Population Estimates at the Ancient Maya City of Chunchucmil, Yucatán, Mexico

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Abstract

This paper seeks to show how GIS has become an essential tool for the recording, storing, processing, and visualization of the archaeological data collected by Pakbeh Regional Economy Project at the ancient Maya city of Chunchucmil (Yucatán, Mexico). Chunchucmil, located in an agriculturally poor region but at the edge of several ecological zones, grew to become one of the most densely settled cities of the Maya area during the Classic Period (AD 400-650) thriving on commerce and trade. At the apogee of Chunchucmil, people chose to settle close to each other in residential groups delimited by boundary walls over an area of at least 25 km^2. In a site where we have recorded more than 6,000 structures, GIS has enormously facilitated calculations for structure and population estimates making GIS an indispensable tool for analysis of such an extensive database.

1 Introduction

The Prehispanic Mayan city of Chunchucmil, Yucatán, Mexico, grew to become one of the most densely settled cities of the Maya area during the middle of the Classic Period (AD 400-650). Since the first report of Chunchucmil in the archaeological literature in the late 1970s (Vlcek et al. 1978), the most striking feature of this site has been the presence of an unusually dense settlement covering at least 12 km^2 in an agriculturally marginal environment. The contradiction between the extremely dense settlement, clearly visible in the aerial photographs, and the limited agricultural environment has attracted the Pakbeh Regional Economy Project to this area since 1993 to investigate this paradox. After 12 field seasons of research at Chunchucmil and its surrounding region, we have gained a much clearer understanding of this site.

In this paper, I will try to answer the question of how many people lived at the city of Chunchucmil during its largest occupation in the middle of the Classic Period (AD 400-650). After a brief review of the methods for estimating past populations, and the shortcomings of those methods, I will provide estimates for the urban residents of Chunchucmil. I will also show how the use of GIS has facilitated the calculations of structure density in a site with an unusual abundance of archaeological features, thus making it possible to estimate the past population of Chunchucmil.

2 The Classic Period City of Chunchucmil

Chunchucmil is located in the driest portion of the Maya region, the northwest corner of the Yucatán peninsula (Figure 1). This is a region with low rainfall, shallow and sparse soils, abundant bedrock, high evapotranspiration, and thus, low agricultural potential (Beach 1998; Dahlin et al. 2005; Vlcek et al. 1978). Palaeoclimatic studies indicate that conditions were similar in the past (Hoddell et al. 1995; Curtis et al. 1996; Whitmore et al. 1996). Despite these limitations, the site of Chunchucmil became a major population center during the middle of the Classic Period with one of the highest population densities recorded for the Maya region. Located only 27 km from the coast and just east of the seasonally inundated savannah at the beginning of the karstic plain, Chunchucmil was strategically situated at the edge of several ecological zones rich in natural resources. Chunchucmil actively participated in maritime trade along the Gulf Coast, exploited the coastal salt flats, and functioned as a regional redistribution center (Dahlin 2003; Dahlin and Ardren 2002) attracting a large population despite being located in an agriculturally marginal environment.

Investigations carried out by the Pakbeh Project have revealed an extremely dense settlement extending over an area of 20-25 km^2 as shown by satellite imagery, aerial photography, and ground reconnaissance (Hixson et al. 2006; Hutson et al. in press). The site was characterized by several groups of monumental architecture dispersed over the central square kilometer and surrounded by dense habitation areas. The residential zone was distinguished by the presence of residential groups delimited by boundary walls and streets that allowed traffic among the tightly bound groups (Figure 2).

3 Chunchucmil's GIS Database

In order to record, store, analyze, and visualize the intrasite data collected at Chunchucmil, I have designed a GIS database in GeoMedia Professional 5.2 (Intergraph). Georeferenced maps were imported into GeoMedia, where all archaeological features were digitized ("heads up digitizing"). I defined 30 feature classes and corresponding attributes to record all the archaeological features as well as some natural and modern features. Other attribute data such

