Cambridge University Press
978-1-107-02793-0 - Tikal: Paleoecology of an Ancient Maya City
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1

Tikal Land, Water, and Forest: An Introduction

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The towering temples of Tikal have become icons of ancient Maya civilization, luring tens of thousands of visitors annually to experience their jungle-shrouded mysteries. Thanks to decades of careful archaeological investigations and epigraphic translation of ancient texts, we now have a good grasp of the human history of this once-glorious Maya city, especially as seen through the eyes of its rulers who commissioned its monumental art and architecture. If one stands atop one of the city's pyramids today, only a few of the largest temples and palaces stand out clear of the forest. The hundreds of more humble residential complexes that sprawled across the hills and valleys are invisible. To the south the forest spreads to a horizon marked by a range of conical hills, the Serranía Macanche, overlooking the central Petén lakes beyond. To the north the forest blankets a rolling landscape and a prominent escarpment marking the outer edge of the Mirador Plateau. To the west and east the land drops away into deep, convoluted basins, or *bajos,* that hemmed in the flanks of the ancient city. In September, this landscape is a lush green, often steaming with recent rains. In March, the green has waned, the taller trees are barren of leaves, and browns and grays mix with a dulling green. Such is the pulse of life in the seasonal wet/dry forest of the Maya Lowlands.

For the ancient inhabitants of the interior of the Maya Lowlands, the annual oscillation from wet to dry season was of critical importance. A delayed onset of rains, or a prolonged or severe canicular drought, could play havoc with crop production as well as the necessary annual "harvest" of water. For not only was the agricultural system that supported Tikal dependent on rainfall, a lack of substantial and dependable surface water sources made the collection of rainwater a requisite of urbanization and survival. Longer-term droughts threatened the survival of the city and its inhabitants. Crops failed. The productivity of forest resources waned. And the life-sustaining reservoirs would dry.

What did the rulers of ancient Tikal see when they looked across this landscape in AD 700? Was it a landscape denuded of forest, with fields stretching in countless succession? Was it a mosaic of fields, orchards, and forest? Were soils degraded or well managed? Did the city's reservoirs fill reliably and amply? Until recently, our ability to answer such questions has been severely limited by a lack of data, and these were the queries driving the impetus for the University of Cincinnati Archaeological Project at Tikal (UCAPT).

The role of environmental science in addressing aspects of complex society has markedly changed over the last two decades. Archaeology has always been in partnership with a suite of biophysical sciences in attempting to explain the behaviors of prehistoric peoples, but with the study of cultures identified by developed writing systems and complex iconographic imagery the scholarly emphasis was often redirected to a careful assessment of what ancient city states deliberately and most tangibly said about themselves. Too, the frequently spectacular investments made by the archaic state in architectural monumentality immediately attracted the high-profile attention of both the archaeologist and the museum director. Understood as a record of a narrow but influential segment of society, these ancient elite and material drivers of social complexity dominated our view of those initial and subsequent experiments in statecraft globally.

The Maya Lowlands of Central America have been especially affected by this research trajectory with past generations of exploration coveting the often-serendipitous discovery of a pyramid complex, palace structure, or set of Classic period stelae. The forces drawing the archaeologist to those tombs/rooms with "yes, wonderful things" (Howard Carter's oft-quoted, perhaps apocryphal words upon opening Tutankhamen's tomb) continue to influence interpretations – likely disproportionately affecting an assessment of the overall social and economic development of ancient Maya culture. This is not to say that what is now understood about the ancient Maya as derived from the hard-won contexts (indeed, the decipherment of Maya writing is a remarkable intellectual accomplishment) is anything but highly significant and relevant; that understanding is now, however, markedly augmented by paleogeographers, biological ecologists, computational modelers, and a suite of collaborative scientists.

One such project directed by a biologist, a geographer, and an anthropological archaeologist (www.cambridge.org/Tikal; See S. Fig. 3) is the subject of this volume. The UCAPT has been a multiyear focused program to capture aspects of the coupled nature/human dynamic at one large site prominent in the Maya area from its early well-established blossoming during the Late Preclassic period (400 BC–AD 200) to its apogee of florescence and regional control in the Late Classic period (A.D. 550–800) to its great fragmentation or collapse by A.D. 900 (Figure 1.1). The chapters presented cover the methods and techniques employed in the interpretation of the quantity and quality of data obtained. Each author was encouraged to analyze his or her data sets without regard to preconceived outcomes and directed only by initial hypotheses, though once field and laboratory assessments were established, significant attention was invested in correlating patterns of information among researchers and data in conveying meaningful interpretations.

