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Compact Section: Ancient Maya Inequality

Gini coefficient at La Corona: The impacts of variation in analytical unit and aggregation scale

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Abstract

Measurements of inequality, like many other analytical phenomena, are affected by the definition of analytical units (for example, buildings or residential groups) and the spatial unit within which those units are aggregated (for example, sites or polities). We begin by considering the impact of secondary or seasonal residences on the calculation of Gini scores when dealing with regional-scale settlement data, which is a common consideration in regional-scale population estimates. We then use LiDAR-derived settlement data from northwestern Guatemala to calculate Gini coefficients for two ancient Maya sites: Late Classic La Corona and Late Preclassic Achiotal. We investigate how the scale of the spatial unit of aggregation affects our interpretations of inequality using various architecture-based indices. Finally, we provide some preliminary interpretations for the differences calculated between these two centers.

Resumen

Archaeology has long regarded the development of inequality as an important indicator of ancient complexity. However, the topic of inequality has been integral to the study of every branch of the social sciences since the mid-eighteenth century. However, with the rise of bureaucratic states using statistics to identify and "solve" sociological problems, such as poverty and criminality, this topic took a quantitative turn with the development of the Gini coefficient. Meant to provide an empirical estimate of inequalities rather than to propose causes for or functional relations between them, this coefficient has provided archaeology with a method to evaluate degrees of differentiation in ancient populations, using indices such as (among others) architecture, material goods, or burials (see Kohler and Smith 2018). While we are aware that most material indices represent, at best, indirect proxies for differentiation in the ancient world, in this article, we develop several Gini coefficients for two ancient Maya settlements located in the northwest Peten of Guatemala: Late Classic La Corona and Late Preclassic Achiotal. Relying on different architecture-based indices, we use these coefficients to suggest methodological refinements to the application of Gini coefficients in Maya studies, but also to offer some preliminary interpretations for the differences we calculated between these two centers.

Settings and sample

We focus on two centers located in the northwest Peten, Guatemala. This region is an ecotone, grading gently from east to west (Figure 1). Its eastern extreme, around the Late Preclassic and Early Classic center of Achiotal, is part of a karst margin plain that defines the western part of the Peten Plateau. Its western extreme is part of the Laguna del Tigre wetlands, characterized by many small freshwater lagoons and small perennial surface streams. La Corona is positioned at the point of transition between these two landscapes. The entire region is exceedingly flat, with limited surface drainage.

Though remote, La Corona was peppered with sculpted monuments that recorded its political association with the important Classic Maya dynasty of Kaanul, the hegemonic rulers of the Classic period centers of Dzibanche and Calakmul with which it maintained a close alliance for over two centuries in the Late Classic period (Baron 2016; Canuto and Barrientos Q. 2020; Lamoureux-St-Hilaire et al. 2019; Martin 2001:183, 2008; Stuart et al. 2018). Despite this important role as a tightly integrated but geographically distant political dependency, La Corona's civic-ceremonial core was small (~1 km^2), composed of two main architectural complexes, interspersed with a handful of minor shrines and residential clusters (Barrientos Q. et al. 2011). Moreover, initial mapping, survey, and reconnaissance efforts indicated that the surrounding region was

