4 RESIDENTIAL INEQUALITY AMONG THE ANCIENT MAYA: OPERATIONALIZING HOUSEHOLD ARCHITECTURAL VOLUME AT CARACOL, BELIZE

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The size and dominance of architecture in Caracol's epicenter and outlying monumental nodes demonstrate, at least in part, the hegemony of the rulers who governed and administered Caracol. While Caana, with its enormous construction effort and widespread visibility, phenomenologically dominates the landscape, the actual significance of this architectural feature can best be evaluated in comparison with other structures of a similar nature. Both a residential and administrative structure, Caana is relatively unique in form and scale; however, other household structures occur in at least two distinct architectural forms at Caracol – as both acropoli and plazuelas. In order to operationalize a measurement of hegemony through architecture, energetic analyses – reduced to architectural volume – permit a comparison of wealth inequality as unequal access to labor for household construction. When viewed as a Gini Index, these data allow for a comparative measure of inequality in construction efforts among and between different cities. While other operationalizations of hegemony through architecture and urban design will be required for both a more complete picture of the ancient Maya and to facilitate comparison among Maya cities, this analysis provides one method for discussing the nuances of hegemony using architecture to answer questions of inequality, control, and power.

Introduction

Archaeological data can provide information on social inequality in the past, providing additional datasets to contrast with modern power dynamics and societal diversity. At Caracol, in modern Belize, the hegemony of the state and power of the ruler can be easily seen from the size, visibility, and monumentality exhibited by Caana – the most massive construction at the site (for in depth analysis and description of Caana see A. Chase and D. Chase 2017). In addition, the importance and centrality of Caana and the epicenter can be seen through the dendritic causeway system (A. Chase and D. Chase 2001:273), radiating from the city core to link together the city's monumental architectural nodes (A.S.Z. Chase 2016b:figure 3). These nodes and the epicenter contain all the large architecture at Caracol, excluding one temple standing alone along the Conchita causeway. However, Caracol contained more than just these nodes of architecture. Between and among these monumental structures and white roads were the residential *plazuela* groups (A. Chase and D. Chase 2014), agricultural terraces (A.S.Z. Chase and Weishampel 2016; A. Chase and D. Chase 1998), and residential reservoirs (A.S.Z. Chase 2016a).

One method of investigating the roles of hegemony and power involves a consideration of social inequality. Two simple, intertwined, and commonly used methods of measuring inequality exist today: the Lorenz Curve and the Gini Index (see Gastwirth 1972). Not only are these methods used to measure modern inequality, but archaeologists have also used them to measure inequality in the past (Brown et al. 2015; Hutson 2016:153-156; Smith et al. 2014). In this analysis, the Gini Index provides a measure of the disparity in volume among residential architecture including: the ruler's palace Caana, the large residential acropoli, and the raised *plazuela* housemound groups. This measurement system permits a consideration of both the elite's ability to harness construction efforts and the ability of the average household to construct its residence.

When economists and governmental organizations use the Lorenz Curve and Gini Index measures today, they generally include more variables than just household size (Gastwirth 1972:311-312), but that is not a strict requirement. However, the methods do require that comparisons only be made when the data are measured in the same way. As such, one index of household wealth should not be directly compared with a separate index without proof of a correlation between those metrics. For example, measuring household areas and household volumes provide two distinct measures of inequality, but they are not by

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necessity mutually comparable without corollary supporting data.

In this analysis we only look at household volumes. Several research projects have used area measurements to analyze inequality in the archaeological record (Brown et al. 2015; Smith et al. 2014). Other studies have attempted to measure inequality by calculating household wealth from the material remaining within the dwelling or from ritual offerings and burial goods (see Smith et al. 2014:313 and Smith 1987:301-302). Tomb volume has also been used as a measure of inequality at Caracol (A. Chase 1992; D. Chase and A. Chase 1996). Measuring material wealth in this manner is difficult. The researcher must create or determine the relative value of individual objects owned by the people who dwelt in the houses (Smith 1987:301-317), as well as separate differences in material culture from aspects of market forces (A. Chase et al. 2015; D. Chase and A. Chase 2014) or material goods related to identity (D. Chase and A. Chase 2004:142).

