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Water and Landscape: Ancient Maya Settlement Decisions

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ABSTRACT

In this chapter we present the major transitions in Maya history from the Late Preclassic through Terminal Classic periods in the Maya Lowlands, focusing first on major settlement and subsistence systems, followed by major social and environmental costs. We particularly focus on how the Maya built and relied on increasingly complex water and agricultural systems to adapt in the humid tropics where everything in life was rainfall dependent. The seasonality of rainfall required innovative strategies to contain water throughout the long dry season in the face of growing population and socio-political complexity. Drastic changes occurred when several prolonged droughts struck the Maya area, resulting in them exploring new areas and subsistence practices. The chapter concludes with a few thoughts on how understanding ancient Maya water and land use is relevant for today's issues regarding sustainable land and water use. [settlement patterns, water management, seasonal issues, agricultural strategies, climate change]

The ancient Maya lived in a diverse tropical setting with dispersed pockets of soils suitable for agriculture, differential water resources, noticeable seasonality, and an abundance of floral and faunal species. Everything in Maya society was rainfall-dependent, especially agriculture. Timing was crucial, including predicting when the rainy season would start, which is also the onset of intensive agricultural activities. Because of these characteristics, water and agricultural land availability impacted how people lived, built, and moved across the landscape. They also meant that the Maya were more susceptible to major shifts in seasonal or long-term rainfall patterns. To compensate for seasonal vagaries and differential soil distribution, the Maya engineered features that provided access to, control over, and improvement of water and soil resources from small-scale household systems to massive and intricate ones in centers. Reservoirs were particularly critical in the 4–5 month annual dry season, especially in areas without

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permanent surface water and, in many instances, low water tables.

In this chapter, we touch upon the transitions in Maya history, and then briefly present the social and environmental costs of the growing reliance on an engineered landscape. We conclude with a few thoughts on how understanding ancient Maya water and land use is relevant for today's issues regarding sustainable land and water use.

Transitions in Maya History

Late Preclassic to Late Classic

In the southern Maya Lowlands, the Maya started migrating into interior areas such as the Petén in Guatemala from riverine or coastal areas in the Early Preclassic period by ca. 1000 B.C.E. (Ford 1986:59, 80–82; Wahl et al. 2006). They moved into areas with fertile agricultural land and little surface water, which presented particular challenges, especially during the long dry season. The dry season in the southern Lowlands, usually from January through May, transforms the landscape into a green desert where it might not rain at all for several months, and where temperatures and humidity noticeably climb (see Graham 1999; Scarborough 1993). Although this season involved few agricultural tasks, the Maya still needed water for daily drinking needs, cooking and food preparation, plaster manufacture and ceramic production, as well as other domestic and production activities (e.g., Marcus 2006). The length and intensity of the rainy and dry seasons also are important variables that impacted agricultural schedules and strategies. The beginning of the rainy season can vary up to five weeks in any given area, and the annual amount of rainfall can vary 30 to 40 percent ranging from 1350 to 3700 millimeters (Gunn et al. 1995; Gunn et al. 2002; Scarborough 1993). Adequate amounts of rain are vital for crops, especially since the major staple of maize is a relatively thirsty plant compared to staples grown elsewhere such as millet and sorghum (Vince 2010).

Tikal and its environs provide an excellent case to illustrate the intricate relationship between water availability, fertile land, and settlement decisions (see Figure 1.2 in chapter 1 for map with major areas and sites mentioned). Relative to other regions, this polity has a noticeable amount of dispersed agricultural soils, but limited water sources (Ford 1986, 1996). It, like other regional capitals such as Calakmul and many other centers without permanent water sources, was surrounded by *bajos*, or seasonally inundated swamps. Forty to 60 percent of the southern Lowlands consists of wetlands, mostly bajos (Dunning et al. 2006), and the Maya exploited them for agriculture, fishing, and hunting (Scarborough 2006). While some bajos were perennial wetlands, many were seasonal (Dunning et al. 2006). In some bajos, the Maya practiced flood–recession agriculture, indicated by the noticeable number of terraces and berms along their margins, as well as terracing, to avert soil loss (Beach et al. 2008; Kunen 2006; Scarborough 2006).