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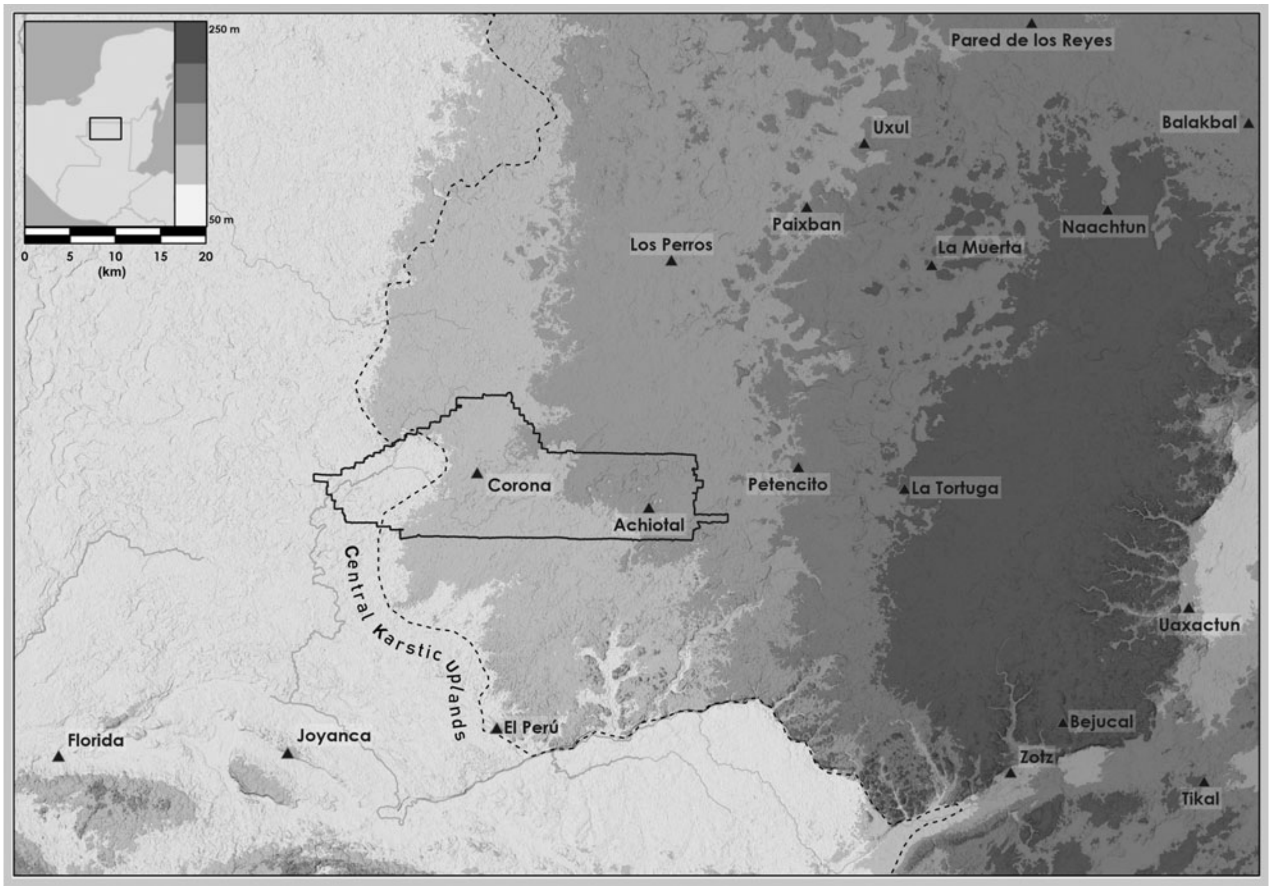

Figure 1. Maya sites in northwestern Peten, along with the boundaries of the ALS capture.

sparsely settled (Canuto et al. 2005; Chiriboga 2013; Guzmán Piedrasanta 2012; Marken 2010).

In 2016, the Pacunam LiDAR Initiative (PLI) undertook a 2,144 km^2 airbone lidar scanning (ALS) survey of the Central Maya Lowlands in northern Guatemala (see Canuto et al. 2018, for details on PLI). Data were collected by the National Center for Airborne Laser Mapping (NCALM), which produced digital terrain models with a 1 m grid resolution. Proyecto Regional Arqueológico La Corona (PRALC) provided a 432 km^2 block of LiDAR data that present the singular opportunity to study how a small Late Classic center of outsized political importance correlates with a sparse population (Figure 1).

In this study, we pose the question of how the application of the Gini coefficient can help further illuminate the nature of La Corona as a small subordinate center. Would its populations reflect a degree of inequality as acute as that of those populations living in the shadows of larger political centers such as Dzibanche or Calakmul? How would the Late Preclassic populations located further east compare with their Classic period successors?

Settlement density and typology

Heads-up digitization iterating with field validation resulted in the identification of 3,853 structures and 10 small centers, suggesting that the Late Classic population of the region was around 12,000 people, with an overall population density of less than 0.5 people/ha—sparse by Lowland Maya standards (see Culbert and Rice 1990). Assessing the distribution of settlement throughout the survey domain demonstrated that much of the region was nearly vacant, while the rest had less than 60 structures/km^2, a measure often interpreted as indicating "rural." At the opposite end of the density spectrum, the region's highest recorded density was 227 structures/km^2, a value that characterizes a small ~100 ha area within the La Corona polity core. Relative to the rest of the Peten, in which Lowland Maya monumental centers reach settlement densities above 300 structures/km^2, even La Corona's densest area registers as both small and low.