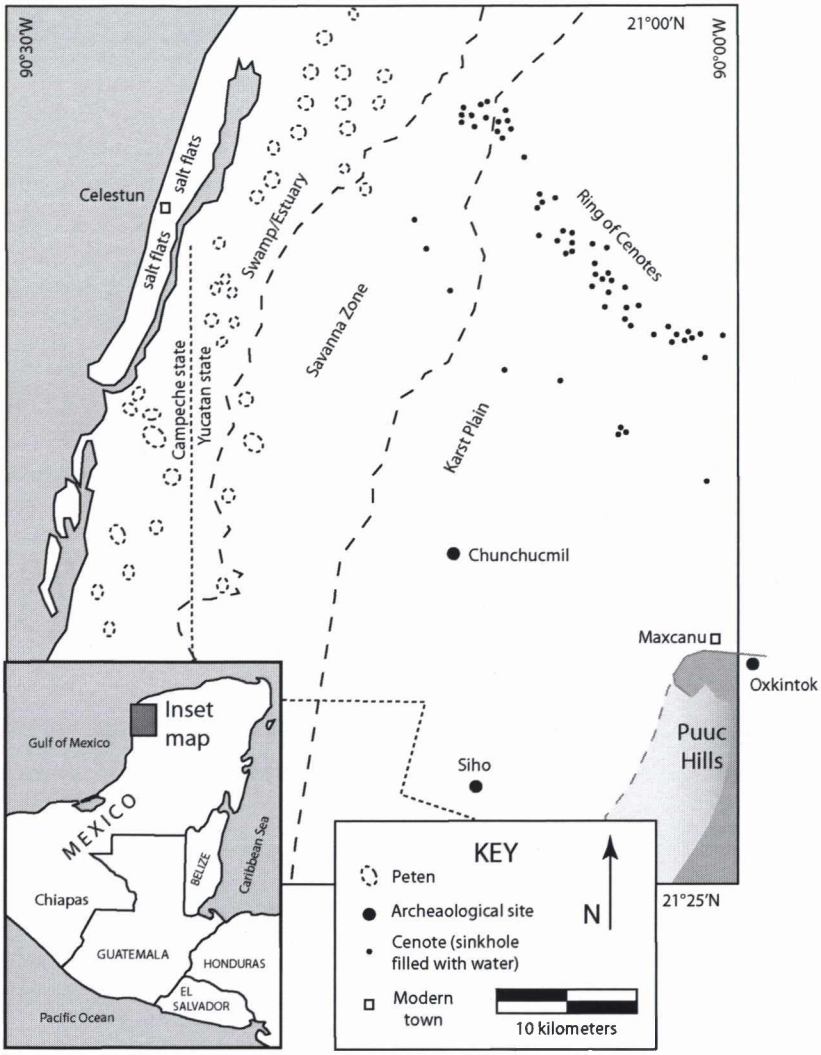

Figure 1. Map of the Maya region showing the location of Chunchucmil.

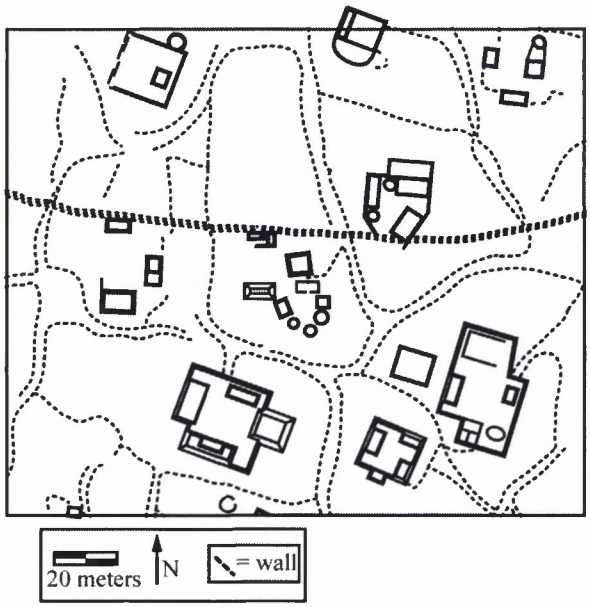

Figure 2. Map of a densely settled residential neighborhood with bounded houselots and streets.

as artifact databases from excavations are being entered either in Excel® spreadsheets or an Access® database so that they can be attached as attribute tables to the vector data. Topographic and soil data from INEGI (Mexican Geographic Institute) maps, aerial photos, and soil data collected in several parts of the site by the Pakbeh Project are being integrated as separate layers in the GIS database.