To offset seasonally limited water supplies, the Maya built water retention systems (Scarborough 1993; see Scarborough 2001:354). By the Late Preclassic period (ca. 300 B.C.E.–C.E. 250), these systems included wetland reclamation adaptations (e.g., Cerros, Belize) and "passive" or concave micro-watershed systems where the Maya took advantage of the natural landscape, namely depressions, as found at the major Preclassic center of El Mirador in the Petén (Figure 3.1; Scarborough 1993, 2000). A growing concern would have been increasing sedimentation into these low-lying, gravity-driven water systems due to erosion.

By the Early Classic period (ca. C.E. 250–550), population growth led to a growing reliance on increasingly larger artificial reservoirs, a trend that continued into the Late Classic period (ca. C.E. 550–800) when water systems were further augmented in size and scope. These sophisticated engineered reservoir systems are epitomized by elevated convex micro-watershed systems whereby reservoirs, dams, channels, sluices, filtration systems and switching stations were designed to capture, store and distribute water as seen at, for example, Tikal and Caracol (Figure 3.2; Scarborough 1993, 2003:50–51, 2007; Scarborough and Gallopin 1991; Scarborough et al. 2012). Gravity release of water during the dry season supplied water to urban center inhabitants in lower–lying settlements (Scarborough 2003:110–111). As the dry season wore on and water levels dropped and water quality worsened, the Maya diverted gray water into agricultural fields and holding ponds for other purposes including fishponds, ceramic production, and plaster manufacture. The entire system depended on adequate rainfall and maintaining water quality, especially in the core reservoirs (Lucero 1999; Lucero et al. 2011).

The need for potable water was critical in the tropics where people can lose up to 10 liters per day sweating and thus require more water than their counterparts living in temperate areas of the world (Bacus and Lucero 1999). Maintaining water quality in the humid tropics presents challenges, especially since standing water provides prime conditions for both water-borne diseases and disease carriers such as mosquitoes (Burton et al. 1979; Miksic 1999). To maintain water quality in reservoirs, the Maya applied their understanding and knowledge of wetland biosphere systems by introducing a balance of macrophytic and hydrophytic plants, as well as other organisms such as fish (Lucero

