintain relations with the water spirits for everyone.

By way of excavation and survey, the McIntoshes provide a model of social complexity through time in which subgroup diversity and occupational specialization allow a level of complexity similar to that of the ancient Maya or the living Balinese. The role of spatially defined "districts" is again discernible from R. McIntosh's presentations, an apparent emergent property of such corporate units in cooperation with one another—coined as "resource-specialized communities" for the ancient Maya (Scarborough and Valdez 2003, 2009). At present, different ethnic groups specialize, for example, in fishing (Somono-Bozo) and rice farming (Nono/Marka [Soninké]), all "cemented by exchange and alliances" (McIntosh 1999:160).

The significant function of ritual specialists and their elevated role in imposing order over the unpredictable and variable "natural" and artificially altered environs is a fundamental component of these corporate units and their cooperative inter-group functions (again, see the Maya and Balinese examples). The "rain-makers" throughout the contemporary societies of sub-Saharan Africa are a testament to these ritualized corporate units and their unifying community influence even today (Scarborough 2011).

Discussion

Diverse, dispersed resources and unpredictable rainfall (seasonal timing, too much or not enough) together result in a landscape blanketed by a patchwork of communities that develop specialized activities and subsistence strategies in the context of a socially cooperative mode for accessing the fruits of specialized labor (vs. technological innovations). This complex web of interacting and intersecting groups pulsates with the varied and numerous directions through which information, knowledge, and goals are transmitted or achieved. And all this happens without absolute rulers, without a hierarchical guise. Rather, it is a "network of equals" (McIntosh 2005:204) organized under heterarchical principles. By cooperating and organizing in this manner, groups make day-to-day decisions at the local level that have broad ramifications. As these cases demonstrate, we see the emergence of a sustainable and resilient, low-density urbanism with less overt hierarchy; cooperation without deeply entrenched competition or conflict. The developing social structures incorporate complex networks of human engagement, but not complex technology per se. Specialized labor pools and supra-community interaction are key to such sustainable and resilient systems, evidenced, for example, by the continued availability of wild flora and fauna for human consumption (vs. large-scale biodiversity loss) (cf., Piperno and Pearsall 1998).

A major and common theme among the five cases is water availability. While reservoirs and raised fields (and other means of wetland cultivation) define the engineered landscape, the societies discussed are rainfall-dependent. Much effort can be expended to build reservoirs, but with little water (precipitation) to fill them such efforts are moot. Furthermore, since the cases discussed rely less on technology and more on labor to produce staples, these societies frequently need more land/landscape to produce the necessary surpluses in maintaining their complex networks—another feature that favors a dispersed settlement pattern. The vagaries of too much or too little precipitation are countered by labor's self-organizing investments in the engineered landscape and the flexibility of societal network scheduling. Rain gods, after all, can be unpredictable and capricious; societal intervention is the only corrective.

While each subgroup in a regional case study is identified by its own set of microenvironments, a common and universal need is that of access to adequate amounts of water, whether for immediate domestic consumption, agricultural ends, or collective corporate construction projects. Water in the semitropics, however, can take on an especially deleterious significance due to the humidity and consistently warm temperatures that do not kill carriers of diseases and thereby enhance the viability of water born maladies.

Globally, water serves as the vital source around which communities settle and define their place in the world. The preciousness of the resource frequently acts as the principal force in unifying a community and structuring many of its activities. For example, based on the distribution of water systems and iconography, Fash and Davis-Salazar (2006) propose a similar institutional organization around water sources for the Precolumbian Maya as Vogt (1969, 1981) describes among the Zinacantan Maya of Highland Chiapas today. Within the Zinacantan Maya, several linage-based corporate groups (*snas*) come together to form larger collectives centered around a water source where each *sna* has a role in making the necessary offerings and maintaining the source as designated by an elected head of the "water hole group." These water hole group districts or communities become the core from which the Zinacantan Maya engage with others.

Among the case studies, urban-like centers or simply sizable aggregates of people co-evolve with their subcommunities—or water districts—in integrating the different resource spheres and providing scheduled forums for interaction, material exchange and the promotion of inter-community relationships. Absolute hierarchies are thwarted by equalizing ideologies expressed via myths, folktales, and other creeds kept in the forefront by ritual authorities and sacred rules of landscape usage. Conflict is avoided since each group relies on one another. Non-hierarchical complexity is attained; that is, heterarchy or a complex system of (near) equal networks integrates the low-density agrarian urban-like landscape and resists the emergence of hierarchical systems that interfere with local adaptations.

