

## TORMENTAS TROPICALES EN EL CARIBE

### Implicaciones ecológicas en las prácticas de subsistencia de los mayas en la península de Yucatán

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#### RÉSUMÉ

Les effets écologiques causés par les ouragans sont analysés dans le contexte de l'adaptation des Mayas préhispaniques à la forêt de la péninsule du Yucatán. Des textes préhispaniques, coloniaux et contemporains, ainsi que l'information climatique sur la Caraïbe en général, appuient l'hypothèse que l'ouragan était l'élément central dans la cosmovision et le paradigme écologique préhispanique. L'auteur argue que la destruction de la forêt causée par des tempêtes tropicales, et les cycles de successions suivants sont similaires non seulement à l'agriculture d'essartage, mais aussi aux cycles de succession naturels, qui sont plus lents et prévisibles. Avec de différents niveaux de succès, la flore et la faune de la région s'adaptent aux effets radicaux écosystémiques dans les parties qui sont plus fréquemment affectées.

Tandis que les causes les plus contestées du déclin de la civilisation Maya préhispanique sont dérivées de la guerre, du commerce, des facteurs politiques et des patrons démographiques, l'auteur propose que l'adaptation effective de celle-ci aux effets écologiques des tempêtes tropicales a contribué au succès ou à l'échec des stratégies de subsistence dans la péninsule.

#### SAMENVATTING

De ecologische effecten, veroorzaakt door orkanen, worden geanalyseerd in de context van de aanpassing van de prehispanische mayas aan het oerwoud van de Yucatán schiereiland. Prehispanische, koloniale en hedendaagse teksten, alsook klimatologische informatie over het Caraïbisch gebied, wijzen erop dat de orkaan een centrale element was in de prehispanische wereldbeschouwing en de ecologische paradigma. Terwijl meestal verwezen wordt naar politieke, demografische en andere factoren als de situatie van oorlog en handel, om de verdwijning van de prehispanische maya beschaving te verklaren, hier wordt gesugereerd dat de aanpassing aan de ecologische effecten van de tropische stormen heeft bijgedragen tot het succes of de mislukking van de overlevingsstrategieën in deze regio.

## CARIBBEAN TROPICAL STORMS

### Ecological implications for pre-Hispanic and contemporary Maya subsistence practices on the Yucatán peninsula

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#### ABSTRACT

The ecological stress factor of hurricanes is examined as a dimension of pre-Hispanic Maya adaptation to a tropical forest habitat in the Yucatán peninsula. Pre-Hispanic, colonial and contemporary texts as well as climatic data from the Caribbean region support the thesis that the hurricane was an integral feature of the pre-Hispanic Maya cosmology and ecological paradigm. The author argues that destruction of forests by tropical storms and subsequent succession cycles mimic not only swidden — “slash-and-burn” — agriculture, but also slower, natural succession cycles. With varying degrees of success, flora and fauna adapt to periodic, radical ecosystem disruption in the most frequently hard-hit areas. While not ignoring more widely-discussed issues surrounding the longevity and decline of pre-Hispanic Maya civilization, such as political development, settlement patterns, migration, demographic stability, warfare and trade, the author suggests that effective adaptation to the ecological effects of tropical storms helped determine the success of pre-Hispanic Maya subsistence strategies.

#### RESUMEN

Los efectos ecológicos causados por los huracanes se analizan en el contexto de la adaptación de los mayas prehispánicos a la selva de la península de Yucatán. Textos prehispánicos, coloniales y contemporáneos, así como información climática sobre el Caribe en general, apoyan la hipótesis de que el huracán era un elemento central en la cosmovisión y el paradigma ecológico prehispánico. El autor argumenta que la destrucción de la selva causada por tormentas tropicales, y los ciclos de sucesión que siguen, se asemejan no sólo a la agricultura de roza, o de tumba-roza-quema, sino también a los ciclos de sucesión naturales, que son más lentos y predecibles. Con distintos niveles de fortuna, la flora y fauna de la región se adaptan a los efectos radicales ecosistémicos en las partes más frecuentemente afectadas. Mientras que las más discutidas causas del declive de la civilización maya pre-

hispanica se refieren a factores políticos, patrones demográficos, guerra y comercio, este autor sugiere que la adaptación efectiva a los efectos ecológicos de las tormentas tropicales repercutió en el éxito o fracaso de las estrategias de subsistencia en esta región.

## INTRODUCTION

The mystery of how pre-Hispanic Maya constructed and maintained monumental architecture, great cities, and a sophisticated civilization in a tropical forest habitat has puzzled scholars since Bernal Díaz and the Spaniards' first descriptions of Maya cities in the early 16th century. Whereas Spanish clerics, such as Bishop Landa, were inclined to see in Maya civilization a divine plan somehow corrupted by evil forces, modern researchers have made great strides in probing Maya science, social organization, and economic activity. But as new discoveries help to answer old questions, they raise new ones, as well. Recent research about Southern Lowland Maya cities such as Calakmul, Nakbé and El Mirador, for example, suggests that current chronologies identifying Formative, Classic and Postclassic periodization may no longer be accurate (Folan, 1990; Hansen, 1991). The discovery of monumental architecture and associated large-scale populations suggests that tropical forest adaptation by the Maya was more successful, and extended over longer time periods, than previously thought (Hansen, 1991). Such archaeological evidence, however, is insufficient for a reconstruction of past conditions, for the natural habitat has undergone many transformations and the remaining physical evidence is largely mineral — stone and ceramic — rather than the vegetable and animal materials which might several Maya means of subsistence. This paper sets aside, for the moment, the question of archaeological remains to examine tropical storms as one factor of ecological stress on the tropical forest habitat. Using contemporary and historiographic data from both the Yucatán peninsula and the Caribbean area as a whole, it suggests an additional dimension to reconstructions of pre-Hispanic Maya subsistence strategies. My objective is not to provide definitive answers, but rather to begin framing an important question which has received inadequate consideration.

Despite a great deal of attention to subsistence strategies, the

question of ecological paradigms employed by the Maya has been for the most part bypassed by recent publications (Adams, 1977; Andrews and Sabloff, 1986; Ashmore, 1981; Chase and Rice, 1985; Culbert, 1973; De Montmollin, 1985; Flannery, 1982; Friedel and Sabloff, 1984; Hammond, 1977; Hammond and Willey, 1979; Harrison and Turner, 1978; Turner, 1983; Turner and Harrison, 1983; Willey and Mathews, 1985). The earlier work sponsored by the Carnegie Institution of Washington (CIW) and headed by Sylvanus Morley focused primarily on maize agriculture. It has been greatly expanded by current research showing that a variety of strategies were involved, including raised field intensive agriculture, homegarden plots, root and/or tree farming, aquaculture, silviculture (harvesting of forest products), and swidden, or slash-and-burn agriculture. Modern scholars, however, have failed to come to any consensus regarding actual productivity, habitat carrying capacity, or demography. Research spearheaded by Arturo Gómez Pompa emphasizing silviculture options provides key insights. In contrast to archaeological evidence based largely on mineral remains, Pompa's work focuses on the flora of the regional tropical forest habitat which either directly or indirectly became the basis for Maya subsistence. His summary of silviculture techniques provides a useful basis for identifying the basic ecological paradigm employed by pre-Hispanic Maya (1987, 6). The conclusion of this paper will refer to these silviculture techniques, among others, as elements that helped to alleviate the ecological stress caused by tropical storms.

Climatologists refer to tropical storms as "seasonal tropical disturbances," weather patterns which normally originate over the Atlantic Ocean and frequently affect the Yucatán peninsula. The maximum expression of such storms is the hurricane, an intense system with counter-clockwise winds of at least 118.5 kilometers per hour. Winds may reach up to 300 kilometers per hour, and speeds of 150-240 kilometers per hour are common for hurricanes striking coastlines. Hurricanes also bring high water levels (storm surges), exceptionally heavy rainfall, and after the following dry season, extensive forest fires. As recently demonstrated by Hurricane *Gilbert* (September 1988) and the 1995 hurricanes, these accompanying phenomena have a significant, destructive impact on habitat. This is what I refer to as the ecological stress factor.