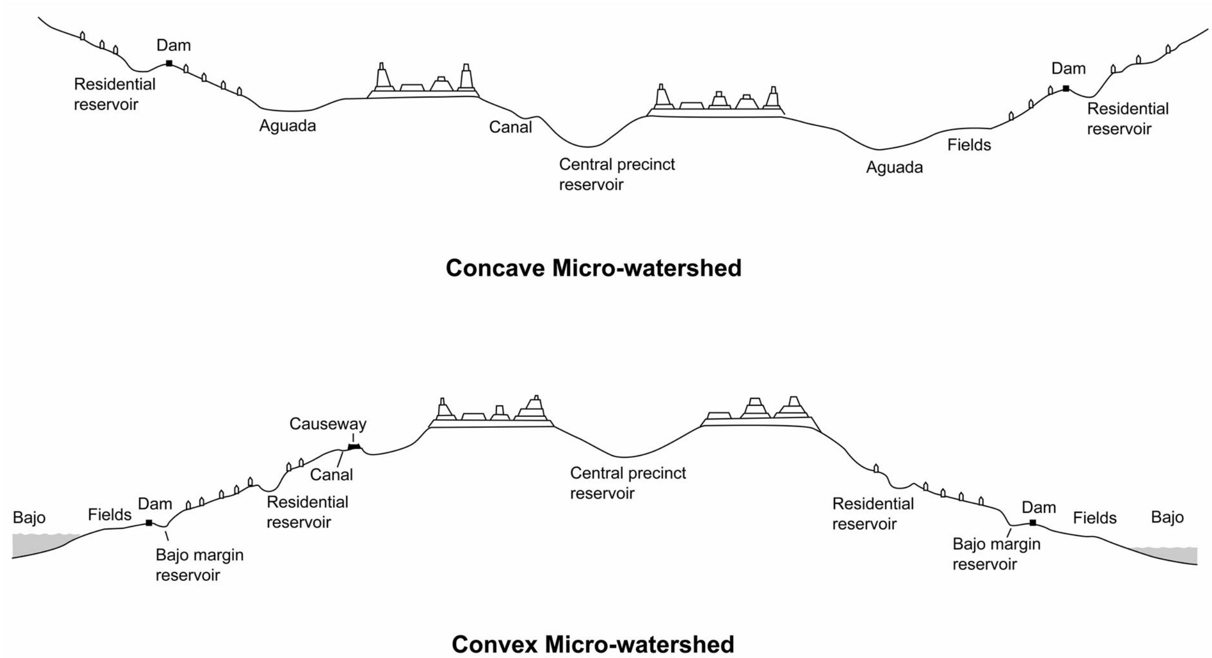

Figure 3.1. Schematic of concave and convex watershed systems (courtesy of V. Scarborough).

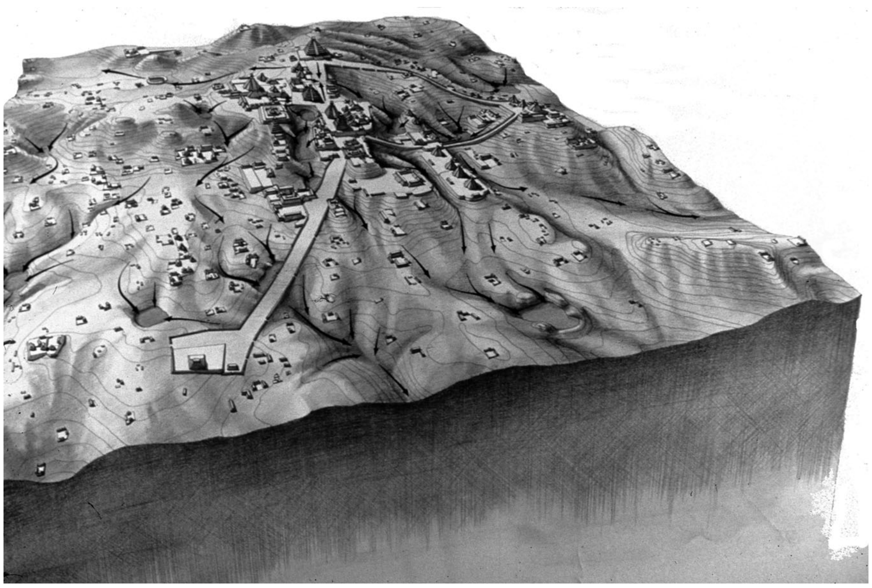

Figure 3.2. Tikal and its reservoirs (courtesy of V. Scarborough).

1999). Associated bacteria, along with a certain amount of algae, together purify water since plants absorb phosphorus and nitrogen, elements that accumulate in standing water (Hammer and Kadlec 1980; Nelson et al. 1980). For instance, investigations of both urban and hinterland reservoirs at the Petén sites of San Bartolo and Xultun indicate that the Maya went to great lengths to secure clean water, including investing in plaster linings in some reservoirs and siltation tanks in others fed by surface runoff (Akpinar-Ferrand et al. 2012).

Because a major role of kings was providing clean water to their subjects, it is not surprising that royals highlighted the association between their power and clean water in the iconographic record, especially via water lilies (Finamore and Houston 2010; Lucero 1999; e.g., Rands 1953:figures 3.1–6). Water lilies, *Nymphaea ampla* (Salisb.)