The region's flat, ecotonal setting leaves it with a paucity of preferred landforms relative to the rest of the Maya lowlands (see Canuto and Auld-Thomas 2021). For instance, the highly preferred ridge and *islote* landforms comprise only ~19 percent of the whole area. Yet these landforms contain nearly 90 percent of its settlement, resulting in a *productive density* of ~56 structures/km^2. Even so, in adjacent parts of the Maya Lowlands, the settlement densities of preferred landforms are three to six times greater than those of the Corona region. Overall, these various assessments leave us with one inescapable conclusion: by any reasonable measure, the "Corona community" is indeed less dense than the rest of the Central Maya Lowlands, in both absolute and relative terms.

Before we turn to our Gini results, we focus on our settlement typology to further clarify the kind of settlement and populations that inhabited this region. Settlement classification and field verification efforts centered around the monumental cores of La Corona, Achiotal, and Chable (Canuto and Auld-Thomas 2020, 2021). To date, PRALC's field validation has conducted full-coverage survey of ~23.5 km^2 throughout the region, which has demonstrated excellent fidelity between what we identified through heads-up digitizing and what we encountered on the ground (single-pass assessment: 0.908 user accuracy; 0.752 producer accuracy; 0.823 F1-score; Canuto and Auld-Thomas 2021; see also Garrison et al. 2022). It has also allowed us to develop a locally parameterized settlement typology with a robust local sample.

Field validation showed that our digitizing was conservative, with false negatives outnumbering false positives. This is highly relevant to our purpose here, because "false negatives" were, overwhelmingly, small buildings. If there were a way to reliably account for them in our calculations, our derived Gini coefficient would be higher, since the additional small buildings would not be offset by the addition of midsize or large buildings, all of which were reliably identified in the LiDAR data.

Our survey defined a "group" as any set of archaeological features located within 35 m of one another (see Ashmore et al. 1994; de Montmollin 1985). With ALS data, we quantified each structure's proximity relationships, demonstrating that over 85 percent of structures were located within 35 m of one another, thus buttressing our initial spatial definition of a group. We then classified each group into six categories, based on: number of mounds, mound height, presence of focal mound or patio within the group, and overall spatial arrangement (Figure 2). Notably, settlement in our study area consists of a hodge-podge of single mounds, informal clusters of buildings, formal patios, and so on, implying that the region's population was predominantly organized into single (multigenerational) family households. Basal platforms and clearly defined patios are both uncommon; instead, single mounds and irregular clusters of buildings represent some 40 percent of the dataset.

In our typology, the smallest unit (Type I) is the isolated mound; it represents a significant portion (~30 percent) of all settlement. Single buildings have long been regarded by some Mayanists as non-permanent or secondary residences, drawing on the ethnographic analog of "field houses," used by Maya farmers to be close to their outfields during busy agricultural seasons (Ford 1986; Horn III et al. 2023; Sanders 1981). We do not dispute this argument; in fact, our own excavations support the idea that some isolated