Formal classification of tropical storms is based on wind speed. A tropical depression (a system with winds of less than 62.9 kilometers

per hour) may escalate into a tropical storm (speeds between 62.9 and 118.5 kilometers per hour), or reach hurricane force (greater than 118.5 kilometers per hour). Hurricanes are now further classified in terms of a five-scale system, referring to wind intensity and destructive potential. Hurricane *Gilbert* was a Category 5 storm. Both tropical storms and hurricanes can have significant ecological impact. In this paper, I will not always distinguish between them for the period prior to 1899, however, as insufficient data on particular storms and standardization of classification systems had not yet been established (Neumann *et al.*, 1985, 5).

The impact of recent tropical storms can be quite accurately measured. A disproportionate amount of this work has been done in areas where the U.S. National Oceanic and Atmosphere Administration (NOAA) has major reporting responsibility. Therefore, while a great deal of information is available on tropical storms that have affected the mainland or offshore U.S.A., there is much less data about storms affecting Mexico. Since the Caribbean coasts of Mexico have until only recently had major populations reporting on such phenomena, information here is even more scattered. Because these storms also affect the Caribbean Islands, one must take this area as a whole in order to get a more comprehensive picture of frequencies and impact in the post conquest period.

#### THE HISTORICAL RECORD

Pre-Hispanic records left by the Maya provide clues but few specific details on tropical storms affecting the Yucatán peninsula. Aztec myth identifies the hurricane as the origin of one of four worlds that were created and destroyed prior to the one existing at the time of Spanish conquest. According to the Maya *Popul Vuh*, the second world was destroyed by rains and floods. And as Thompson has indicated, most Maya areas have myths identifying great storms as destroyers of past epochs (1957, 399-417). While flood destruction is common in creation accounts worldwide, there is more concrete evidence from Maya sources which suggests that there was indeed large-scale destruction caused by storms and flooding. Lacombe (1988) argues that the numerous references to rain gods in the Maya codices (*Dresden, Madrid, Paris*) refer primarily to hurricanes. Taking his argument one step

further, he sees references to climatic cycles in these sources as convincing evidence that the Maya not only recorded tropical storms, but had also devised a method of predicting future storms. In view of what is presently known about the frequency of hurricanes, the Lacombe hypothesis lacks credibility, although it does reinforce the more tenable position that the ancient Maya were seriously affected by hurricanes and attempted to record them.

Both conquest-period European and post-conquest Maya writings such as the *Chilam Balam* and the *Ritual of the Bacabs* confirm specific Maya recording of tropical storms. Landa (1986, 19) reports information he got directly from the Maya about "a hurricane of the four winds," which struck the Yucatán peninsula in 1464, as follows:

One night a wind came that grew into a great hurricane that overthrew all large trees, destroying tall houses and every sort of game...The people were crippled by the blows from the wood...and so the land lost the name it formerly bore, the land of deer and turkeys, and remained treeless, so that today all those young trees which have grown up in their place have the same height, and looking down from higher points it appears that this whole part of the forest has been cut to the same height.

Although we do not know which part of the peninsula was involved, the impact described conforms significantly to what is currently known about a maximum hurricane force. In the Landa account it became a historical reference point, a practice also common in the Maya *Chilam Balam*, which use famine, war and drought to mark historical periods. Information about actual storms striking the Yucatán peninsula during the colonial era, however, is uneven and sporadic.

For the Caribbean area as a whole the colonial record is much better. Columbus learned about tropical storms on his second voyage (1493-1495), and his first settlement of Isabella was struck in June of 1494 and October of 1495 (Millas, 1968, xii-xiii). Fernández de Oviedo y Valdés describes two hurricanes that struck the island of Hispaniola on August 3rd, 1508 and July 29th, 1509 with particularly impressive impact on tropical forests (1944, I, 300-305). He also refers to high water levels, great rains, high seas and the destruction of ships, buildings, crops and animals (1944, I, 300-304).

The Caribbean history of tropical storms has received considerable attention from two Cuban writers: José Carlos Millas (1968), who provides a chronology of hurricanes from 1492 till 1800, and Fernando Ortiz (1947), who examines the mythology and symbolism of hurricanes. Ortiz's analysis of Caribbean and Mesoamerican iconography led him to the conclusion that the God of Storms, or Huracán, whose indigenous names are Guabancex, Maboya, and Jurakan, was the most important deity in the pre-Hispanic Caribbean Islands. He further argues that iconography showing circular and cross-like forms can be related to tropical storm deities throughout Mesoamerica.

Millas, who was director of Cuba's National Observatory of Meteorology for many years, states that "there is no known cycle for severe hurricanes in any one region," although in Cuba, for example, it was thought that every fifty years a very severe hurricane would strike the island (1968, xvii). For the western Caribbean Millas identified 45 hurricanes for the 16th century, 64 for the 17th century, and 136 for the 18th century (7-23).

Alison Reading's recent work covering from 1500 to the present locates the greatest number of hurricanes between 1871 and the 1980's, although, she adds, this may be "entirely a function of the improving quality of data" (1990, 372). Her data for earlier centuries indicates low levels of hurricane activity in the Yucatán peninsula in the 1500 to 1800 period, increased activity in the XIX century, and extensive activity in the 20th century (373). According to her data the areas of most frequent impact during the colonial period were the Lesser Antilles, Cuba and Jamaica, Hispaniola and Puerto Rico. Yet for the more recent period the Yucatán-Belize area has as high frequency rates as the other Caribbean islands. It is important to note that the Caribbean Islands were continually occupied by Europeans, while the eastern Yucatán peninsula did not have a European, colonial population reporting or recording tropical storms. Data from 1871 onward, however, is available in equal measure for all areas.

#### TROPICAL STORMS, 1871-1990

Annual charts for the 1871-1990 period identify storm-track location and intensity. This allows for a more systematic analysis of the last 120 years of tropical storm activity affecting the Yucatan peninsula. When

compared with Cuba and Jamaica, the peninsula was only slightly less affected by storms (106) than Cuba (120), and considerably more than Jamaica (40).

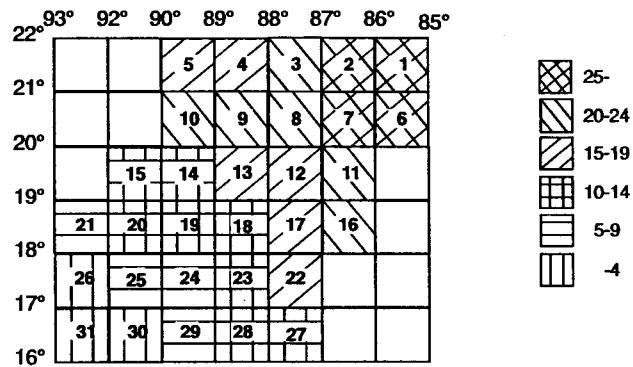
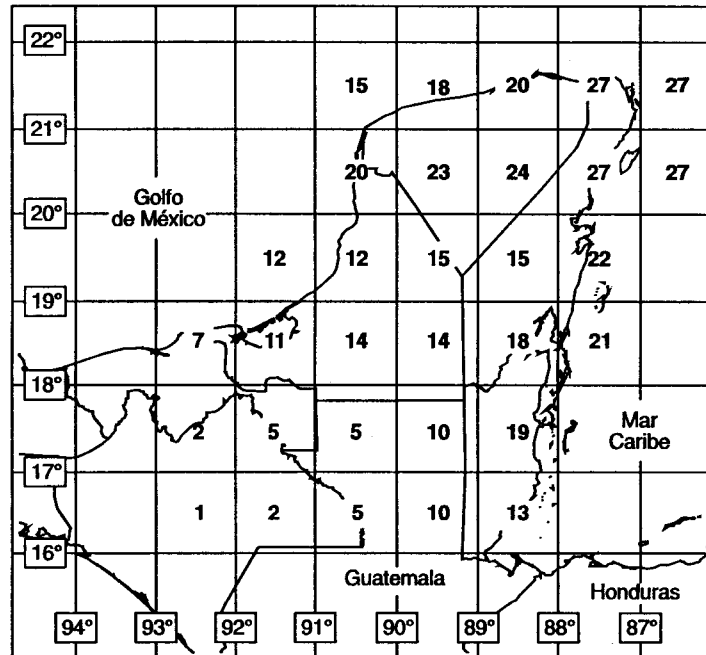
Identifying areas crossed by storm tracks over the 120 year period, as shown by the annual North Atlantic Hurricane Tracking Charts (NAHTC), we can construct a synchronic view of peninsular impact. This is illustrated below in Map No. 1, showing the number of cyclonic disturbances affecting specific areas marked on the map. The totals within the circles indicate totals for each area, showing greatest impact along the eastern coasts and in the north. These patterns have then been divided into zones which reflect the directional nature of passing storms and their concentrations (Map No. 2). Most of the storms approach the peninsula from the southeast, crossing in a northwesterly direction, while some, like *Gilbert*, cross in an almost east-west direction. Since landfall (the moment when the hurricane strikes land) eliminates the warm ocean water, or energy source of a cyclone, there is a significant reduction of velocity and intensity when storms cross land. When entering the Yucatán peninsula, Hurricane *Gilbert*, for example, had 300-320 kilometer-per-hour winds, which had fallen to about 155 kilometers per hour by the time it left the peninsula and entered the Gulf of Mexico (NOAA data). Such energy loss reduces hurricanes to tropical storms. South of Belize City, major storms often die quickly after encountering the mountainous terrain in that portion of the peninsula. Most tropical-storm-intensity cyclones become tropical depressions (*i.e.* wind velocity of less than 62.9 kilometers per hour) when crossing the peninsula and are no longer considered significant destructive factors. Such velocity reduction is clearly shown in Map No. 1, and is particularly relevant for the southern portion of the peninsula.