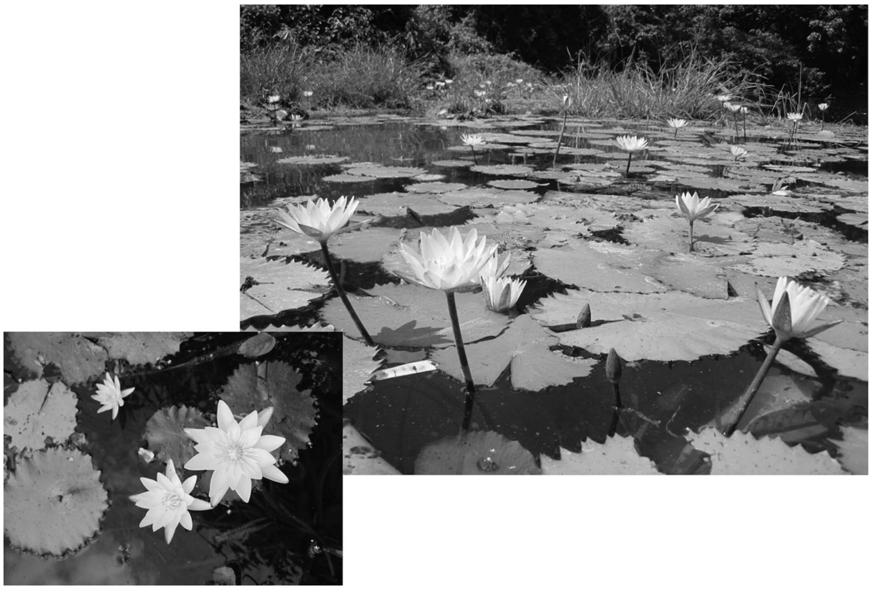

Figure 3.3. Water lilies at Cara Blanca (photo by L. J. Lucero).

DC., on reservoir surfaces actually indicate clean water because they are sensitive aquaflora that require specific conditions to flourish, including relatively shallow depths (1–3 meters) of still, non-acidic water without too much calcium or algae (Figure 3.3; Conrad 1905:116; Lundell 1937:18, 26). Their significance is also highlighted in many inscriptions, where *Nab Winik Makna*, or water lily lords, refers to Maya kings (Ford 1996), while *Ah Nab* refers to Maya nobility as water lily people (Schele and Freidel 1990:94). As we discuss below, significant changes in rainfall patterns had major repercussions for Maya rulers because of the close relationship between water and power in Classic Maya society.

People living in centers located along rivers also built reservoirs for a steady supply of drinking water, as rivers were not always reliable sources of potable water. At the height of the rainy season, the rains churned up sediment (e.g., Davis-Salazar 2003; Fash and Davis-Salazar 2006), while at the height of the dry season, rivers became low, murky, and disease-ridden (e.g., Houston 1998). We should note that in certain situations the Maya built water systems, such as aqueducts and canals, to divert water away from monumental architecture and living areas, as was the case at Palenque. This major center has over 50 streams and springs, not to mention a higher than average annual rainfall exceeding 3600 millimeters (French 2002; French et al. 2006). Evidence also suggests that farmers constructed irrigation canals on the plains below to take advantage of the abundance of water (Barnhart 2001:101; Liendo 2002). In most cases, however, the main goal of water systems was to contain water during the dry season.

In the northern Lowlands, we find a different situation which has to do with its higher water table and thinner soils. For instance, in the Yalahau region of the northeast Yucatán Peninsula, water was readily available in freshwater wetlands, wells that tapped into an abundant freshwater aquifer, and *cenotes*, or steep-sided sinkholes fed by the relatively high water table (Brown 2006). During the Late Preclassic, the Maya extensively modified the wetlands with rock alignments to manage soil and water. The Maya likely tapped the Yalahau wetlands for recession agriculture for domesticated crops, or alternatively for the management of economically important wetland plant and animal species, or as a source for biofertilizer transported to upland gardens (Fedick et al. 2000; Fedick and Morrison 2004). Rising water levels in the Early Classic may have actually contributed to the abandonment of wetlands because there might have been too much water.