Studies using household areas and volumes arguably provide far easier metrics for wealth inequality because they do not require a schema of comparative wealth values of archaeological material. In addition, Smith et al. (2014:312) strongly suggest that volume can more effectively elucidate inequality than area measurements due to the vertical nature of Mesoamerican household construction. In addition wealth accumulation and inequality, as exhibited by household size, has been observed in anthropological studies (see Smith et al. 2014:312) supporting the use of household volume as a measure of wealth and inequality among various societies.

Sampling Households at Caracol, Belize

Caracol (figure 1) was occupied by over 100,000 people during its apogee in 650 to 700 CE (A. Chase and D. Chase 2016:1; D. Chase and A. Chase 2017) and earlier studies have documented the variability in households at Caracol including both the number of structures around the central plaza and the occurrence of special features such as kitchens or sweat baths (A. Chase and D. Chase 2014:table 1). In addition, all excavated residential groups at the site appear to have been occupied during this apogee. Thus, while the LiDAR data captures the last phases of Caracol's occupation, excavation data suggests that each of these features would have been occupied in 700 CE. While a 200-year window exists between 700 and the collapse at approximately 900 CE, the subsequent construction activity was for the most part less than it was for earlier time periods. Therefore, I argue that this analysis provides a reasonable proxy of household volumes in the Late Classic Period toward the end of the city's lifespan.

In order to conduct this analysis, a representative sample of 4058 elevated constructions was analyzed. This sample included 4040 raised *plazuela* groups, 17 acropoli, and Caana; all identified in the 2009 and 2013 LiDAR datasets for Caracol (A. Chase et al. 2014; A. Chase et al. 2011). This sample does not represent the complete universe of residences at Caracol. Instead, it is the result of a first pass analysis of the site dataset, which should represent relative household density across the city. Additional passes through the dataset will reveal more housing architecture in the future, which will likely change this volumetric analysis, but given the size of the sample any future variations should be subtle.

In this analysis household volumes act as a proxy for construction effort and can be considered as a reduced version of a more complex energetics analysis (Abrams 1994; Abrams and Bolland 1999; A. Chase and D. Chase 2014; Erasmus 1965), especially because this analysis utilizes the existing LiDAR dataset to provide an approximation of these values. It does not require on the ground survey and test excavations of every household at Caracol to determine and calculate the type of household construction present (A. Chase and D. Chase 2014:table 1). Actual energetics analysis of the costs of moving earth, placing limestone blocks, and plastering would provide a more accurate representation of inequality in residential construction at Caracol, but this is unlikely given the dataset. Also, we do not know exactly where the stone, plaster, and other construction materials came from for each house. Caracol has only one currently known quarry and without precise information on the sourcing of materials, such an analysis