Our work followed in the footsteps of a long procession of scholarly investigations of Tikal. Of special merit for grounding our studies were the decades of work initiated and developed by the University of Pennsylvania Museum of Archaeology and Anthropology and their research investments at Tikal. Several scholarly tomes have been written on this long-term project, and we were extremely fortunate to draw on those publications and archived notes. We also benefited from subsequent work sponsored by the Instituto de Antropología e Historia de Guatemala, including a professional visit from Vilma Fialko – one of the principals responsible for excavation and mapping in the Lost World area of the site in proximity to several water management features. Of the many sources made available to our teams, perhaps the most significant for a project interested in the ancient engineered landscape derived from a water, soil, and plant perspective has been the published *Map of the Ruins of Tikal, El Petén, Guatemala* by Carr and Hazard (1961). Representing the principal platform controlling nearly all of our synthetic sitewide assessments, these maps were carefully scrutinized for accuracy, digitized, and georeferenced, allowing us to incorporate our work into a GIS framework (see Carr et al., this volume). The monograph by Dennis Puleston (1983) further complemented our locational efforts, particularly along his East Transect extending beyond the 16 km^2 block associated with the Penn maps and Central Tikal.

In addition to the impetus pushing the wave of new work in the Maya Lowlands that emphasizes the role of ecological assessment from subsistence exploitation strategies to climate change impacts, our project was hatched in the context of a series of empty coffee cups lingering still on the University of Cincinnati campus and within our three respective departments. For friends sheltered by an interdisciplinary umbrella and within immediate physical proximity to one another, numerous interactions both informal and formal allowed an uninterrupted flow of synergetic exchanges and activities among faculty and students from the outset.

As developed in the NSF proposal (Grant BCS-0810118) supporting much of this research, our goals were fourfold: to "(1) assess the impact of Maya agroforestry practices on the Tikal environs across its nearly 2000 year occupation history, (2) examine how changes in water management adaptations effected and were affected by broader political-economic changes in Maya society, (3) assess the importance of 'bajos' (seasonal wetlands) and their role in forest resource extraction and agricultural activity, and (4) determine how the Tikal reservoirs, which potentially represented a carefully designed water storage and hydraulic distribution system, may also have functioned as locations for an array of civic-ceremonial activities" (Lentz et al. 2009).

Previous research at Tikal and elsewhere in the Maya Lowlands helped frame these questions. Archaeological research at Tikal spans more than a century. Systematic explorations began in 1881 when Alfred Maudsley produced the first useful maps and photographs of the site (Coe 1963). Other great Mayanists to work at the site were Teobert Maler (1911), Sylvanus Morley (1938), Alfred Tozzer (1911), Edwin Shook (1951), and Tatiana Proskouriakoff (1946). In 1956, the University of Pennsylvania launched a multidecade Tikal Project, designed not only to restore and preserve one of the world's outstanding architectural monuments, but to ascertain more about the history of the site and learn the reasons for its meteoric rise and catastrophic collapse. Most of the basic data from those excavations appeared in a series of reports published by the University Museum (Tikal Reports 1986; Culbert 1993; Puleston 1983; Haviland 1985;

Coe 1990; Jones 1996). Efforts to synthesize the Tikal data have been published in subsequent works (e.g., Harrison 1999; Sabloff 2003). Research continued under the Proyecto Nacional Tikal de Guatemala (Laporte 1987, 1993, 1995, 1997, 2003; Laporte and Fialko 1985), whose efforts contributed significantly to our understanding of the prehistory of the site. Recently, Webster and associates completed a study of the earthworks surrounding Tikal (Webster et al. 2007). As the result of these earlier efforts Tikal is well known archaeologically and extensively mapped in fine detail.