There are two general patterns related to distribution and frequency: one showing decreasing frequencies along an east-west axis, and two showing decreasing frequencies along a north-south axis. The impact zones shown in Map No. 2 provide a peninsular overview of a 120-year period, indicating differences in frequency throughout the peninsula.

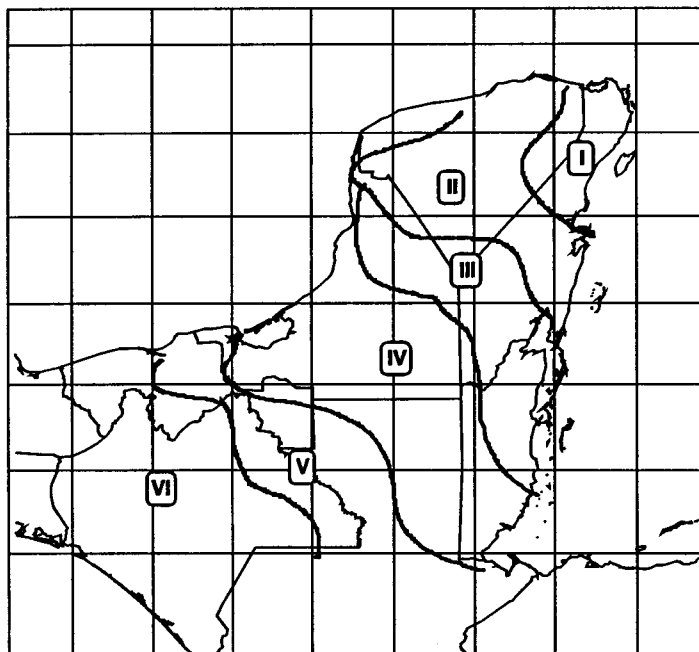
In addition to synchronic differences in occurrence, distribution and frequency, considerable diachronic fluctuation has been noted for cyclonic activity throughout the Caribbean area as a whole (Reading, 1990), as well as for North Atlantic tropical cyclones (NOAA).



MAP No. 1. Peninsular cyclonic impact, 1871-1990  
(Number of impacts in specific areas)



MAP No. 2. Peninsular cyclonic impact, 1871-1990



<i>Zone</i>	<i>No. of impacts</i>	<i>Frequency classification</i>
I	25 plus	Extreme
II	20-24	Very significant
III	15-19	Significant
IV	10-14	Moderate
V	5-9	Rare
VI	1-4	Insignificant

Cyclone frequency in the Caribbean increased from the 1870's up to the first decade of the 20th century, and decreased between 1910 and 1930. This was followed by a dramatic increase, in the 1930's and 1940's, a subsequent decrease in the 1960's and 1970's, and a slight increase in the 1980's (Reading, 1990). When only storms reaching hurricane velocity are taken into consideration, there is a relatively constant number of about 40 hurricanes per decade (369). If we do not isolate hurricanes from tropical storms, the Caribbean pattern holds true in the Yucatán peninsula as well. The eastern and northern areas of the peninsula are more frequently hit by tropical storms, a diachronic pattern also consistent with the 120-year synchronic overview.

Seasonal occurrence is another important variable. In recent times the official hurricane season begins in June and terminates at the end of November (NOAA), coinciding with the growth and maturation period of most subsistence crops. This seasonability is directly related to ocean water temperatures, then at their annual warmest, allowing weather systems crossing the Atlantic to develop into tropical storms. And although such storms may occur as early as June and July, and as late as November, most strike in August, September and October (77.04%). Cyclonic storms are most likely to strike the Yucatán peninsula in September (roughly 40 percent).

The impact of cyclones is further influenced by short-term frequency factors. In some years there are none and in others there may be many. According to Neumann *et al.* (1989), in almost half the years between 1871 and 1989, there was no cyclonic impact. On the other hand, 92 of the 106 registered cyclones took place in 63 of these same 118 years.

Storm data from the recent past indicates that the geographic location and size of the Yucatán peninsula make it perhaps the greatest continental mainland area of cyclonic impact in the Western Hemisphere. And although from the early colonial reports and Maya documents we have scattered references that similar phenomena occurred in the pre-Hispanic epoch, we do not have confirmed, substantive evidence directly applicable to, for example, the Classic Maya period. Indirect evidence, however, does provide useful directions for further investigation. These are directly related to climatic factors, such as warmth of oceans and long-term temperature fluctuations. Recent global warming trends associated with the 'greenhouse effect' have been used — after Hurricane *Gilbert*, for example — to predict increas-

ing numbers of Category 5 hurricanes if this warming trend continues. As Reading indicates, "sea-surface temperature is one of the cardinal factors controlling cyclone development" (1990, 375). And Walsh (1977), taking as his reference the 1650-1975 period, has noted a correlation between increased cyclone frequency and mean sea-surface temperatures over the Atlantic. Reading (375) also relates frequency to tropical lake levels, glacial surges and retreats, and *El Niño* phenomena. Long-term weather patterns thus become an important clue for reconstructing cyclonic activity in the Formative, Classic and Postclassic Maya eras. In view of the recently-reported evidence mentioned at the beginning of this paper, this would be the period from roughly 1800 BC until 1500 AD, encompassing three millennia.

According to climatic evidence, high cyclone frequency would fall in periods of warmer weather. Folan (1985) and collaborators (Folan *et al.*, 1982; 1983; 1984) have suggested that the greatest Maya expansion and development occurred during periods characterized by humid/cool conditions, or periods of glacial surges, while long-term warm/dry periods related to glacial retreat correspond to periods of Maya disruption and contraction. Cyclone activity would have increased precisely during these periods of warmer temperatures.

Although far from definitive, the available data on cyclone activity affecting the Yucatán peninsula in post-colonial and recent times does allow for suggestive projections for earlier periods. Recent data shows clear patterns of frequency, seasonability, and impact zones, and suggests that similar patterns occurred in pre-Hispanic periods. A more detailed analysis of the ecological impact of storms on a tropical forest habitat might help interpret what these projections imply in reinterpreting pre-Hispanic Maya adaptation to the tropical forest habitat.

#### THE ECOLOGICAL IMPACT OF TROPICAL STORMS

Contemporary Maya in eastern Yucatán have the following explanation of the hurricane (Konrad, 1985, 321):

[A] hurricane is actually a battle between good and evil *chacs* or rain gods. The offshore or approaching weather systems represents the evil *chac* (the destroyer) with malevolent intentions on man and his environment, who

is confronted by the good *chac* (the protector) with benevolent intentions on man and his environment. The physical manifestations of the hurricane, particularly the high velocity winds, are by-products (the sound and fury) of a titanic cosmic battle between the forces of good and evil. The intense rains are the by-product of the energy expended, the 'sweat of the gods' as it were, and the relative degrees of havoc (storm surge, floods; destruction of settlements, crops, flora and fauna) become an indication of the evil *chac's* success while positive aspects (survival of natural and human environments, increased rainfall in areas peripheral to the center of storm activities) are associated with the good *chac*. And post-hurricane dry spells or seasons occur because the good *chac*, having expended so much force in celestial combat, may require a lengthy period of recuperation.