To date, we have recorded in the GIS database 6.5 km^2 of the 9.2 km^2 mapped so far (cf., Magnoni 2004). In this area of the site we have recorded 6,600 structures, 2,100 grinding stones, 630 quarries, and 165 km of walls. Despite the large data input efforts that have been and are still being undertaken to record these numerous features, GIS is an essential tool at Chunchucmil for the analysis of such a large quantity of intrasite archaeological features over an extensive area. GIS allows us to easily count and measure features that number in the thousands, to run queries that can discriminate between specific features, and to spatially display the results of the analyses.

4 Population Estimates: Methods and Uncertainties

Estimates of past populations are generally based on: 1) human skeletal remains (e.g., Howells 1960); 2) artifact assemblages, especially ceramics, from surface or excavated contexts (e.g., Parsons 1971; Sanders et al. 1979); 3) architectural features such as residential units (e.g., Culbert et al. 1990; Haviland 1969, 1972; Ringle and Andrews V 1990; Tourtellot et al. 1990; Webster and Freter 1990); 4) calculation of mean family size based on roofed-over or living floor area (e.g., Le Blanc 1971; Naroll 1962); and 5) carrying capacity of the land (e.g., Turner 1976).

In the Maya region, an area of poor preservation for human remains and with abundant vegetation cover that generally hinders surface collection, counting architectural features is the most frequently used method for estimating past populations. Since residential structures are usually built on top of raised stone platforms, and the actual residences are often made of masonry, they preserve well in the archaeological record. Thus, counting structures and converting the numbers of structures into numbers of people by applying adjustments has been

the most common way of estimating past populations. The following calculations have to be determined before a final count of structures can be provided: 1) the date of occupation of structures; 2) the percentage of residential buildings; 3) the percentage of residences in use at the same time; and 4) an estimate of the number of invisible or hidden structures (e.g., structures made of perishable materials or structures that have been obliterated by soil and vegetation). Once the number of contemporaneous residential structures in use at the same time is calculated, it is multiplied by the number of residents in each structure to give us the final population estimate. This step involves some assumptions about the number of people that inhabited each residence.

Different figures for the number of residents in each house have been suggested based on ethnohistorical and ethnographic data on Maya households and families. The commonly used figure of 5.6 individuals per nuclear family, which would have inhabited one structure, is based on Redfield and Villas Rojas' (1934) ethnographic study of the Yucatec Maya village of Chan Kom, Yucatán. This figure was used at Mayapán (Smith 1962) and at Tikal (Haviland 1970). There has been a lot of debate about the accuracy of the figure. Alternative figures have been put forward based on ethnohistorical accounts of the sixteenth century, such as Haviland's (1972) figure of 4.9 individuals in a nuclear family based on the Cozumel census of 1570 (Roys et al. 1940). The figure of 4.9 individuals per nuclear family also matches the family size calculated by (Steggerda 1941) for modern Yucatán. This figure rounded up to 5 has been variously applied, for instance by Haviland in his revised Tikal calculations (Haviland 1972) and also at Late Classic Seibal (Tourtellot 1988). Sanders (in Rice and Culbert 1990) has suggested the lower figure of 4 individuals/house based on sixteenth century Mexican census data. Several early colonial censuses from Yucatán indicate that household sizes may have been larger, ranging from 6 to 13.58 individuals per house, since they housed extended families (Roys et al. 1940; Ringle and Andrews V 1990:table 11.7). Changes in rule of residence, however, may have occurred as a result of colonial policies and drastic depopulation following the Conquest, so these early Colonial data may not be easily extrapolated for Prehispanic times.

Most recent population estimates put forward by Maya archaeologists have used the 4, 5, or 5.6 conversion figures (Rice and Culbert 1990). Here I will use the most commonly used figure of 5 persons per residential structure as well as 4 persons per residential structure to provide a more conservative estimate. The important thing to remember about this conversion figure is that it is an average to try to compensate for variation across time and space as result of environmental, economic, social, and political changes, diseases, nutritional stresses, and natural causes.