In stark contrast to the vast knowledge of the architectural features, settlement patterns, ceramics, lithics, and other artifact assemblages from the site, much less is known about the water and land management and ancient agroforestry practices at Tikal. Part of the reason for this situation is historical: Archaeologists of the 1950s were less interested in the environment and more interested in the durable aspects of material culture. Accordingly, excavations were not organized to record evidence of ancient subsistence and water use activities. While the detailed maps made by the Penn Project allowed for initial modeling of water flow and collection at Tikal (Scarborough and Gallopin 1991), a lack of published excavation data from the reservoirs limited understanding of how the ancient water management system worked. A notable exception to this dearth of information on ancient Maya water use activities in the area, however, was Fialko's work (2000) in her survey of the Holmul River that discussed modifications of the river's channel for water control as it passes near Tikal.

Our project was designed partially to remedy this dearth of knowledge, aiming to collect basic data on the present and past forests of Tikal and new field data on Tikal's elaborate water management system and on the history of land use and environmental change at Tikal and surrounding areas. Before summarizing the work we set out to do, a brief review of Tikal's natural and historical setting is in order.

ENVIRONMENTAL CONTEXT

Tikal is situated near the southern end of the Elevated Interior Region (EIR) of the Maya Lowlands, a large, complex physiographic region that lies at the heart of the Yucatan Peninsula (Figure 1.2) (Dunning et al. 2012). The EIR is composed of variably exposed beds

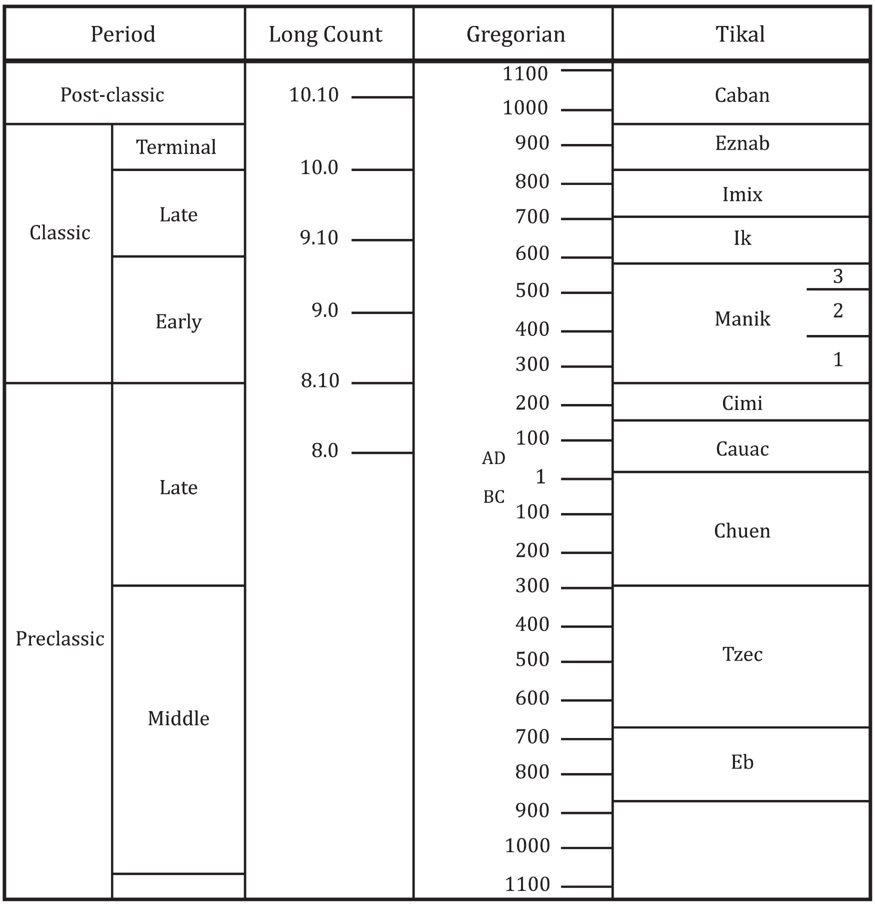

Figure 1.1. Tikal chronological chart including period, Maya Long Count, modern Gregorian calendar dates, and ceramic phases. Redrawn from Houston and Inomata (2009).

of Late Cretaceous and Lower Tertiary carbonate rock, uplifted and deformed over many millions of years. Drainage within this karst region is almost exclusively internal, and the permanent groundwater table typically lies many tens of meters below the surface, essentially inaccessible to the ancient Maya except through infrequent deep cave systems. The southern end of the EIR is composed of the Central Petén Karst Plateau and the Three Rivers Region. Embedded within the karst plateau is a structural subsidence basin (the Mirador Basin) the southern and eastern edges of which are marked by the Buenavista Escarpment. This escarpment dominates the skyline northwest of Tikal.