This seemingly mythic version does represent a rather factual description of real impact phenomena, which can be devastating at point of impact, yet provide crop-saving rains at considerable distances from the storm center, if the storm occurs during a short-term dry spell. The Maya are also technically correct in locating the activity in the sky, for this is where, at altitudes of up to 4 000 meters, the main force of such storms is expended. During a 24 hour period, a Category 4 hurricane expends energy equivalent to the heat energy released from 400 twenty-megaton hydrogen bombs (Jennings, 1970, 59). The impact felt at ground level is only a minimal fraction of the storm's force.

One hurricane by-product not mentioned in the cited Maya explanation is forest fires. Peninsular experience in this century demonstrates that major hurricanes are invariably followed, in subsequent dry seasons, by large-scale forest fires in areas adjacent to coastal points of impact. In the July following Hurricane *Gilbert* (1988), roughly 160 000 hectares of forest were burned despite all efforts to contain and extinguish fires.

Ecological impact can be divided into four main categories: 1) storm surge damage along coastlines, 2) wind destruction, affecting flora, fauna and human settlements, 3) high water levels and flooding activity resulting from extreme rainfall, which has been recorded as high as 107 cm in a 24-hour period (Hebert, 1980) and 4) post-hurricane forest fires. The following sections of the paper present a more comprehensive picture of ecological impact based on selected storms affecting the peninsula in the past century.

## 1916 STORMS

Two hurricanes struck the peninsula's east coast in 1916, the first on September 1, at Payo Obispo (now Chetumal) and the second, on October 15, at what was then the important port of Vigía Chico. The impact of the first hurricane's storm surge was described later by Gann (1924, 22-23) as follows: the "hurricane and tidal wave simply wiped out houses and shipping and tore great gullies through the site occupied by the town [Xcalac]." His description of the second was that it "destroyed most of the east coast [of the peninsula] settlements. Vigía Chico, once a flourishing port, [was] now a depressing dump of ruined houses, wharf and rolling stock" (27). Mérida newspapers reported serious damage to forests and buildings, a paralysis of forestry activities (chicle collection), and destruction of the area between Bacalar and Santa Cruz, now Felipe Carrillo Puerto (*Voz de la Revolución*, 1916/11/08). The Mexican Federal Government had only occupied this part of the peninsula in 1901 and had made great infrastructural investments along the coasts to stimulate and implement ambitious forestry projects. Most of that 15-year investment was wiped out by the 1916 storms. Forestry was paralyzed, and the Vigía Chico and Xcalac thereafter remained insignificant, commercial activities moving to alternative locations in the ensuing years.

## EARLY 1930 STORMS

The 1930's were particularly active storm years. One hurricane and three tropical storms crossed the peninsula in 1931, two tropical storms in 1932, and in 1933 two hurricanes and three tropical storms hit the peninsula — a total of three hurricanes and eight tropical storms in a three-year period. Virtually all areas of the peninsula were affected, and there were additional storms in 1934 and 1936. Archaeologists with the Carnegie research teams working out of the Chichén Itzá site gave graphic reports on forest fires after the 1937 fieldwork season. Here they describe the region between Dzitnup, just west of Valladolid, and Cobá — though similar conditions were reported on the Caribbean coast:

For the last six years, possibly longer, annual dry-season fires have swept through... In some sections, not a living plant remained from the former

forest, only fallen trees and standing skeletons. Not only has the forest been killed, but the destruction of the humus and roots by fire has resulted in complete erosion of the thin mantle of soil into underground crevices to leave barren stretches of white pitted limestone [CIW Yearbook, No. 27, 938, 146-147].

One 1931 storm passed directly over Belize City on September 10, causing large-scale destruction. At impact wind speed was 211.2 kilometers per hour; its storm surge destroyed a large part of the town and swept debris and boats in the Belize River mouth ashore. The storm took fifteen hundred lives, seriously damaged or destroyed the majority of the settlements' wooden buildings, and caused drastic decline in mahogany and cedar extraction. Chicle production dropped 90% in the season following the hurricane (WNRC, Record Group 59, File No. 248).

1933 storms had a very mixed impact. The tropical storm of May 14-19 skirted the entire northern perimeter of the peninsula. Coming as it did at the beginning of the rainy season, it would have provided desired moisture for recently-planted crops and those planted immediately after the storm. The July 13-19 storm, which passed on a east-west direction across the peninsula, would have inundated young plants, but in areas less affected, would have had a beneficial effects. Well-advanced maize crops would have also benefited from the September 10-15 storm. But the heavy rains produced by this storm, which was quickly followed by the hurricane of September 16-24, would have already softened rooted plants, assisting the following hurricane to flatten and destroy most of the year's maize. What the 1933 storms illustrate is that positive or negative effects depend on where and when the hurricane hits, and on the status of ground crops. To frame this in Maya interpretative idiom, the evil *chac's* successes, in late September, would have largely wiped out the good *chac's* earlier successes.

#### 1955 STORMS

The two hurricanes crossing the peninsula in September of 1955 virtually destroyed Chetumal, then a town of 5 000 inhabitants. It was from the ruins of the town that the modern city of Chetumal was

reconstructed. In the Belize town of Corozal (2 000 inhabitants) 90% of the homes were destroyed. The first, Hurricane *Hilda* (September 10-19), crossed the peninsula on a slightly north-of-west trajectory, entering land September 16 at the Bay of Ascención and exiting roughly at the mid-point between Celestún and Sisal. Twelve days later, on September 21, Hurricane *Janet* began crossing the peninsula on a similar trajectory, entering at the Bay of Chetumal September 28 and exiting just south of Champotón, Campeche on September 29. Both were major storms, *Hilda* Category 2 and *Janet* Category 4.

Extensive newspaper accounts allow for a reconstruction of the scope and intensity of these storms, both on urban and rural areas. *Hilda* had a rather narrow band of Category 2 hurricane-intensity wind with a forty-kilometer diameter and Category 1 wind velocities over a much wider radius. *Janet*, on the other hand, represented a Category 4 storm with a 130-kilometer diameter and Category 1 hurricane-intensity gusts extending as far as 400 kilometers north and 160 kilometers south of the eye of the storm. Thus, the two storms were felt in varying degrees of intensity across virtually the entire peninsula. Although both storms decreased in intensity while crossing the peninsula, *Hilda* produced crop losses of up to 95% as far as 200 kilometers inland near in the town of Teabo, 80% losses up to 250 kilometers inland, and 50-60% losses on the eastern portion of the peninsula. *Janet* had an even more violent impact on areas further south and in areas already affected by *Hilda*.

Property damage in the narrow path of *Hilda* was intensive. It left no building standing in Vigía Chico and the Bay of Ascención was "full of great tree trunks, dead birds, coconut palms and mangroves and refuse of all kinds, making navigation difficult;" its storm surge was four meters high and waters reached four kilometers inland. Felipe Carrillo Puerto lost houses and trees, and communication systems were interrupted. Regional forestry workers were trapped, unable to return to settlements after the massive destruction to the forest and the consequent blockage of roads and trails. In Peto buildings were damaged and large trees uprooted; Yaxcabá lost a great number of houses, stone walls and trees, and in the town of Muna, houses, windmills, and trees were destroyed (*Diario de Yucatán*, September 18). Along the north coast at Telchac Puerto the hurricane hit coconut plantations hard, and on the east coast town of Sisal, did significant damage to houses, trees and boats. The detailed invento-



ries of destruction from some forty different locations present a picture of extreme crop, fruit tree, and architectural damage. Loss of life, however, was restricted to the east coast with a reported 11 deaths at Vigía Chico and a few inland casualties.

*Janet* took many more lives than *Hilda*. Quintana Roo had an estimated 500 deaths, Belize 16, and Campeche also reported several deaths. In the week following *Janet's* passage the majority of Chetumal's surviving inhabitants were evacuated to Mérida. While we know that *Janet* passed directly over the most heavily forested states, Quintana Roo and Campeche, and left a broad path of uprooted or denuded trees, no realistic information regarding impact on forest fauna is available for this storm.