Settlement was widespread across the northern Lowlands during the Late Preclassic, with numerous settlements dispersed to take advantage of natural water sources, chiefly cenotes, tracts of higher quality soil, and coastal resources such as salt (Glover and Stanton 2010). While many Preclassic sites were abandoned for unknown reasons by the onset of the Early Classic, including many Puuc centers (Smyth et al. in press), the region as a whole was not completely depopulated. Settlement was sparser in areas such as the Puuc Hills with few natural water sources, but some small and a few large Preclassic centers emerged, including Xcoch and its elaborate system of rain–fed reservoirs (Dunning, Weaver, et al. in press). However, Xcoch exhibits a period of abandonment early in the Early Classic, perhaps related to a period of increased aridity that even its elaborate reservoir system was unable to overcome (Smyth et al. in press).

In summary and in general, the major transition between the Late Preclassic and Late Classic consisted of the Maya successfully having met increasing land and water demands in areas without adequate sources of surface water.

Late Classic to Terminal Classic and Beyond

In the Terminal Classic period (ca. C.E. 800–1000), people no longer could rely on artificial reservoirs in the southern Lowlands because of increasingly frequent multiyear droughts, especially between C.E. 800 and 930 (Medina-Elizalde et al. 2010); ultimately, and through varied trajectories, the Maya largely abandoned major centers. Those Maya who did not leave the southern Lowlands lived in small communities near permanent water sources including the Belize River valley, wetland areas in northern Belize, nearby lakes and rivers in the Petén, and coastal areas in general (e.g., Demarest et al. 2004; Lucero 2006b; Lucero et al. 2004; McAnany et al. 2004; Mock 2004; Willey et al. 1965:292). Living near coasts provided Maya access to marine resources and maritime trade routes as evidenced in the emergence and growth of trade ports (Sabloff 2007). The Maya also practiced wetland agriculture along slow–moving rivers and near shallow lakes.

In the northern Lowlands, surface water was always severely limited due to its relatively small number of *aguadas*, lakes, small springs, and cenotes (Matheny 1982). However, Uxmal, a Late and Terminal Classic center, had at least 13 reservoirs within its sprawling urban area that undoubtedly were an important factor in its explosive growth and the construction of massive monuments in the site core between C.E. 870 and C.E. 910 (Dunning and Beach 2010). While household cisterns were vital to the Maya in the Puuc, urban reservoirs were also employed at some northern sites from an early date (Carmean et al. 2004; Dunning, Weaver, et al. in press; Isendahl 2011).

These apparent limitations in the northern Lowlands did not prevent the Maya from building large centers; nor did they prevent the Maya from migrating from the south into this area. For example, people moved to Chichén Itzá in the Terminal Classic (ca. C.E. 800–1000); it has two major cenotes, one within the site core and the other located at the end of a causeway 400 meters to the north (Sharer and Traxler 2006:562–565). Occupants of Chichén Itzá also benefitted from opportunities in trade and other production activities (Cobos Palma 2004). Maritime trade in subsistence (e.g., salt) and prestige goods became increasingly important (McKillop 1995, 1996). Areas in the Yucatán peninsula, such as the southern areas of Quintana Roo, incorporated the use of irrigation canals to support the growing immigrant populations (Carmean et al. 2004). Interestingly, the Yalahau region of northern Quintana Roo remained virtually vacant through the Late Classic period, despite an abundance of readily available fresh water (Glover 2006).