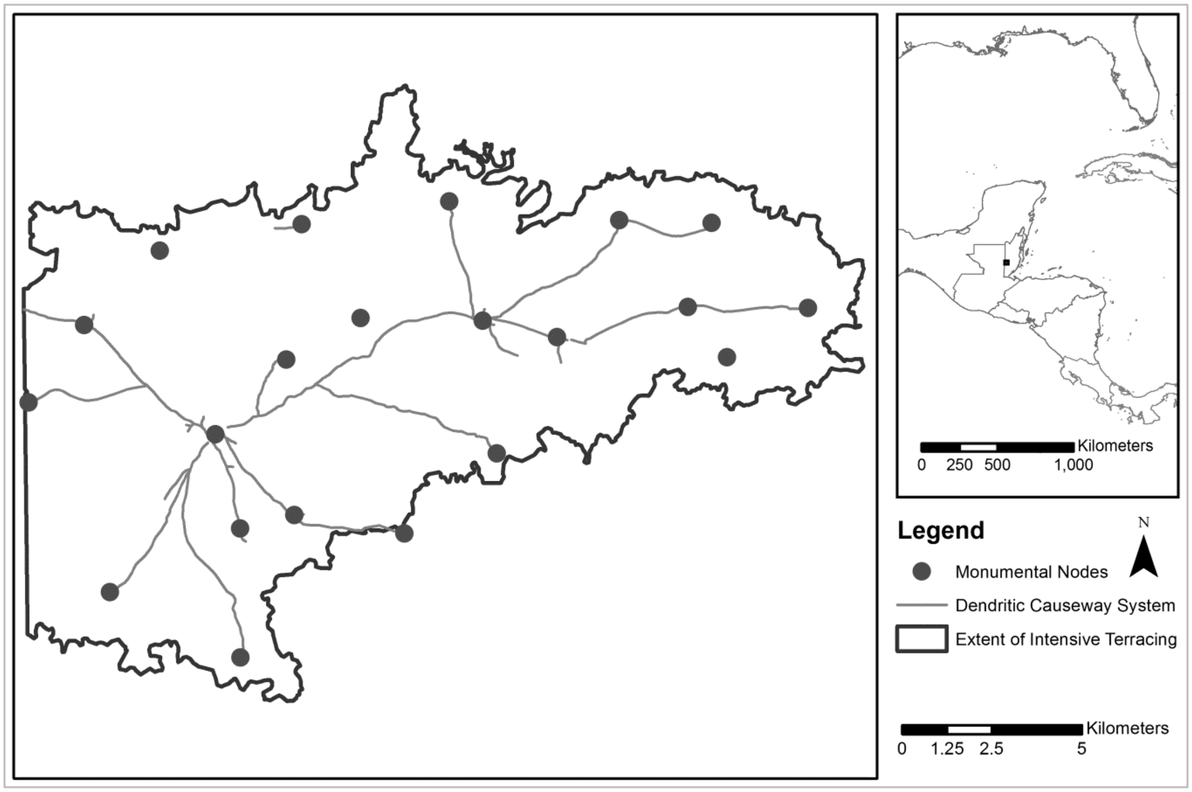

Figure 1. The location of Caracol with its dendritic causeways connecting nodes of monumental architecture.