#### 1988 STORMS

The most significant storm in 1988 was the Category 5 Hurricane *Gilbert*, whose winds officially reached 300 kilometers per hour. For this storm I have used NOAA data, media reports and interviews as well as personal surveys conducted along the east coast of Quintana Roo, the interior of Yucatán and along its northern coast. *Gilbert* passed relatively close to the peninsula's northern extremity, over what is perhaps its least-forested area. I will therefore discuss impact on the coastal and interior peninsula.

The NOAA rates *Gilbert* the most intense storm of the century, making their calculations according to wind velocity and a record low air pressure reading for Atlantic storms: 885 millibars, reported in the eye of the hurricane, between Swann Island and the Yucatán peninsula. *Gilbert's* winds moved counter clockwise around a 60-kilometer-wide circle and had the destructive force of a tornado. As it approached the peninsula its eye narrowed considerably and an outer ring — a second eyewall — formed 160 kilometers from the center, packing winds of 200 kilometers per hour. It struck in two stages, between the islands of Cozumel and Isla Mujeres: first the outer ring of Category 3 winds and two hours later the very narrow circle of what were by then Category 5 winds. As it crossed the peninsula the outer eyewall contracted while the inner eyewall collapsed. By the time the storm left the peninsula, 12 hours later, winds had fallen to 155 kilometers per hour. Satellite images revealed a 600-kilometer diame-

ter at landfall on September 14, and as *Gilbert* passed over land the system covered the entire peninsula. Its accompanying storm surge, topped off by wind-driven waves, had notable coastal impact from Vigía Chico on the Caribbean side to the City of Campeche on the Gulf Coast. *Gilbert* was considered a 'dry' hurricane, however, for rainfall accompanying the storm was a mere 8-10 centimeters.

*Gilbert* damaged and destroyed buildings within 50 meters of the shoreline, from Playa del Carmen to Campeche. The small Maya temple on the southern tip of Isla Mujeres was left a pile of rubble. The main floors of hotels along beaches at Cancún and on Isla Mujeres were gutted and beach houses all along the northern coast suffered serious damage. Cancún beaches were converted to 'hurricane beaches,' sandless and limestone-strewn, while beaches peripheral to the main impact zone were severely eroded. The mangrove growths along the east coast were swamped with water and stripped of leaves. Reefs near the Quintana Roo coastlines were also extensively affected. Along the northern coast, where coastal sandbars are backed by *ciénegas*, or salt-water swamps, over a dozen new channels between sea and *ciénega* were formed. Two large ships 60-80 meters long were deposited against beach buildings in Cancún and Progreso, and innumerable smaller craft were left at considerable distances inland.

Impact on coastal flora, fauna, and constructions was extreme along a 100-meter-wide band of the coastline. North coast saltbeds were seriously affected and many years of natural beach-forming deposit eliminated. Shoreline vegetation, mostly mangrove, suffered intense damage. Sea-bottom sand disturbance affected marine species inhabiting shallow coastal waters inside of the reefs along Quintana Roo coasts. Over a year later mangrove growth was only beginning to show initial signs of recovery at Puerto Morelos and Playa del Carmen. Even two years after the storm, there were large patches of permanent damage to northern, *ciénega*-associated tree species as far as 500 meters inland.

Inland impact on forest growth was also massive. Extensive human activity over the past century and previous storms had already virtually wiped out primary forest, although there are many individual species of greater age. Mature trees are most vulnerable to the impact of high velocity winds and are the most likely to be uprooted, as they were in both settled and uninhabited areas. Two key factors in mature-tree vulnerability are their bulk and rigidity. Extensive moisture

softens or weakens root systems below the ground, and when large trees are uprooted they bring surrounding younger trees down along with them. In this sense we have an intensification of the forest patch-clearings formed under normal circumstances of tropical succession patterns in primary forests. More important in terms of ecological impact, however, is the effect on canopy structure.

*Gilbert's* effect on standing trees is clearly visible along a 200 kilometer north-south stretch of coastal Quintana Roo. Near the center of the storm path most standing trees lost virtually all secondary branches and many primary branches. This canopy structure damage exposes the complex, layered flora, even if it remains standing, to open area conditions. The loss of forest canopy has very significant ecological implications. Not only is the debris on the forest floor (tree trunks, branches vines, and leaves) subject to a more rapid drying-out process, causing forest fires, but the whole succession process is affected. The hurricane's impact on forests becomes a natural large-scale version of the swidden cycle's preparation for planting. And, as maize growers in the Chumpon area told me, after major tropical storms destroyed regional forests, the forest Maya's traditional response was to plant extensively where their *chacs* had cleared the forests.

*Gilbert* drastically reduced bird, animal and other populations. The loss of forest vegetation, the stripping of tree fruits, leaves and other sources of nourishment also created a subsistence crisis for many species. Following heavy casualties, many of the remaining flamingo flock at the Río Colorado breeding grounds migrated to an area near Uaymitún where the storm had enhanced growth of the birds' food sources. Turkeys, pheasants, monkeys, regional feline species, and deer ventured into human settlements in search of food. Abnormal infestations of parrots were also reported raiding fruit-producing zones along the northern slopes of the Puuc hills (Oxkutzcab, Ticul, Tekax), areas less affected by the storm. The after-effects of *Gilbert* demonstrate how dramatically a hurricane may alter the subsistence patterns of regional fauna.

#### STORMS AND ECOLOGICAL STRESS

If we take storm patterns as seen in recent times as probable patterns in the past, then post-conquest data is sufficiently strong to allow for

the hypothesis that what we have seen of ecological stress caused by tropical storms applies not only to the contemporary Yucatán, but also to the entire period of Maya occupation of the peninsula.

Despite the paucity of botanical, geographical and zoological studies from the Yucatán peninsula, certain trends in short- and long-term consequences of cyclonic disturbances can be gleaned from historical and contemporary data already identified here and from studies in other cyclone-prone areas such as Northern Australia (Hopkins and Graham, 1987; Stocker and Unwin, 1989; Webb, 1958). Post-*Gilbert* research, ongoing and projected, may alter the patterns identified below, thus they are tentative rather than definitive.

1) Offshore (Reef and shallow water). Reef structures may be severely damaged and shallow-water sea-bottoms seriously disturbed. Resident flora and fauna are either damaged or destroyed. Marine zoologists at Puerto Morelos suggest that conches and mollusks suffer high mortality rates. Lobster reproduction rates two years after *Gilbert* had reached roughly 50% of pre-hurricane reproduction in some areas. Food sources for surviving shallow-water species of fauna suffer short-term degradation. Thus recovery of normal ecological balance among flora and fauna requires time. This gives the advantage to species better adapted to severe environmental stress. The short-term implications for food resources in this habitat would be considerable.

2) Shorelines. Storm-surge and wave action cause serious erosion. Up to a century, and in the case of a Category 5 hurricane several centuries, of normal shoreline deposits are eliminated in a matter of hours and are deposited in the sea or as new beaches. Shoreline vegetation suffers extreme disturbance and destruction and storm activity introduces species from other ecological niches. Hardy colonizing species of flora have reproductive and dominance advantages over more delicate species. Shoreline species of flora with a life span greater than roughly twenty years, or subject to at least one hurricane, would need to adapt to cyclonic interventions.

3) *Ciénegas*. Such salt-water marshes and lakes bordering much of the Yucatán peninsula are severely affected by storm-surge, wind and wave action. Mangrove species are virtually defoliated, with considerable limb and stem breakage and uprooting. Two years after *Gilbert*, large patches of dead mangrove remained. The storm-surge floods these areas with sea water and on entry and retreat closes existing

channels to the ocean and opens others. This significantly alters species composition within the *ciénegas*, at least in the short term, especially as bird nesting and marine reproduction cycles are interrupted. Altered ecological conditions force some waterfowl species to relocate breeding grounds; the same is probably true for sea-turtles and marine reptiles.

Since *ciénega* coastal habitat is subject to extensive and periodic disturbance, it must be characterized as a constantly shifting ecological niche. For human populations depending on subsistence resources from these areas, past and present, this requires access to alternative resources. Cyclones may periodically eliminate certain flora and fauna species on low-relief offshore islands and keys, resulting in recolonization and minimal dependence on long-term evolutionary adaptations.