5 Counting Residential Structures and Estimating Population at Chunchucmil

At Chunchucmil, where there is little soil accumulation and an abundance of stone to build masonry structures, all architectural remains are clearly visible on the surface and thus offer the best way to begin estimating the number of urban residents. Because of the shallow soils and lack of topography, no stone platform or structure can be missed during mapping, so the problem of "invisible structures," which are hidden by soil and vegetation in other parts of the Maya area, is not present at Chunchucmil. In addition, systematic excavations throughout the non-architectural areas of three residential groups have failed to reveal any hidden architectural remains (Hutson et al. 2007). I am confident that all stone-built structures were mapped by the Pakbeh Project, though structures made of perishable materials would have gone unnoticed. As I mentioned above, in the 6.5 km^2 entered in the GIS database, 6,600 structures have been recorded. My goal was then to discriminate between residential and non-residential structures across Chunchucmil in order to calculate residential structure density and then estimate population density. Extensive excavations from Chunchucmil as well as other Maya sites indicate that residential groups usually contained a domestic shrine on the east side, one to four residential structures, and additional non-residential structures that were used as kitchens, storage, and processing areas, all arranged around one or more common patios (Ashmore 1981; Becker 1982, 1999; Hutson et al. 2004; Tourtellot 1983). Our extensive excavations in four residential groups corroborate the notion that extended families with more than one nuclear family were living at these household groups, with a nuclear family per residence (Magnoni et al. 2004; Hutson 2004; Hutson et al. 2004).

Taking the data on residential group composition into account, I eliminated all structures that have an area smaller than 18 m^2, from the count of residential structures since they would have been too small to live in for a family of 4 to 6 people (see Kolb 1985; see also Tourtellot 1983:37). This excluded many round, oval, and rectangular structures that were probably used as ancillary structures for storage, kitchens, animal pens, and other purposes. The figure of 18 m^2 is based on Kolb's (1985) ethnographic analysis of Prehispanic Mesoamerica which indicates that the dwelling average area per person was 6.2 m^2. Considering that a small nuclear family of three would require 18.6 m^2, I decided to use the figure of 18 m^2 as the minimum requirement for a dwelling for a small nuclear family, thus excluding from the residential structure count all structures with an area less than 18 m^2. While realizing that this figure is somewhat arbitrary and that some families may have lived in structures with an area smaller than 18 m^2, an aerial limit to exclude small auxiliary structures has to be set, otherwise our count of residential structures will be inflated. Extensive excavations in four residential groups have corroborated the notion that smaller structures were non-residential and were used for a variety of other purposes (e.g., kitchens, craft and work areas) (Magnoni et al. 2004; Hutson 2004; Hutson et al. 2004). Large pyramids and other monumental architecture that did not serve as residences were also excluded from the count. Domestic shrines, recognizable by their eastern location in the residential group, their square dimension and often relatively tall architecture (Becker 1982, 1999; Hutson et al. 2004) were also eliminated from the count. Basal platforms, on top of which the foundations for perishable structures

or the actual masonry buildings sit, were not counted. The total number of residential structures counted in the 6.5 km^2 mapped and analyzed of Chunchucmil is 4,666.

The next crucial step was to determine which structures were contemporaneous. At Chunchucmil, the presence of shared boundary walls between contiguous residential groups and streets meandering among these bounded houselots clearly indicates that the city was functioning as an integrated unit at a specific point in time. Excavations in 105 of these walled residential groups show a date of late Early Classic and early Late Classic (AD 400-650). Preclassic settlement was incorporated into the urban layout of the Classic Period site, leaving no visible traces on the surface, while later occupation is very limited and recognizable. During the Late-Terminal Classic a small number of large platforms, often bearing Puuc-style architecture, never enclosed by boundary walls, and often disrupting earlier settlement, became the common residential structures. A maximum of 20 of these platforms dispersed in an area of one km^2 around the site center have been recorded. Since we have located all Late-Terminal Classic structures across the site, we can automatically exclude them from our count. Since most of Chunchucmil's occupation dates to one single period and the identifiable later structures can be excluded from the count, I can apply a small correction factor of only -5% to account for non-contemporaneous structures that we were not able to identify.