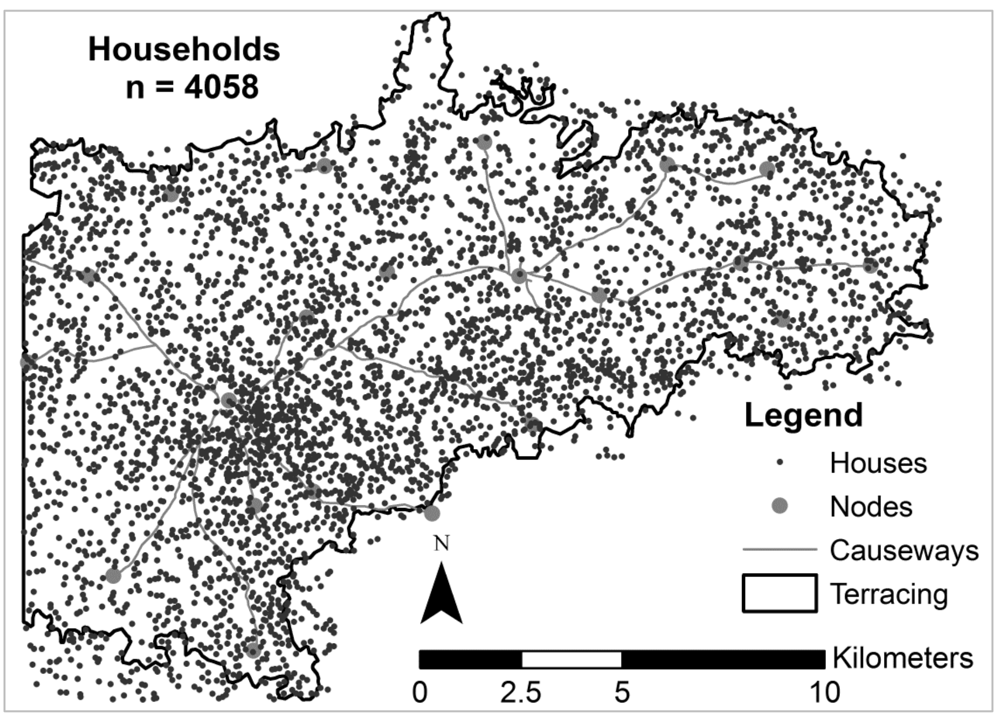

Figure 2. First pass representative sample of 4058 residential groups at Caracol: 4040 plazuelas, 17 acropoli, and Caana (sufficient for this analysis, but below the number of residential groups at Caracol based on survey, excavation, and local high intensity LiDAR survey).

would be flawed as the primary energetic cost for heavy materials like stone involves moving these materials to the construction site. This analysis simplifies energetics to architectural volume; nevertheless, this follows from an energetic argument of labor costs in residential construction that has previously been used to distinguish inequality and leaves room for a more comprehensive future energetics analysis.

Obtaining Volume

For this analysis, residential architecture was first digitized. Volumes were subsequently extracted from the LiDAR-derived DEM dataset. Thankfully, raised *plazuela* groups are distinct enough to be unambiguously identified from remote survey. In addition, several years of prior field survey had identified many households, allowing for a large sample training dataset. Potential residential groups discovered with remote survey were compared against this dataset of known ground truthed residential groups. This process of remote survey resulted in this sample of 4058 households (figure 2).

The process of obtaining the household volume was slightly more complicated. While there are methods in both ArcGIS and GRASS GIS to obtain volumes, they require a single, flat elevation to be predetermined. This relates to their primary use of gauging flood damage or the capacity of reservoirs in modern dam construction. While adding an elevation to each residential group could be accomplished, two factors complicate this analysis. First, construction at Caracol occurred on non-flat terrain, and second, a faster and easier method should encourage other researchers to repeat this methodology with their own datasets.

Determining construction volume on uneven terrain required a multi-step process. First, a new DEM was created that substituted NODATA values – null values to represent a lack of data – under the digitized household locations. Second, new elevation values were interpolated to fill those NODATA cells. This reconstructs a potential landscape that might have existed if the houses had not been built. Third, using *map algebra* – a GIS toolset to allow the user to add and subtract DEM maps with standard algebra expressions – the new DEM without houses was subtracted from the original DEM, creating an additional new DEM of residential architectural volume in each cell. Finally, the values under each digitized feature were added together per residential feature giving the volume of each structure.

While ArcGIS proved to be inferior to GRASS GIS for the above analysis, neither GIS package contained more than one interpolation method. GRASS has a routine, called *r.fill*, with the ability to interpolate and fill in empty DEM cells; however, it is only compatible with spline interpolation. This remains superior to ArcGIS in which a combination of *map algebra* and *focal statistics* filled empty cells without detailed interpolation methods; neither interpolation method has been shown to be superior for obtaining reconstructed volumetric data than any other potential interpolation method. As such, neither GIS package truly facilitated the above analysis with their existing tools and routines, but this analysis can be used as a first-step approximation. Future research will test a diverse set of interpolation methods – including but not limited to: inverse-distance weighting (Philip and Watson 1982; Watson and Philip 1985), natural neighbors (Sibson 1981), spline (Franke 1982; Mitáš and Mitášová 1988), and kriging (Oliver 1990; Royle et al. 1981) – and each one could fundamentally change the resulting interpolated DEM from their application.

Lorenz Curves & Gini Indices

The Lorenz Curve provides a graph of wealth distribution. The Gini Index is derived from the Lorenz Curve because the Gini Index is the numeric representation for the area under the Lorenz Curve. Both measures are used on an aspect of wealth, as defined by the researcher, applying both methods in units of either *individuals* or *households*. For archaeological cases, households present a more standardized unit of measurement. The researcher must also ensure that their data present a representative sample of the population under analysis.