The eastern side of the Central Petén Karst Plateau is fractured into a complex horst and graben landscape dubbed the Three River Region (Dunning et al. 2003). The horst uplands have weathered into rugged karst forms. The grabens are home to large, clay-floored

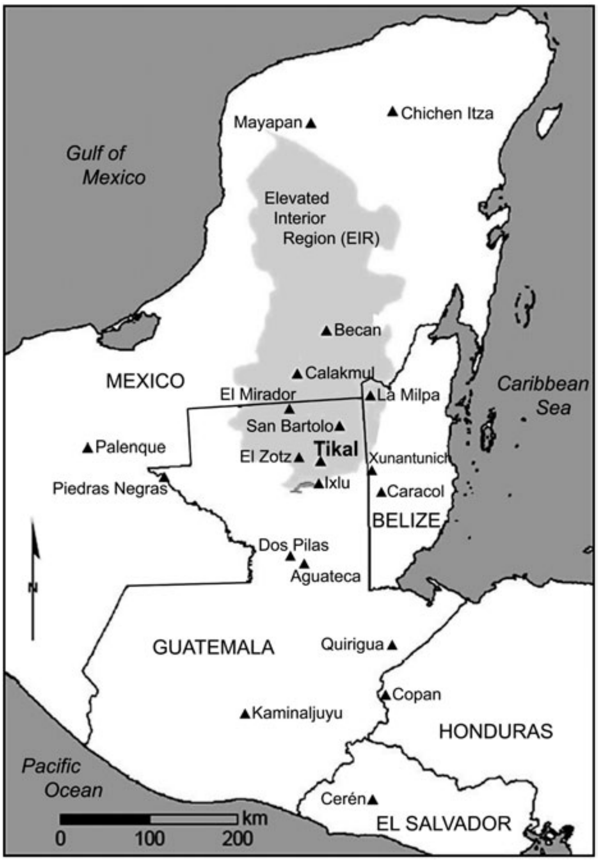

Figure 1.2. Map of the Maya Lowlands Region showing the situation of Tikal in the Elevated Interior Region and sites mentioned in the text.

complex depressions with seasonal wetlands (*bajos*), including the sprawling Bajo de Santa Fe, Bajo de la Joventud, Bajo de la Justa, Bajo de Azúcar, and Bajo de los Alacranes. These megabajos are interlinked by two drainage systems, the Rio Azul and Rio Holmul, which also connect with a number of smaller, higher elevation depressions. Two smaller, but still sizable *bajos* hem in the Tikal uplands on the southwest and west: Bajo Socotzal (or Tzocotzal) and Bajo Ixtinto (Figure 1.3). Another sizable depression, Bajo Bejucal, lies northwest of Tikal at the foot of a section of the Buenavista Escarpment. Numerous smaller depressions, ranging in size from a few square kilometers to a few hundred square meters (which we have dubbed "pocket *bajos*"), pockmark the karst uplands, including within the central residential area of Tikal (e.g., Perdido Pocket Bajo and Arroyo Corriental Pocket Bajo; Figure 1.4).

Today, most of the bajos in the region are seasonal swamps, characterized by periods of standing water during parts of the rainy season and edaphic desiccation during the dry season. Hence, the