At Edzná, located along the Río Candelaria in Campeche, the Maya built complex water management systems consisting of extensive canals, reservoirs, and a moat (Forsyth et al. 1983). While built sometime in the Late Preclassic, the Maya used them through the Terminal Classic period. Of the 29 known canals, the most impressive is the Great Canal; it is over 12 kilometers long, up to 50 meters wide, and ca. 1.5 meters deep (pp. 68, 73, table 30). However, Doolittle (2006:6) argues that most of these supposed water systems, other than the Great Canal, are natural geological formations called grikes, or "solution-enlarged structural joints found in karstic landscapes."

In southwest Yucatán, the Maya constructed ridged field systems (ca. 1.5–2 square kilometers in area) and hundreds of canals one to two kilometers in length along the upper Candelaria (Seimens and Puleston 1972). The challenge is dating them since they could have been constructed by 15th–16th century inhabitants of Acalan, or from earlier time periods based on ceramics dating to ca. C.E. 800–1200. Some of the linear features may also have served as fisheries, which also have been found in northern Belize and northern Veracruz (Siemens 1996).

In summary and in general, the major transition between the Late Classic and Terminal Classic periods and beyond consisted of a move away from the interior southern Lowlands out towards coastal and riverine areas and to the northern Lowlands where the Maya could access a different suite of resources and participate in commerce and trade.

Environmental and Social Costs

Late Preclassic to Late Classic

To appreciate the environmental and social costs experienced in the Late Preclassic through Late Classic periods, it is important to reiterate the fact that many people relied on large scale artificial reservoirs in areas with and without permanent water sources (e.g., Ford 1996; Lucero 1999, 2006a, 2006b; Scarborough 1998). The social costs of an increasing reliance on artificial water systems include spending more time and labor constructing and maintaining them coupled with a growing dependency on water systems ostensibly controlled by others. As population densities grew and mobility decreased, the Maya faced increased uncertainty as they became more dependent on engineered landscapes.

Major environmental costs include the impacts from increasing population spread and growth, as well as landscape modification and transformation (e.g., diverting water, trapping soils). Evidence from Tikal (Lentz and Hockaday 2009), Aguateca (Lentz et al. 2014) and the Belize River valley (Lentz et al. 2005) indicate that a growing Late Classic population was associated with an increased demand for forest products in many areas of the Maya Lowlands. Accumulating evidence shows that widespread tropical forest clearance can impact local hydrological cycles, weaken precipitation recycling, and influence rainfall patterns (D'Almeida et al. 2007). In addition to the hydrological impact, reduced forest cover results in greater water run-off and concomitant erosion. In parts of the interior southern Lowlands, soil erosion and sedimentation exacerbated by drying conditions tainted some of the bajos and other water sources (Dunning et al. 2006). All of these factors increased noticeably through the Late Classic when population reached its height, particularly in areas without much surface water (e.g., around Tikal, Caracol, Calakmul).

Some archaeologists suggest that the Maya used sustainable agricultural practices that did not involve monocropping or environmentally destructive practices (Fedick 2003, 2010; Ford 2008; Ford and Nigh 2009). Increasing evidence also suggests that the Maya practiced some degree of sustainable forest management to offset overuse and limit deforestation, for example, through creating "forest gardens" (Ford 2008). Preliminary analysis of botanical samples collected in the tropical forests of central Belize in areas with and without sites suggests that the Maya modified their surroundings by removing some non-beneficial tree and plant species, adding beneficial domesticated ones, and maintaining useful non-domesticated species (Lindsay 2011; see also Ford and Nigh 2009; Lentz et al. 2002; Ross 2011; Ross and Rangel 2011). In conjunction with terraces, raised fields, and other agricultural features, the landscape, if not completely engineered, was significantly modified (e.g., Fedick 2010; Robin 2012). In fact, Gómez-Pompa (1987) hypothesizes that the forest at present actually is a descendant forest reflecting pre-Columbian forest management.