Today these methods of measuring wealth can be determined from national tax returns or census data. For archaeologists, as indicated earlier, wealth is often determined either from some combination of the size of residences or features – often as volumes and areas – or

Table 1. Sample spreadsheet with formulas for calculating the Lorenz Curve and Gini Index with Microsoft Excel formatting shown.

	A	B	C	D
1	Volumes	Sum of Sums	Portion	Lorenz Curve
2	…	=SUM(A2:Ax)	=A2/\$B\$2	=C2
3	…		=A3/\$B\$2	=C3+D2
…	…		…	…
x	…		=Ax/\$B\$2	=Cx+D(x-1)

material goods – often as mortuary goods. In the first case of areas and volumes, wealth is simply the measurement of a given feature, while in the second case of material goods wealth requires the creation of a schema representing the value of each given artifact. The first archaeological use of the Gini Index and Lorenz Curve was by McGuire (1983), and while simple to calculate and compare, Lorenz Curves and Gini Indices have not entered mainstream archaeology in the following thirty plus years (Smith et al. 2014:320).

In order to create the Lorenz Curve, it is useful to start with a spreadsheet program such as Google Sheets or Microsoft Excel (table 1). In this analysis, all of the household volumes were arranged in order from least to greatest in the first column. The sum of all household volumes was calculated and stored in the next column. Each volume was divided by the total volume, this value is located the next column. The cumulative volumes were calculated, and the next column represents the sum of the value above it (the previous sum) with the value of the current household. This column provides the values for creating the Lorenz Curve.

In the Lorenz Curve, the x-axis shows the proportion of households while the y-axis shows the proportion of wealth represented by those households. The curve can vary between two extremes (figure 3). The first extreme is perfect inequality in which one household has all of the wealth. This would be represented by a line running parallel to the x-axis until the last household where that line would take a 90-degree right angle to represent one hundred percent of the wealth. The second extreme is perfect equality in which every individual has equal wealth. This forms a 45-degree line on the graph.

Perfect inequality has a Gini Index value of one while equality has a Gini Index value of zero; that is because the Gini Index itself is a calculation of area in the Lorenz Curve graph (figure 4). The Gini Index is the ratio of the area under the line of perfect equality but above the Lorenz Curve and the entire area under the line of perfect equality. As an equation, it is represented as A / (A + B). Technically, this measure of area under a graph is by definition calculus; however, with the actual data required to make this graph no actual calculus is required in order to calculate the Gini Index. Instead, the existing data can be used similarly to Riemann sums (Stewart 2005:343-350) to approximate the area under the graph. Area A is always the same 45-degree line where one percent of households would have one percent of wealth minus the actual observed value of wealth that one percent of households had. The observed value forms the line delineating the separation between area A and area B. Also bear in mind that because of these area measurements two identical Gini indices may possess from very different Lorenz Curves.

I would argue that if we expect clearly defined social classes with large wealth disparities, then these should be shown as inflection points – also known as “kinks” – on the Lorenz curve. These inflections would be the fulcrum between the elite and non-elite. However, if there are no strict barriers between social classes, such as in modern society, then there should be a constant curve with few flat zones indicating multiple people with the same wealth levels (also see Hutson 2016:168-169). The Lorenz Curve from Caracol (figure 3) displays three interesting features: there are no “kinks” representing strict differences in wealth between classes among *plazuela* groups, Caana’s architectural volume alone accounts for 0.02 of