4) Coastal forests. Published research on cyclonic impact in north-western Australia by Hopkins and Graham (1987, 25) led to the conclusion that "cyclones have moulded the structures of the rain forests in the area." Together with Webb's work (1958, 220-228), their research identifies extreme defoliation of trees above three meters, universal crown damage to canopy and subcanopy trees, and stem breakage or uprooting of 10-80% of larger trees. This represents an accurate description of the coastal impact zone affected by Hurricane *Gilbert* and the other storms mentioned earlier in this paper. Since, as indicated by Beadle and Costin (1952), "freedom from gross disturbance for a period of time longer than the life span of the longest-lived individuals is necessary for a community to reach maturity" (Webb, 1958, 227), the capacity of coastal forests to reach a climax or mature state is negligible. Webb concludes that "Present observations in north Queensland suggest that cyclones are a potent ecological factor which regularly upsets forest equilibrium, with far-reaching consequences for the regeneration, suppression, and reproduction of species" (1958, 227). There are as yet no botanical studies directly related to cyclones in the affected coastal forests of the Yucatán peninsula, but the information available from areas such as north Queensland provides valuable references and guides. Evidence available to me would indicate that parallel processes have and are taking place on the peninsula, and that generally, in peninsular areas affected by cyclones, we must abandon the notion of climax forests achieving and maintaining stability over long periods of time (Map No. 2, Zones I-IV).

5) Inland forests. These would include forests beyond 30-50 kilometers from peninsular coasts. These forests, although they suffer lesser degrees of defoliation, do suffer considerable crown damage to canopy and subcanopy trees and, in the case of mature trees, uprooting. The forest understory is thus left exposed to intense sunlight. Forest gaps greatly increase both in size and number. The forest-gap regeneration process (from previously dormant seeds, root and damaged-stem sprouts and gap-colonizing species) then plays an important role in the forest succession process. The Australian research describes an unusual post-cyclone flowering among smaller tree and shrub species and particularly vines (Hopkins and Graham, 1987). Both the intensive rains accompanying cyclones, and changing intensities of light, act as trigger mechanisms affecting the flowering and fruiting of forest species. On the other hand, pollination and seed dispersal patterns are altered, exposed new leaves and sprouts are subject to insect attacks, and damaged trees are vulnerable to parasites. In view of the virtually certain forest fires that follow hurricanes, many of the immediate recuperative responses are but short-term, giving a clear advantage to light- and fire-resistant species in the longer-term succession patterns. This produces unexpected forest species compositions. Australian research has led researchers to suggest that "unexplained examples of... unusual local abundance of particular species" in tropical forests are directly linked to cyclonic disturbance (Hopkins and Graham, 1987, 29). High concentrations of various palm species and the *Achras zapota*, as well as other trees in Quintana Roo and Belize may well be a by-product of post-cyclone succession patterns.

For the Yucatán peninsula as a whole, the gradual increase in forest height from north to south has been attributed primarily to differing rainfall and moisture levels. While not denying this factor, I would suggest that persistent, periodic cyclonic disturbance has also constituted a formative factor; we can see that the impact zones identified in Map 2 correlate not only with rainfall levels but also with degrees of cyclonic impact. The tropical forest of the peninsula may to a certain extent owe its composition to the molding influences of the 'evil *chacs*'.

6) Soils and forest floors. The virtual absence of forest-floor soils and the abundance of broken limestone debris characterizes much of northern Quintana Roo. Three cyclone-related factors can be identified which would affect soil formation processes, and add to long-rec-

ognized soil generation limitations within canopy-closed tropical forests. These would be the intense heat of forest fires, the leaching and erosion caused by cyclone-generated rains, and excessive exposure to sunlight. Under normal conditions the death of terminal age trees, when they fall of their own account or assisted by strong winds, causes a certain degree of uprooting and breaking-up of surface limestone. Cyclonic winds, on the other hand, uproot a greater number of mature trees with firm root structures, and intensify the breaking-up of forest-floor surfaces. Tropical forests acquire an almost rubble-strewn appearance of limestone debris, with subsurface crevices and uneven surfaces that become catchment basins for existing soils. Forests acquire a widely varied localized distribution of plant energy reservoirs, enriching heterogeneity and diversity for flora and fauna reproduction and sustenance.

Backyard plots (*solares*) of Yucatecan peasant maize growers today show a highly sophisticated exploitation of precisely such varied niche opportunities. That Maya agriculturalists in the distant past recognized such potentials, utilized them, and passed them on to succeeding generations, is entirely consistent with their basic strategy of diversity in agrarian and silviculture subsistence practices. Periodic cyclones, I would argue, provided them with large-scale natural laboratories in which they could experiment and refine their knowledge of their habitat and its resource potentials.

7) Fauna. Cyclonic disturbance invariably affected insect, bird and animal life in tropical forests. The instability of canopy-level environments would suggest a somewhat different sequence of evolutionary processes than found, for example in the more stable Amazonian tropical forests (Balée 1991; Caufield, 1985). Fauna species occupying the understory and forest floors would possess evolutionary and adaptive responses to periodic and dramatic short-term alteration of natural habitats. Those species capable of regional migration, either from areas devastated by cyclones or to areas with post-cyclone succession habitats, would have better chances of reproductive success and species domination. Post-*Gilbert* bird and animal migrations to less affected zones or even to urban centers in search of food, provide contemporary examples of regional migratory patterns. Long-term gradual ecological transformations also have important implications. In addition to seasonal and long-term ecological transformations, the regional fauna, in order to ensure survival and repro-

ductive capacities, also had to contend with the more dramatic and disturbing repercussions of cyclonic impact — fire, flood and fierce winds.

#### ETHNOECOLOGICAL IMPLICATIONS AND PRE-HISPANIC SUBSISTENCE STRATEGIES

Despite the great advances made in recent research concerning the pre-Hispanic Maya occupation of the Yucatán peninsula, there seems to be an overriding concern with a limited set of environmental restraints and opportunities. The current debates about carrying capacities, agricultural systems, population densities, external and internal trading patterns, disease, class factionalism, and external conquests do not sufficiently take into account the nature of tropical forests. The physical evidence of past Maya civilizations is still, in large part, circumscribed by the tropical forests. How the Maya handled, or mishandled, this natural garden of biodiversity remains open to speculation. I suspect that their knowledge of their environment was more complex and sophisticated than is currently recognized, that their successes were linked to such knowledge, and that their failures were the result of ignoring or miscalculating the dynamics of its composition, succession patterns and cyclonic interruptions.

In a previous article I suggested that hurricanes could be seen as 'trigger mechanisms' for settlement patterns, subsistence patterns, migrations and demographic stability, warfare, and trade (Konrad, 1985). These elements arise frequently in discussions of the rise and fall of classic Maya civilizations. Although I do not rule out factors mentioned in the list above, I am chiefly concerned with Maya strategies of coping with environmental restraints and opportunities.

Since Maya civilization developed and flourished in essentially inland centers, the southern lowlands representing perhaps the most important nucleus, understanding their dependence on tropical forests becomes paramount. The tropical forest is highly complex in its multi-layered-layered structure, succession cycles, and energy recycling processes. It harbors an extremely diverse range of flora and fauna. Tropical storms not only alter the complexity or diversity of habitat, they also alter (many times accelerating) the timing and rhythm of existing life cycles and succession patterns among both flora and fauna.



The Maya choice of the tropical forest, represented by the ceiba, as their paradigm of the center of the world and the source of sustenance reflects a logical understanding of succession dynamics. Experts have accepted for some time that swidden systems in many ways mimic natural succession cycles of tropical forest processes. What may well have been overlooked is the fact that slash-and-burn agriculture replicates, in a very direct manner, the impact that tropical storms have on peninsular tropical forests, that is, the felling of the forest, forest fires, and succession. Human intervention comes into play in selection and planting of ground or tree crops useful to humans. The hurricane presented induced succession cycles on a far greater scale than possible with slash-and-burn methods. And an already fragile tropical forest ecosystem subject to unpredictable, periodic interventions from natural causes would have necessitated a delicate balance of use versus preservation.

Reliance on narrow strategies like swidden agriculture, tree or root crops would have been a poor choice for the pre-Hispanic Maya. These could not sustain high population levels over extended periods, nor provide a necessary surplus buffer against uncontrollable natural events such as drought, cyclones, or flora diseases. Reliance on the broadest possible strategies, however, would represent a good choice with a higher probability for long-term subsistence. Thus the picture of broad-based agricultural strategies emerges: swidden agriculture, terraces, raised fields, hydraulic systems, intensive agriculture similar to chinampas, and homegarden plots (Gómez Pompa, 1985, 5-6). Although not all employed at the same time or place, these techniques would have allowed the Maya to minimize damage to, yet utilize the benefits from, the tropical forest.