I now turn to the question of discriminating residential versus non- residential structures. After excavations, at Tikal, non-residential structures were calculated to be 16.5% of total structures (Haviland 1965), while at Seibal they were 14.3% (Tourtellot 1983, 1990). Thus, when estimating population density, these researchers applied a correction factor of -15% to the structure figure. Of the Chunchucmil structures, 16.5 % of the structures were already eliminated because they were considered non-residential (structures with an area smaller than 18m^2, ceremonial structures, and monumental architecture). Despite this, I have decided to still apply a -5% correction factor to account for other unidentified non-residential structures. Moreover, we should also consider that not all structures in a residential group were used as residences at all times because of changing household life cycles. Thus, I also applied a -10% correction factor to account for this.

On the other hand, we have to take into consideration that the number of residential units may have been undercounted since structures made of perishable materials, generally sitting on basal platforms, did not preserve and were not counted. Several basal platforms, which were not part of our count, did not show traces of foundation braces for structures, but we can assume that they would have supported some structure made of perishable materials. To account for this undercount I apply a +5% correction factor. Thus, adding up all the correction factors I come to a final correction factor of -15% to apply to our total count of residential structures.

This provides us with the figure of 3,966 residential structures, or 610 structures/km^2 for the mapped 6.5 km^2. I calculated residential structure densities per 250-x-250-m quadrant by running a thematic query in GeoMedia, which in turn allowed me to display visually the different structural densities per quadrant in Figure 3. Structural density figures were divided into four groups (recognizable in Figure 3 by four different shades of gray) that contained an equal range of numbers, and for each group the average structure density (legend of Figure 3) was calculated. Higher density of structures, marked in darker color, was mainly concentrated in and around the site center, especially to the north, and dropped off with distance from the site center. There were pockets of lower structural density in the site center too, though in several cases this is due to later disturbance. The structural density varies from 273.6 str/km^2 in the residential periphery along the western and southwestern edge of the mapped area to 1,237.6 str/km^2 in the densest portion of the central residential area. At this point I multiplied the figure of 3,966 residential structures by 5, the most commonly used figure in the Maya area for the number of residents in a single residential structure, and obtained a population estimate of 19,830 people living in the 6.5 km^2 mapped at Chunchucmil (or 3,050 person/km^2). To provide a more conservative estimate I also multiplied the same figure of total residential structures by 4 (instead of 5) as the number of residents in a single residential structure. This provides a figure of 15,864 people. Thus, 15,900 to 19,800 people were estimated to have been living in the central 6.5 km^2 of Chunchucmil (Table 1).

The site of Chunchucmil, however, covers much more than the mapped portion analyzed here. Satellite imagery, aerial photography, and ground reconnaissance indicate that it extends for 20-25 km^2 (Hixson et al. 2006; Hutson et al. in press). Using the structural density calculated here for the mapped areas, the structural density for the rest of the site (using a site size of 20-25 km^2) can be extrapolated (Table 1). Considering that a sizable portion of the dense urban residential area (2 km^2) is mapped but not entered in the GIS, I used an average structural density figure (of 876.8 structures/km^2 for 1 km^2 and 566.4 structures/km^2 for another km^2) from similar areas already digitized into the GIS to estimate the structural density of this portion. On the other hand, for the remaining unmapped residential periphery (an area of 16.5 km^2) I used the lowest figure of structural density calculated in the analyzed portions. For the first 6.5 km^2 I used the structural density of 273.6 structures/ km^2, the lowest density calculated along the western and southwestern edge of the mapped portion, while for the remaining 5-10 km^2 I cut this figure in half to 136.8 structures/km^2.

By adding up all these numbers, I obtained a total figure of 7,872 to 8,556 residential structures in 20-25 km^2. Once I multiplied this total number of residential structures by the figure of 4 people per residential structure, I obtained a population estimate of 31,486-34,224 and when I multiplied by the figure of 5 people per residence I obtained 39,358-42,778 people. So, the population estimates for 20-25 km^2 Chunchucmil range from ca. 31,000 to 43,000 people. This is many more people than there are in the region today. These figures are provisional and may be revised upward or downward with the mapping of transects in the residential periphery, which will be carried out in the near future to determine site limits and structure density of these areas.