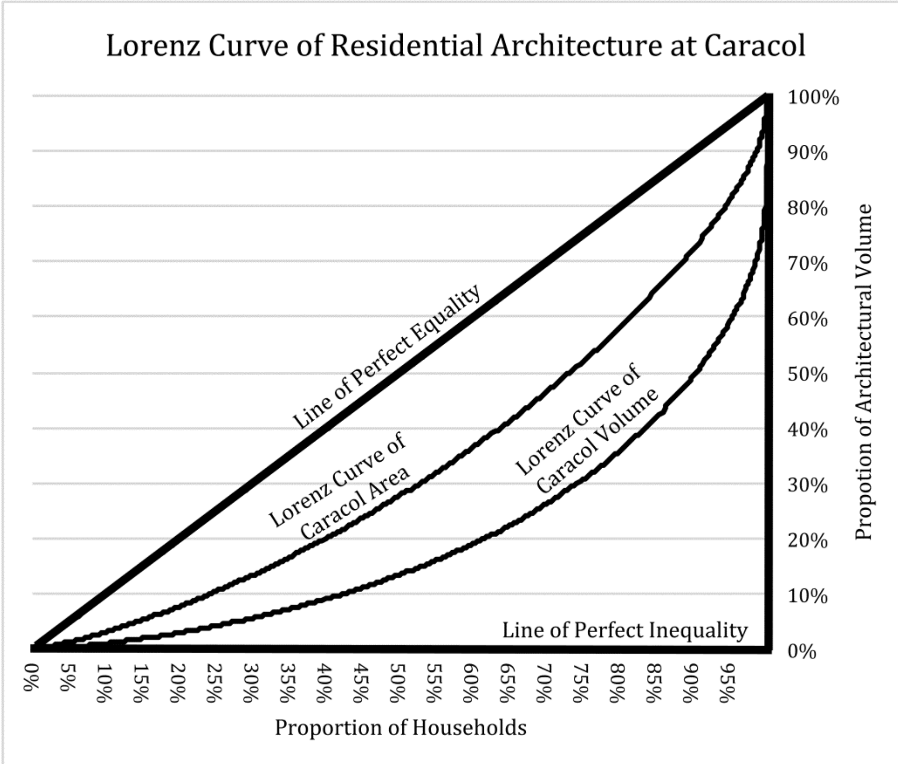

Figure 3. Lorenz Curve of residential architecture volume at Caracol and the lines of perfect equality (Gini = 0) and perfect inequality (Gini = 1).

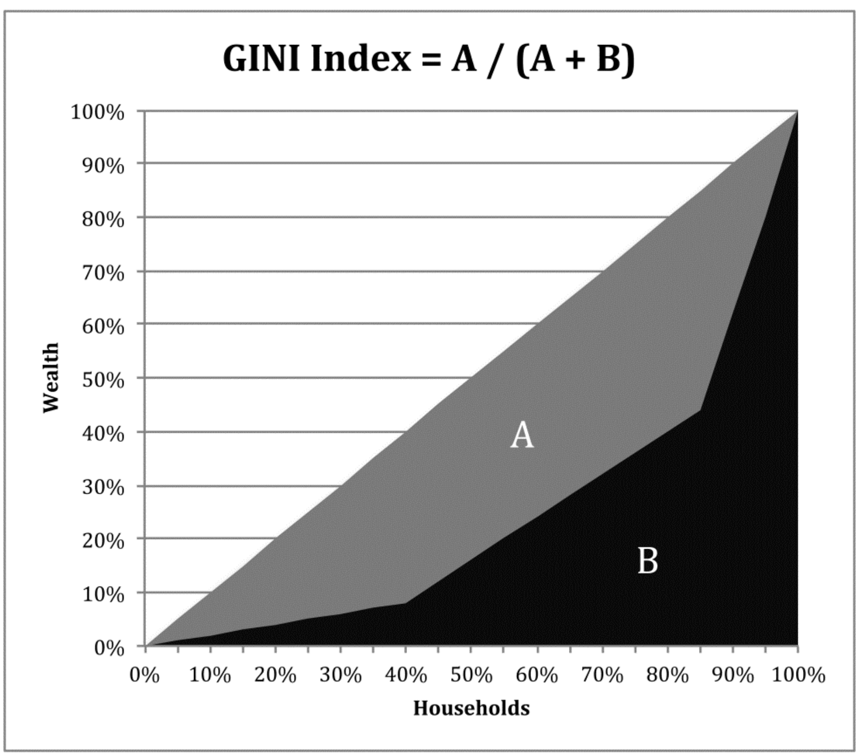

Figure 4. The Gini Index equals this formula with areas A and B. Gini Index = A / (A + B).