Analysis of pollen from sediment cores collected from cenotes, lakes, and aguadas (rain fed natural sinkholes) provide evidence for both deforestation and forest management (e.g., McNeil et al. 2010; Mueller et al. 2010). For example, analysis of a sediment core from a cenote at Cara Blanca, central Belize dating between C.E. 550 and 1730, has identified pollen from the family Poaceae, which includes grass species such as bamboo (*Merostachys* sp.) and *Paspalum* sp., among others (Lucero and Lindsay 2013). The most common species, however, is *Zea mays*, or maize. The Asteraceae family, also present in the core, includes flowers and other "composite species," both indicative of a cleared landscape. Common tree families, however, are still present; for instance, Moraceae, or flowering trees such as figs, as well as Melastomataceae and pine (*Pinus* sp.). At ca. C.E. 1730, the core still contains abundant Poaceae, but few *Pinus* sp. grains. Aguadas near the sites of San Bartolo and Xultun, Guatemala also produced pollen demonstrating significant land clearance in the Late Classic, but with sizeable amounts of arboreal species still present, including economic species such as Sapotaceae and *Spondias* (Akpinar-Ferrand et al. 2012).

Indications are that the landscape was both cleared and managed throughout the Classic period, though the extent of deforestation and forest management is yet to be completely unraveled. There is little doubt that we are dealing a complex mosaic of local responses to subsistence needs, which makes sense given the diverse and dispersed resources.

Late Classic to Terminal Classic and Beyond

Growing demands for agricultural and drinking water combined with several prolonged droughts (Hodell et al. 2007; Medina-Elizalde et al. 2010) resulted in a population decline over the long-term, especially in interior areas without much surface water. The droughts set in motion events (e.g., crop failure, depletion of reservoirs, decreasing water quality, social upheaval, political factioning, etc.) that ultimately resulted in the Maya abandoning centers and kings in search of areas with more reliable water sources, including rivers and coasts (Lucero 2002). These events culminated not only in rulers being unable to provide adequate food supplies and clean water to their subjects, but also in them being unable to maintain their seats of power. Kings thus eventually disappeared in the southern Lowlands.

A major social cost was that many farmers in the southern Lowlands had to leave their homes to find more suitable areas to support their families. Those who moved north likely had to negotiate with well-established occupants and live in denser communities due to the distribution and limited nature of water sources and thinner soils. Immigrants still were obligated to "pay" for access to some resources in areas into which they moved since other Maya groups had been living there for centuries. Newcomers, however, found diverse economic opportunities, including exploiting salt pans and participating in commerce and maritime trade. They also found a completely different political system—one that emphasized shared leadership rather than individual kings, as suggested in the archaeological record that lacked funerary temples and centralized palaces; and in the iconographic record that de-emphasized kings and instead highlighted the gods, a complete reversal from the Late Classic (Sharer and Traxler 2006:544–569).

The major environmental cost in the southern Lowlands was the repercussions of several prolonged droughts on crops, forests, and water resources. Small groups of farmers continued to live in the areas adjacent to the more dependable aguadas at Tikal (Dunning, Griffin, et al. in press) and likely used the un-maintained center reservoirs as well—after all, archaeologists a millennium later relied on these same reservoirs at both Tikal and Caracol. Some areas were impacted more by overexploitation than others, especially those with limited resources at the outset. For example, the populace at Tikal, which relied almost entirely on rainfall to recharge reservoirs and grow crops, was living close to the carrying capacity of its extractive zone given the available technology and the population it supported during the Late Classic period (Lentz et al. in press). Erosion has been noted in several areas of Tikal, particularly in the bajo margins (Dunning, Griffin, et al. in press). When the droughts of the 9th century became manifest, all of the resiliency had been wrung out of the landscape and the polity was no longer able to support its expanded population.

Copán in Honduras demonstrates a case with a different type of limited resources. The alluvial soils around the site core are concentrated within a 24 square kilometer area, which itself is surrounded by steep hills (Webster 1999). Copán's occupants extracted timber from both pine-oak forests and tropical deciduous forests as paleoethnobotanical studies (Lentz 1991) and sediment core analyses indicate (Fedick 2010; McNeil et al. 2010). These forestry activities likely contributed to bouts of erosion and environmental degradation in susceptible areas (Abrams and Rue 1988).