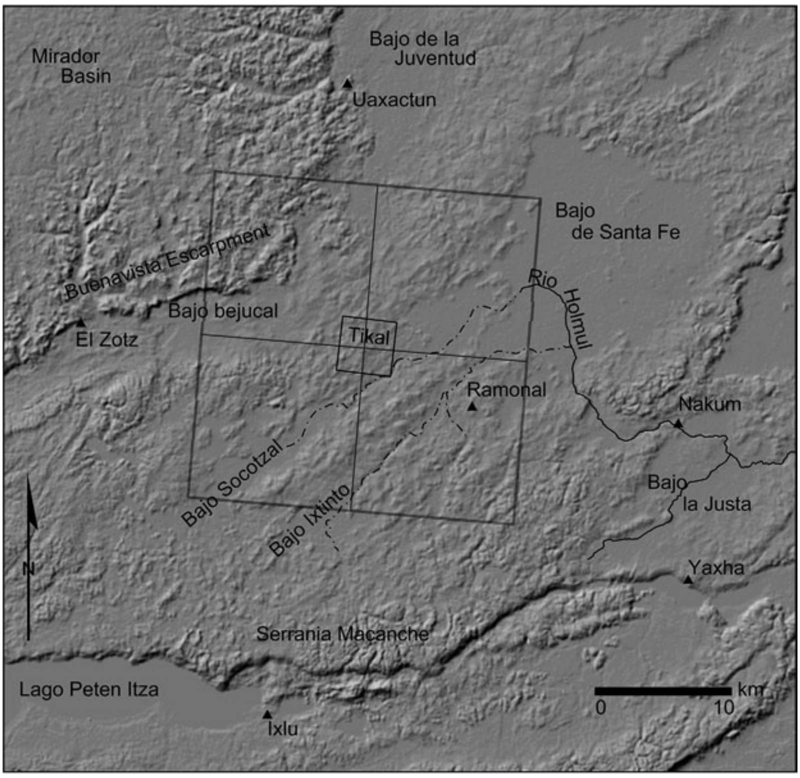

Figure 1.3. Map showing the situation of Tikal in a landscape of uplands and *bajos*. Large square represents the boundaries of Tikal National Park. The small square is the limit of the University of Pennsylvania site map.

swamp forest that occupies much of the land surface within the regional bajo system is composed of woody and herbaceous species that are adapted to severe soil moisture differences. Given the prevalence of bajos around Tikal, it is likely that these features played a significant role in the history of regional settlement. Over the past decade, evidence has accumulated indicating that bajos have experienced considerable environmental change over the past several millennia – likely the result of both climatic and anthropogenic influences (Beach et al. 2003, 2008, 2009; Dunning et al. 2002, 2006; Hansen et al. 2002).

Soils within the region fall largely into four orders: Mollisols, Vertisols, Entisols, and Histosols. The Mollisols are Rendolls (Rendzinas), including Typic, Lithic, Cumulic, and Vertic subgroups. These are generally shallow, base-rich, clayey soils mantling hard limestones and lying on generally well-drained upland terrain. The skeletal Lithic Rendolls and even thinner Entisols occur on steeper slopes. Cumulic Rendolls occur along the base of slopes and merge into Vertic Rendolls along the margins of bajos. Vertisols are the dominant soil type observed in the bajos. These are deeper clay soils

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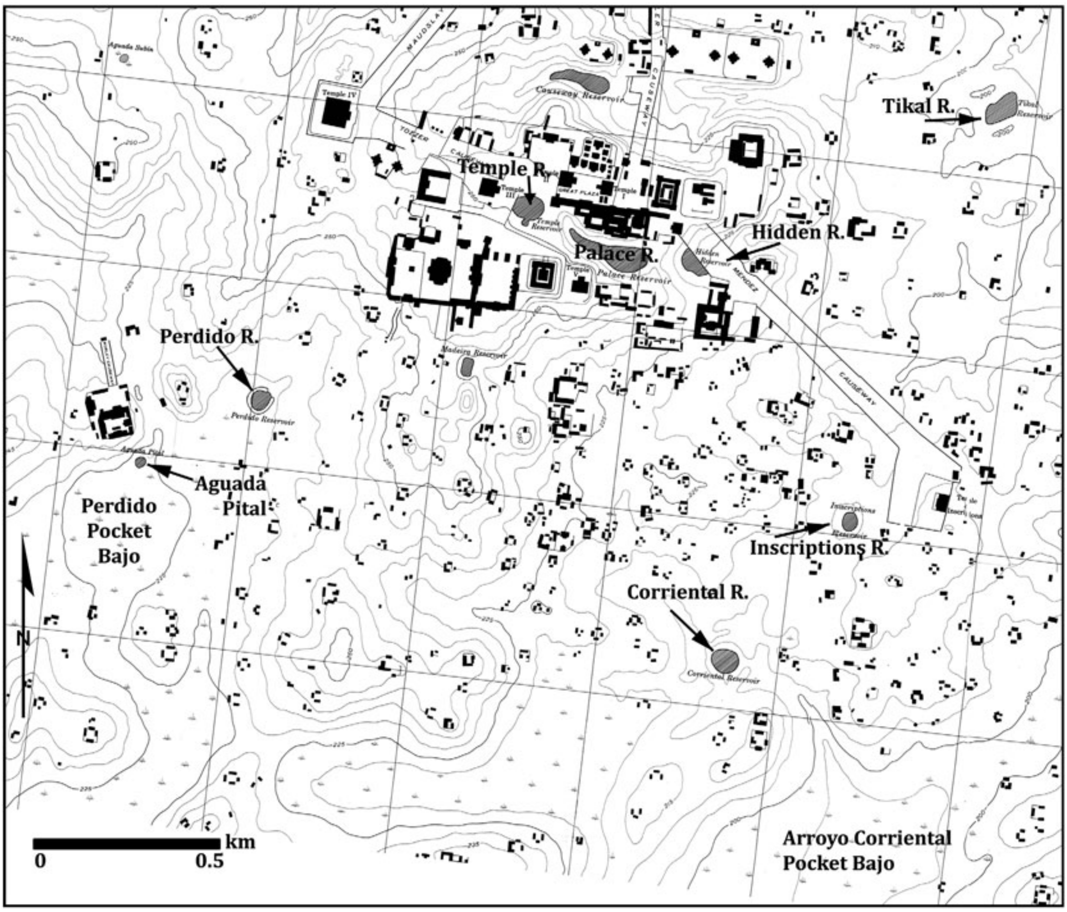