There are still clear differences among the five cases; Maya and Balinese kings "ruled" over ritual-political domains, while the Khmer king truly acted as sole ruler. These hierarchical systems, however, were superimposed on and did not subsume heterarchical systems. The major difference between centralized and hierarchical versus decentralized and heterarchical systems to the Balinese or Maya farmer/producer/specialist was that the latter contributed more of their labored material resources at scheduled times and set places to one another than they would in a more traditional definition of the State. Although the semitropics force a dispersed resource base, they accommodate a wealth of resource diversity that when tapped and directed to human societal ends can be exceptionally productive and long lived. If permitted to self organize on a landscape over many generations, a set of incremental changes evolve in producing a "loose knit glove fit" between society and the environment. Water use and management is the principal means to accommodate this kind of societal sustainability.

Concluding remarks

We have attempted to explain how people organize in semitropical environments. The case studies illustrate several self-organizing principles with the ultimate outcome of a sustainable way of living. The mechanisms of cooperation are varied and complex, and revolve around aspects of water access as well as a diverse set of biophysical resources spread throughout the landscape. Consequently, people settle and frequently identify themselves by way of their water sources. Specialized communities emerge and exchange their knowledge and goods with groups in other resource areas at set times and places. Central nodes or urban-like centers co-evolve with their environs to bring people together for community integrative events and spiritual fulfillment. Participation in these developing institutions promotes group identity beyond the specialist group, a critical requirement where people lived dispersed across the landscape.

One assumption laid to rest in these cases is a "tragedy of commons" (Hardin 1968) assessment for a semitropical wetlands resource—inclusive of intensive rice cultivation. The notion that a collective good—like water—will be compromised by way of its diversion or consumption by one group in excess of its benefit to others is the essence of this economic tragedy; a logic based on self interest and diminishing returns associate with poorly conserved supplies. We posit that in some semiarid settings where formal and extensive irrigation initially occurs, a greater tendency toward this kind of commons' tragedy develops; it requires significant investments in top-down controls—hierarchy—and a bureaucracy to oversee and police the highly limited water resource. For example, a distant feeder canal branching from a major trunk canal is easily left flowing without continual monitoring, an illicit diversion costing the commons. Clearly, the origins of hegemonic state are more nuanced and complex, but these biophysical environments and the societies that occupy them are different from those identified by our case studies.

Semitropical settings with reclaimed wetlands are preadapted to more communal sets of interdependencies as repeatedly noted by those "resource-specialized communities" specifically identified both in the Maya lowlands and the West African example—a condition we suspect is more widespread. Water saturated soils require constant work to buttress field platforms, with frequent dredging events to accommodate proper water levels and sediment renewal back to the elevated agricultural plots—to say nothing about drainage gradients and heightened pest controls in these seasonally water abundant settings. Because water in a wetland is a naturally available resource less dependent on some faraway source—a condition of semiarid irrigation systems–water is an immediately shared collective resource in proximity to a set of neighbors that can rapidly assess overuse or harmful use of the medium and the growing platforms it circumscribes. This and related semitropical water harvesting systems inclusive of point-specific reservoir maintenance suggest a different level of community association, cooperation, and interaction than apparent in semiarid settings generally (Scarborough 2007).

Among those assessing "common-pool resources" (CPR) are those that identify restricted versus open access to certain common good(s) (Ostrom 1990, 2009; cf., Smith and Wishnie 2000). Broadly speaking, restricted access resources like semiarid water access are more conducive to sustainable use when degrees of government monitoring are imposed. Open access resources like wetlands—and especially prior to the Industrial Age—are more difficult to control and oversee by way of central authority, and in our case studies they suggest the role of self organization and the development of complex networks based on environmental and social interdependencies.

While self-organizing groups are found in semiarid and temperate zones of the world, the semitropics as defined by variable seasonal precipitation, dispersed, and critical biophysical resources, limitations in large-scale storage facilities, and complicated scheduling demands do and did provide a setting conducive to low-density urbanism and concomitant social networks. Hierarchical political systems are less prevalent and entrenched because of the manner by which people live within and across the landscape (versus concentrated settlement adaptations in proximity to the Nile, Tigris-Euphrates, Indus or Huangho rivers and associated with the first great archaic states). In short, self-organizing heterarchical systems revolving around water and cooperation have proven inherently flexible, resilient, and sustainable over the long-term.

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