Severe droughts at the end of the Classic period ultimately resulted in drastic environmental and social costs, especially in parts of the southern Lowlands. In spite of this fact, the Maya adapted by exploring new areas for commerce and trade opportunities.

Discussion and Concluding Remarks

Our concluding remarks highlight some of the main topics discussed in the context of Maya land use and water management, and their implications regarding coping with similar issues today. Needless to say, the story is not as clear-cut as we might hope, especially regarding the quality and quantity of water sources. The Maya have been adapting to this semi-tropical region for millennia quite well, including moving into new areas and identifying sustainable water sources such as springs, lakes, rivers, streams, and aguadas.

Their social, political, and religious life revolved around water. When the dry season became acute in areas without much or any surface water, such as the elevated interior regions of the southern Lowlands (Dunning et al. 2012), they relied on artificial reservoirs found in nearly every major center and maintained water quality by creating their own wetland biospheres (Lucero et al. 2011). No matter the kind and scale of water systems, they were rainfall-dependent. Surviving annual and regional variation in precipitation was a universal challenge since nearly all agricultural production was rainfall-dependent. Yet they adapted and adopted sustainable agricultural practices that have withstood the test of time for millennia.

A vast portion of the northern Lowlands contains aquifers with water tables high and sizable enough to readily access by hand-excavated wells. This was not the case in the southern Lowlands where the water table is generally unreachable with hand-excavation technology. One only has to consider the 1960s University of Pennsylvania and Guatemalan archaeology project at Tikal where archaeologists abandoned mechanical well digging at ca. 180 meters below the surface when they failed to hit water, and instead turned to the ancient Maya reservoirs to meet their water needs (Siemens 1978). Nevertheless, little attempt has been made in the southern Lowlands to look for perched aquifers and their associated springs and shallow water tables. A perched aquifer is situated at a shallower depth than the permanent groundwater table, and is typically created by the presence of an aquitard, or relatively impermeable layer within the bedrock strata. There is also the question about community or household water storage systems, including small natural and artificial depressions, used to supply water year-round in the southern Lowlands (e.g., Weiss-Krejci and Sabbas 2002). However, a major concern with small–scale systems would have been evaporation and decreasing water quality as the dry season wore on. Yet to the north in the Puuc area, the Maya constructed household-scale, potable water cistern systems (Isendahl 2011).

We need to rethink our notions about water scarcity in the Maya Lowlands, and explore why there was such apparent variability in options and resilience when faced with water shortages. Clearly there are complex and multidimensional issues that came into play when adapting and surviving in the humid, seasonal tropics. The fact that the Maya did so quite well has relevance for unraveling long-term solutions to current problems regarding water and landscape use.

One of the most challenging questions when discussing water and landscape use is how to reconcile the noticeable array of systems found in the Maya Lowlands today and in the past. Understanding how these seemingly incongruous features are linked can help us in understanding and addressing today's problems in the face of global climate change. After all, no matter how diverse things have been, there is no doubt that farmers persevered and continue do so at present; there are lessons here that we are getting closer to revealing. In fact, the Intergovernmental Panel on Climate Change (2007) recommends expanding rainfall harvesting, storage, and conservation to offset the impact of global climate change—something the Maya accomplished for at least a millennium (Lucero in press). Some of the strategies we have presented here might be useful today, especially at the community level.

From small to large-scale water systems, the Maya adapted to living in the humid semi-tropics. How they accomplished this feat varied depending on local factors and variable strategies used for long-term success, even when faced with the seasonal vagaries of too much or not enough rainfall (Scarborough and Lucero 2010). A final lesson with which we can leave readers is the knowledge that no matter the type and scale of water features, local social networking, engagement, and interaction were key to keep the system working.

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