Figure 1.4. Map of central Tikal showing the location of Perdido Pocket Bajo and Arroyo Corriental Bajo.

exhibiting profound dry season cracking, and prevalent shrink-swell activity that results in a rugged, hummocky soil surface. A few areas of Histosols (organic mucks) occur in places of perennial soil moisture within some larger bajos. Histosols may have been more widespread within the region's bajos at some time in the past (Dunning et al. 2006).

Within the Holocene, we now realize that climatic conditions across the region were far from stable. Global and pan-Caribbean mesocycles of climatic fluctuation were felt across the Maya Lowlands marked by cooler and drier periods followed by warmer and moister conditions lasting hundreds of years (Brenner et al. 2002; Haug et al. 2003; Mueller et al. 2009). Shorter-term climatic cycles may also have significantly affected rainfall patterns in the region, most notably a 208-year cycle of solar energy pulses (Hodell et al. 2001; Wahl et al.

2006). Importantly for the Maya, such cycles may have increased the frequency of drought in areas of the lowlands, with potentially devastating results on Maya populations (Hodell et al. 2005; Gill 2000; Haug et al. 2003).

As elsewhere in the Maya Lowlands, the region's hybrid tropical/sub-tropical climate generates severe disparities in rainfall (typically about 90 percent of the region's 1,500–2,000 mm of rainfall arrives during the May–December wet season) and in the availability of water. Even during climatically stable ("normal") times, however, the Maya Lowlands are characterized by significant interannual variation in rainfall – on the order or 30–40 percent – a fact that has played an important role in agricultural strategies over time (Dunning and Beach 2004). Although drought risk and seasonal water shortages have received the greatest attention in scholarly investigation of Maya cultural ecology, the region is also frequently plagued by excessive and damaging precipitation, most notably in the form of tropical storms and hurricanes, which unfortunately often arrive during the harvest season with devastating consequences (Dunning and Houston 2011).

Today, lack of accessible water poses significant challenges for occupation during the dry season. Although flow within the region's streams and rivers effectively ceases during the dry season, deep pools of water remain in sections of the Rio Holmul. Bajos are also the most common location for *aguadas* (ponds), particularly along their margins, where defined by underlying bedrock fractures. These aguadas are likely to have originated as small karst solution or collapse features that have partially infilled with clay sediment, allowing them to retain water (Siemens 1978). Near Tikal many aguadas were clearly subject to human modification to enhance their water-holding capacities. Aguadas are a less frequent feature within the undulating uplands and smaller bajos surrounding Tikal. While many of these aguadas may also have a natural, karst solution origin, others exhibit evidence of strong human modification such as the construction of clay berms around their peripheries. Some aguadas may be entirely artificial, probably originating as quarries that were subsequently modified to retain more water.

Today, well-drained upland terrain is mantled by several subtypes of "upland forest" (following Brokaw and Mallory 1993) that has been called variously "climax forest" (Lundell 1937), "deciduous seasonal forest" (Wright et al. 1959), and "montaña" (a term used widely in the