A broad strategy approach would also include a wide range of silviculture techniques. This is where the research and insights of Arturo Gómez Pompa (1971, 1985) and others working with silviculture aspects take on special significance (Alcorn, 1984; Barrera Marín *et al.*, 1976, and 1977; Gómez Pompa *et al.*, 1972, 1982, 1984, 1987; Flores, 1983). Gómez Pompa identifies a wide range of silviculture techniques practiced by the Maya, past and present (1985, 6). His view, that "Maya silviculture consisted of a series of activities of protection, cultivation, selection, and introduction of trees in their milpas, fallows, plantations, natural forests, houses, living fences, cenotes, and urban centers" (7) provides additional detail about the diversity of

subsistence techniques. Recent studies based on contemporary indigenous knowledge of ethnobotany clearly point to retention and maintenance of a most comprehensive tropical forest nomenclature (Alcorn, 1984; Barrera Marín, Barrera Vásquez and López Franco, 1976). More importantly, the Maya utilized the majority of identified species. The ancient Maya understood both the complexity and diversity of tropical forest habitats, and their societal successes and failures should not be divorced from this understanding.

Although tropical storms could be realistically anticipated, the time, location and impact of any specific storm could not be predicted by the Maya. If knowledge of cyclonic interventions influenced location of major settlements, then settlement patterns would be related to the impact zones identified in Map No. 2. Studying this Map, we find that the greater concentration of classic period sites are located in areas least affected by major tropical storms. Avoiding coastlines, particularly along the Caribbean side of the peninsula, would have been an ecologically sound strategy (Anthony Andrews, personal communication). Tulum, the obvious exception, is at an elevation above storm surge levels.

Measures taken to minimize adverse effects must have become an integral part of basic ecological strategies. In zones I-III the prominence of houses with rounded walls and roofs would be a positive adaptation as these structures resist high winds better than do those with square walls or roofs. The massive stone and masonry temple and elite-sector resident buildings found in all major sites reflect not only societal stratification but also buildings capable of withstanding wind pressures of Category 5 storms. Low stone fences around residences or fields, however, would be virtually useless as windbreaks against hurricane force storms.

Cyclonic stress on habitat, besides shaping fundamental subsistence strategies, undoubtedly had implications for social, political and economic affairs. The absence of sustained, centralized, peninsula-dominating political and economic systems, in contrast to highland developments, may well reflect the need for mobility and flexibility within a larger habitat subject to high degrees of ecological stress. Shifts *in loci* of regional centers of influence, and the rise and fall of specific dynasties, may well have been influenced by the successes of the 'evil *chacs*'. Flexibility and mobility of flora and fauna were also factors to be taken into consideration in Maya adaptive processes.

The objective of this paper has been to introduce rather than resolve questions about cyclonic habitat interventions, ecological stress, and Maya subsistence strategies. If our knowledge of the contemporary Yucatán peninsula's tropical forest habitat is still rather limited, it is more limited still about the pre-Hispanic period. Information from contemporary times can provide definitive answers for contemporary questions; for the more distant past it merely helps to frame questions useful for further investigation.

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#### ARCHIVAL SOURCES

- AGN Archivo General de la Nación, Mexico City
- AGNF Fomento
- AGNG Gobernación
- AGNP Presidentes
- AEC Archivo del Estado de Campeche, Campeche
- AEY Archivo del Estado de Yucatán, Mérida
- CIWY Carnegie Institution of Washington, Yearbooks
- INIBT Instituto Nacional de Investigaciones de Bosques Tropicales,  
Mexico City
- NARA National Archives and Records Administration, Washington, D. C.
- PRO Public Records Office, Kew Gardens, U. K.
- SRE Secretaría de Relaciones Exteriores, Mexico City
- SREAH Archivo Histórico
- WNRC Washington National Records Center, Suitland, Maryland

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- DdY *Diario de Yucatán*, Mérida  
 NdY *Novedades de Yucatán*, Mérida  
 RM *Revista de Mérida*, Mérida  
 RP *Razón del Pueblo*, Mérida  
 NOAA U.S. National Oceanic and Atmosphere Administration  
 NHC National Hurricane Center, Coral Gables  
 NHRL National Hurricane Research Laboratory, Coral Gables

## BIBLIOGRAPHY

- Adams, Richard E. W. (comp.)  
 1977 *The origins of maya civilization*, Albuquerque, N. M., University of New Mexico Press.
- Alcorn, Janis B.  
 1981 "Haustec noncrop resource management: implications for prehistoric rainforest management", *Human Ecology*, 9, 4, 395-417.  
 1984 *Haustec Maya ethnobotany*, Austin, University of Texas Press.
- Andrews, E. Wyllys and Jeremy A. Sabloff (eds.)  
 1986 *Late lowland Maya civilization: Classic to Post-Classic*, Albuquerque, University of New Mexico Press.
- Arzápalo-Marín, Ramón  
 1987 *El ritual de los Bacabs*, México, UNAM.
- Ashmore, Wendy A. (ed.)  
 1981 *Lowland Maya settlement patterns*, Albuquerque, University of New Mexico Press.
- Balée, William  
 1991 "Indigenous history and Amazonian biodiversity," paper presented at the Conference on Forest and Environmental History of Latin America, 18-22, February, San José, Costa Rica.
- Barrera-Marín, Alfredo, A. Barrera-Vásquez and R. López-Franco  
 1976 *Nomenclatura etnobotánica maya: una interpretación taxonómica*, México, INAH-SEP.
- Barrera-Marín, Alfredo *et al.*  
 1977 "El manejo de las selvas por los mayas: sus implicaciones silvícolas y agrícolas," *Biótica*, 2, 2, 47-61.  
 1980 *Diccionario Maya Cordemex*, Mérida, Ediciones Cordemex.
- Caufield, Catherine  
 1985 *In the rainforest*, New York, Alfred A. Knopf.

Chase, Arlen and Prudence M. Rice (eds.)

1985 *The lowland Maya Postclassic*, Austin, University of Texas Press.

Culbert, Patrick (comp.)

1973 *The Classic Maya collapse*, Albuquerque, University of New Mexico Press.

Dahlin, Bruce

1983 "Climate and prehistory on the Yucatán peninsula," *Climatic Change*, 5, 3, 245-263.

De Landa, fray Diego

1986 *Relación de las cosas de Yucatán*, México, Porrúa (editor's translation of quoted passage).

De Montmollin, Oliver

1985 *Classic Maya settlement and politics in the Rosario Valley, Chiapas, Mexico*. Doctoral dissertation, University of Michigan.

Díaz del Castillo, Bernal

1956 *The discovery and conquest of Mexico, 1517-1521*. (A. P. Maudslay, trans.), New York, Farrar, Straus and Giroux.

Farriss, Nancy

1984 *Maya society under colonial rule, the collective enterprise of survival*, Princeton, Princeton University Press.

Fernández de Oviedo and Gonzalo Valdés

1944 *Historia general y natural de las Indias*, Asunción, Editorial Guaraní.

Flannery, Kent V. (ed.)

1982 *Maya subsistence: Studies in Memory of Dennis E. Pulestone*, New York, Academic Press.

Flores, Salvador

1983 "Significado de los haltunes (sartenejas) en la cultura Maya," *Biótica*, 8, 3, 259-279.

Folan, William J.

1985 "Clima y cambios culturales entre los mayas en las tierras bajas: un modelo revisado," *Información*, 10, 123-163.

1985 "Flora, fauna, atmosphere and groundwater: the paleoclimatology and prehistory of Dzibilchantún, Yucatán, Mexico and Environs," in *Arquitectura y Arqueología*, CEMCA (Études Mesoamericaines, Serie II-8), Mexico.

1991 "Calakmul, Campeche, México: una fuerte presencia centralizada en el norte del Petén," paper presented at symposium Campeche: Maya-Colonial, October 3, Campeche.

Folan, William J. (ed.)

1984 *Contributions to the archaeology and ethnohistory of greater Meso-america*, Carbondale, Southern Illinois University Press.