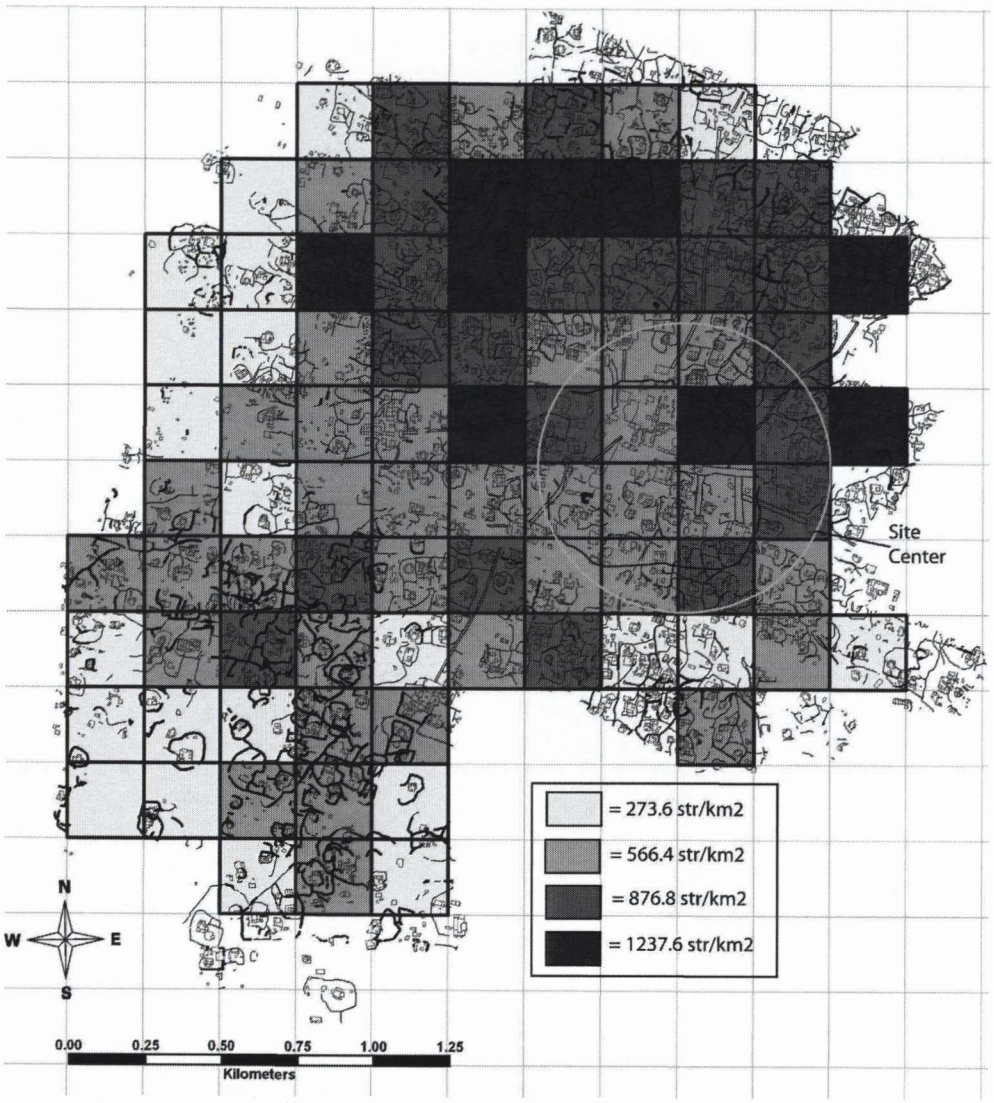

Figure 3. Residential structure density at in the mapped and digitized 6.5 km2 of Chunchucmil.

Table 1. Residential structural density and population estimates at Chunchucmil.