Table 2. Gini values for residential architecture areas and volumes at Caracol and elsewhere (Brown et al. 2015:316-318; Hutson et al. 2004:table 5.1; Smith et al. 2014:figure 1). Hutson also provides a Gini of 0.59 for Sayil based on a smaller sample size than Brown, and Hutson provides additional Gini Indices for Chunchucmil with separate measurements and sample sizes.

Site	Period	Household Area Gini Index	Household Volume Gini Index
Caracol	Late Classic	0.34	0.60
From data presented in Brown et al. (2015:316-318)			
Mayapan	Late Postclassic	0.32	?
Palenque	Late Classic	0.44	?
Sayil	Late Classic	0.71	?
From data presented in Smith et al. (2014:figure 1)			
Capilco	LPC-A	0.10	0.06
Capilco	LPC-B	0.16	0.09
Cuexcomate	LPC-A	0.48	0.46
Cuexcomate	LPC-B	0.25	0.19
Yautepec	LPC-B	0.21	0.33
Teotihuacan	Classic	0.12	?
From data presented in Hutson (2016:table 5.1)			
Chunchucmil	Early Classic	?	0.63
Dzibilichaltun	Late Classic	0.39	?

the final Gini coefficient, and the top 1% of households at Caracol possessed about 26% of the wealth as measured by household architectural volume.

It must be remembered that these Lorenz Curves and Gini Indexes have a potential pitfall; they can only be compared when the datasets are the same or have been shown to be comparable. For example, residential area and residential volume can produce vastly different curves and vastly different Gini values (table 2). That being said, any other archaeological site with a representative sample of households can follow the above steps and then compare and contrast its values with the values at Caracol. For example, data from Maya sites in the Yucatan Peninsula of Mexico (Brown et al. 2015:316-318; Hutson 2016:153-156) and data from Central Mexico (Smith et al. 2014:table 1) provide comparable data and are reproduced in table 2.

Discussion

As a result of this analysis, we can gain a slightly more nuanced picture of inequality at Caracol and the existence of political hegemony in residential construction. One of Caracol's defining aspects is the widespread occurrence of goods at various households in a system dubbed "symbolic egalitarianism" (A. Chase and D. Chase 2009:16-18; D. Chase and A. Chase 2017) and as a result of a strict market economy (Hirth 1998:454-456). The resulting shared identity through shared access to material goods should indicate that Caracol might have other appearances of shared wealth, possibly in semi-equality among household construction.

When looking at the Lorenz curve and Gini Index, Caracol clearly exhibits inequality. However, the absence of a clear inflection point to distinguish between the elite and non-elite presents a high degree in wealth variation between households. There does not appear to be an arbitrary household distinction between the elite and non-elite although at both ends of the scale we can clearly see both elite and non-elite households.

Conclusion

This analysis of inequality in the volume of residential architecture shows that while the hegemony of the state and the power of the rulers existed at Caracol, the ruler's power was not absolute. While there was a difference between the uppermost elite and the rest of society, this analysis finds no clear distinction within the volumes of *plazuela* residential architecture that cleanly separates Caracol's inhabitants into clear categories. Instead we see a wide distribution of unequal household wealth at Caracol with the top 1% of households at Caracol possessed about 26% of the wealth as measured by household architectural volume representing a Gini Index of 0.602.

Various archaeologists have used both Lorenz Curves and Gini Indices over the past thirty years, but these measures have yet to see widespread adoption in the field. These methods provide a quick method for comparing and contrasting two comparable datasets. Hopefully with the more widespread nature of LiDAR at Mesoamerican sites and the methodology presented here, new analyses of residential inequality based on architectural volume can be replicated at other cities in order to learn more about ancient inequality for the Maya and other societies.

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