Folan, William J. and Burma Hyde

- 1984 "Climatic forecasting and recording among the ancient and historic Maya: an ethnohistoric approach to epistemological and paleoclimatological patterning," in *Contributions to archaeology and ethnohistory of greater Mesoamerica*, edited by W. J. Folan *et al.*, Carbondale, Southern Illinois University Press.

Folan, William J. *et al.*

- 1982 "Paleoclimatología y prehistoria: el desarrollo cultural e hidrológico de Cobá, Quintana Roo, México," *Información*, 2, 9-37.
- 1983 "Una nota sobre paleoclimatología, prehistoria y diversificación lingüística de los mayas a través de los tiempos," *Información*, 7, 3-18.
- 1983 "Paleoclimatological patterning in southern Mesoamerica," *Journal of Field Archaeology* 1:454-468.

Freidel, David A. and Jeremy A. Sabloff

- 1984 *Cozumel. Late Maya settlement patterns*, New York, Academic Press.

Gann, Thomas

- 1918 *The Maya indians of southern Yucatán and Northern British Honduras*, Washington, Government Printing Office.
- 1924 *In an unknown land*, New York, Charles Scribner's Sons.
- 1926 *Ancient cities and modern tribes: exploration and adventure in Maya lands*, London, Duckworth.

Gómez-Pompa, Arturo

- 1971 "Posible papel de la vegetación secundaria en la evolución de la flora tropical," *Biotrópica*, 3, 125-135.
- 1987 "On Maya silviculture," *Estudios Mexicanos/Mexican Studies*, 3, 1, 1-17.

Gómez-Pompa, Arturo *et al.*

- 1972 "The tropical rainforest: a non-renewable resource," *Science*, 177, 762-765.
- 1982 "Experiences in traditional hydraulic agriculture," in Kent Flannery (ed.), *Maya subsistence*, New York, Academic Press.
- 1984 "El uso de las selvas por los mayas, II: el 'Pot Ket', un eslabón perdido entre las selvas y los huertos familiares mayas", presented at the Symposium Biogeografía de Mesoamérica, Mérida, Yucatán.
- 1987 "The 'Pet Kot': a man-made tropical forest of the Maya," *Interciencia*, 12, 1, 10-15.

Hammond, Norman de

- 1977 *Social process in Maya prehistory*, London, Academic Press.

Hammond, Norman and Gordon R. Willey (eds.)

- 1979 *Maya archaeology and ethnohistory*, Austin, University of Texas Press.

Hansen, Richard

- 1990 "Excavaciones en el norte del Petén: una interpretación diacrónica de los caciques mayas," Symposium Campeche: Maya-Colonial, Campeche, October 3.
- Harrison, Peter D., and B. L. Turner (eds.)  
1978 *Prehispanic Maya agriculture*, Austin, University of Texas Press.
- Hebert, P. J.  
1980 "The Atlantic hurricane season of 1979," *Monthly Weather Review*, 108, 973-990.
- Hopkins, Mike S. and Andrew W. Graham  
1987 "Gregarious flowering in a lowland tropical rainforest: a possible response to disturbance by cyclone winifred," *Australian Journal of Ecology*, 12, 25-29.
- Huntington, Ellsworth  
1915 "Maya civilization and climatic change," *Proceedings of the Nineteenth International Congress of Americanists*, Washington, D.C. (Kraus Reprint, 1968), pp. 150-164.  
1988 "Hurricane Gilbert, September 8-19," *StormData* 30, 9, 13-29.
- Jennings, Gary  
1970 *The killer storms: hurricane, thyfoons and tornados*, Filadelfia, J.B., Lippincott.
- Konrad, Herman W.  
1985 "Fallout of the wars of the chacs: the impact of hurricanes and implications for pre-Hispanic Quintana Roo Maya Processes," in *Status, structure, and stratification: current archaeological reconstructions*, Marc Thompson et al. (eds.), Calgary, University of Calgary, pp. 321-330.
- Lacombe, Charles  
1988 "Los huracanes: ¿podían los mayas predecirlos?," *GeoMundo*, diciembre, 456-463.
- López de Cogolludo, fray Diego  
1842 *Historia de Yucatán escrita en el siglo XVII*, 2 vols., Mérida, Castillo y Cía.
- Lundell, C. L.  
1934-1938 Articles in *Carnegie Institution of Washington Yearbooks*.
- McGee, R. Ron  
1988 "The Mesoamerican flood myth from a Lacandon Maya perspective" (manuscript).
- Médiz-Bolio, Antonio  
1930 *Libro de Chilam Balam de Chumayel*, San José, Costa Rica, Imprenta y Librería Lehman.

- Millas, José Carlos  
1968 *Hurricanes of the Caribbean and adjacent regions, 1492-1800*, Miami, Academy of the Arts and Sciences of America.
- Neumann, Charles J. *et al.*  
1985 *Tropical cyclones of the North Atlantic Ocean, 1871-1985*, Asheville, N.C.: U. S. Department of Commerce-National Oceanic and Atmosphere Administration.
- Neumann, Charles J. *et al.*  
1989 *Tropical Cyclones of the North Atlantic Ocean. 1871-1980*, Ashville, N. C.: U. S. Department of Commerce-National Oceanic and Atmosphere Administration.
- Ortiz, Fernando  
1947 *El huracán: su mitología y sus símbolos*, México, Fondo de Cultura Económica.
- Reading, Alison J.  
1990 "Caribbean tropical storm activity over the past four centuries," *International Journal of Climatology*, 10, 365-376.
- Rico-Gray, A. Gómez-Pompa and P. Chan  
1985 "Las selvas manejadas por los mayas de Yohaltún, Campeche, México," *Biótica*, 10, 4, 321-327.
- Roys, Ralph L.  
1965 *Ritual of the Bacabs*, Norman, University of Oklahoma Press.  
1967 *The Book of the Chilam Balam of Chumayel*, Norman, University of Oklahoma Press.
- Sabloff Jeremy A. and E. W. Andrews (eds.)  
1986 *Late lowland Maya civilization: Classic, to Post-Classic*, Albuquerque, University of New Mexico Press.
- Stocker, G. C. and G.L. Unwin  
1989 "The rain forests of Northeastern Australia — their environment, evolutionary history and dynamics," in *Ecosystems of the world. Tropical rainforest ecosystems, biogeographical and ecological studies*, edited by H. Leith and M. J. A. Werger, Amsterdam, Elsevier, pp. 241-259.
- Tannehill, Ivan R.  
1956 *Hurricanes, their nature and history* (9th ed.), Princeton, Princeton University Press.
- Thompson, J. Eric S.  
1954 *The rise and fall of Maya civilization*, Norman, University of Oklahoma Press.  
1957 *Historia y religión de los mayas*, México, Siglo XXI.
- Tozzer, Alfred M.  
1907 *A comparative study of the Mayas and the Lacandones*, New York, MacMillan.



Turner, B. L.

1983 *Once beneath the forest: prehistoric terracing in the Río Bec region of the Maya lowlands*, Boulder, Westview Press.

Turner, B. L. and Peter D. Harrison (eds.)

1983 *Pulltrouser Swamp*, Austin, University of Texas Press.

Villa-Rojas, Alfonso

1945 *The Maya of east central Quintana Roo*, Washington, CIW, Pub. No. 559.

Walsh, R. P. D.

1977 "Changes in the tracks and frequency of tropical cyclones in the lesser Antilles from 1650 to 1975 and some geomorphological and ecological implications," *Swansea Geographer*, 15, 4-11.

Webb, L. J.

1958 "Cyclones as an ecological factor in tropical lowland rainforest, north Queensland," *Australian Journal of Botany*, 6, 3, 220-228.

Whigham, D. F., Y. Olmstead and E. Cabrera Cano

1991 "The impact of Hurricane *Gilbert* on trees, litterfall, and woody debris in a dry tropical forest in the northeastern Yucatán peninsula," *Biotrópica*, 23, 4, 434-444.

Willey, Gordon R.

1965 "Structure of Ancient Maya Society," *American Anthropologist*, 58, 5, 777-782.

Willey, Gordon B. and Peter Mathew (eds.)

1985 *A consideration of the early Classic Period in the Maya lowlands*, Albany, Institute for Mesoamerican Studies, SUNY.

Willey, Gordon R. *et al.*

1965 "Prehistoric Maya settlement in the Belize valley," *Papers of the Peabody Museum of Archaeology and Ethnology*, No. 54, Cambridge, Harvard University.