Location	**Number of residential structures**	**Population Estimate** (conversion figure = 4 persons/residence)	**Population Estimate** (conversion figure = 5 persons/residence)
Mapped and digitized central area (6.5 km^2)	3,966	15,864	19,830
Mapped but not digitized urban residential area (2 km^2)	1,443.2	5,772.8	7,216
Residential periphery (inner 6.5 km^2)	1,778.4	7,113.6	8,892
Residential periphery (outer 5-10 km^2)	684-1,368	2,736-5472	3,420-6,840
Total area (20-25km^2)	**7,871.6- 8,555.6**	**31,486.4-34,222**	**39,358-42,778**

6 Conclusions

The results shown here indicate that Chunchucmil was the most densely settled Maya site despite its location in a marginal environment. No other Classic Period site seems to have had such a high structural density and demographic density (Rice and Culbert 1990). The only exception is the small central core (0.6 km^2) of Copán but in the surrounding area structural density drops noticeably (Webster and Freter 1990). In fact, the whole Copán valley, 500 km^2 in extent, included only 18,000 to 25,000 people (Webster and Freter 1990). The total population figure of Tikal—62,000 people—is larger than Chunchucmil's figure of 34,000 to 43,000, but Tikal residents were spread out over an area of 120 km^2 (Culbert et al. 1990). In fact, the central 9 km^2 of Tikal had an estimated population of only 8,300 people (Culbert et al. 1990), in contrast to Chunchucmil's figure of 15,900 to 19,800 people living in the central 6.5 km^2.

Chunchucmil residents were able to support such high population density in this limited agricultural environment because of their reliance on commerce and exploitation of a variety of resources (Dahlin 2003; Dahlin et al. 1998; Dahlin and Ardren 2002; Dahlin et al. 2005; Magnoni et al. in press). Carbon isotope analysis of human remains from five Chunchucmil individuals supports the notion that the local diet relied less on maize compared to other Maya sites and was complemented by other resources (Mansell et al. 2006). Chunchucmil's strategic location close to a variety of ecological zones and their respective resources facilitated Chunchucmil's participation in extensive local, regional, and international trade networks. The proximity to the Gulf Coast (only 27 km) and its harbor at Cambalam guaranteed access to maritime long-distance trade (Dahlin et al. 1998). Local resources from the seasonally inundated savannah, the wetlands, and the Gulf of Mexico coast (especially salt from the second-largest salt flats in the Maya region) as well as agricultural products from the wider interior of northwest Yucatán were exchanged for long-distance traded goods (e.g., obsidian) from other regions of Mesoamerica. Chunchucmil, despite being located in the driest portion of the Maya region with a severely limited agricultural potential, was able to overcome its agricultural limitations by becoming a specialized trading site, redistributing traded goods to the interior, and provisioning maritime and overland traders (Dahlin 2003; Dahlin and Ardren 2002; Dahlin et al. 2005; Magnoni et al. in press).

Intrasite archaeological evidence, such as the widespread distribution of obsidian (95% of obsidian came from El Chayal, Guatemala) across households of all socioeconomic levels, indicates that the majority of households at Chunchucmil widely participated in long-distance trade or had access to long-distance traded goods through market exchange (Dahlin 2003). The burial offerings of a few excavated humble households also reveal unexpected levels of wealth and substantial assemblages of long-distance traded items (Hutson 2004). In addition, several configurational features of the site layout point to a trading economy with a broadly distributed political power structure. The lack of monumental architecture symbolic of one ruling authority that would have supervised civic administration of the city suggests the existence of competing power factions, whose economic and political power was sustained by a market and long-distance trading economy. The lack of city-wide planning also indicates weak civic administration. Moreover, the use of stone boundary walls to demarcate domestic houselots, uncommon at other Classic Maya sites (cf., Folan et al. 1983), may reflect the need to keep not only neighbors and but also visitors and foreigners out of habitational areas in such a densely settled landscape. The presence of meandering streets, completely absent from other Classic Period sites, allowed traffic to enter the city and circulate throughout the tightly bound residential groups, channeling the movement of local residents, out of town visitors, and merchants in the crowded urban environment (Magnoni et al. in press).

In the second part of the Early Classic Period, Chunchucmil grew to become a sprawling and densely settled urban center that attracted large numbers of people from the surrounding region. The economic opportunities provided by commerce and trade not only allowed it to overcome the agricultural limitations of the region, but also provided average Chunchucmil residents with considerable wealth, as shown by domestic assemblages at several excavated residential groups. In conclusion, this study has highlighted an example of intrasite GIS analysis for estimating past population within an extensive and dense urban settlement. Even though the uncertainties intrinsic to methods of estimating past populations cannot be eliminated by the use of GIS, the calculations for structure density over a wide area can be made more accurate and easier to obtain with the use of GIS.

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