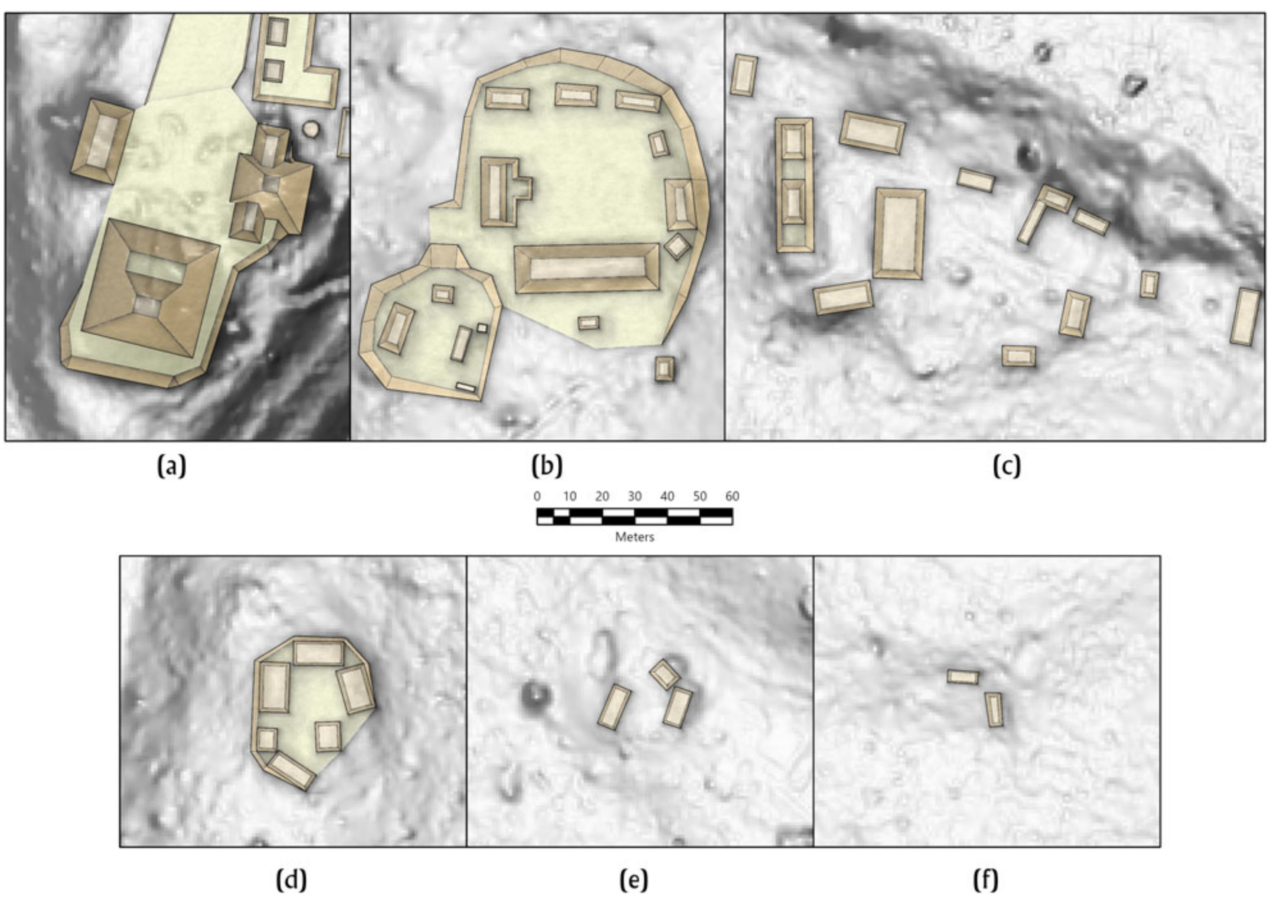

Figure 2. Settlement typology: (a) monumental core; (b) plaza; (c) patio cluster; (d) patio; (e) aggregate mound; and (f) single mound.

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buildings in our region were not permanent homes. However, this analogy does not explain single mounds located *within* communities, which would not be the settings for outfield agriculture. Since most of our isolated mounds were located near other residential groups, it is unlikely that all were field houses or temporary shelters. Perhaps adjacent to now-invisible perishable structures, some Type I groups were nuclear family residences. Nevertheless, a key feature of the settlement in this area is the frequent occurrence of Type I (single mounds) *not* associated with any other buildings. Since these Type 1 buildings represent 10 percent of our total number of structures, how we handle them has a major impact on our Gini estimates.

Clustering methods

To calculate Gini coefficients for our area, we delineated groups beyond ground-truthing. To do so, we first identified each structure within our area of interest with a point using heads-up digitization. We then turned to a combination of two density-based spatial clustering algorithms—DBSCAN (ArcGIS Pro, 40 m search radius, with a minimum of two structures) and HDBSCAN (ArcGIS Pro, with a minimum of two structures)—which identify clusters among a set of unevenly distributed points within a given area; in this way, both tools are well-suited to the characteristic patchiness of Maya settlement. Both these tools resulted in the identification of point clusters of, at minimum, two buildings. We used both approaches: (1) to confirm the validity of one tool's clusters with those of the other; and (2) to provide alternative clusterings when one tool produced a cluster that did not meet our expectations of single household units.

After reviewing and confirming the clusters, we qualitatively eliminated clusters according to strict functional criteria. Our analysis eliminated a handful of complexes in the entire Corona-Achiotal region as categorically non-residential and disarticulated from a household. We also excluded a complex of two conical mounds north of La Corona, which are formally distinct, clearly not residential, and not contemporaneous with the rest of the Corona-Achiotal region's settlement system.

Returning to the thorny problem of "single mounds", they are of no small consequence for estimations of inequality in Maya society. Excluding them altogether would risk artificially flattening Maya society, excluding the poorest people from analysis. But if the single mounds are secondary residences, to whom should they be attributed in the calculations? To deal with these two problems, we invoked spatial relationships. Single mounds *within* communities—where there would be no advantage to building a *rancho* for agricultural convenience—are included as genuine standalone houses. Single buildings that occur *outside* of communities are excluded from the analysis under the assumption that they mostly represent non-permanent dwellings. That these mounds are universally small and shabby, rarely more than 25 m^2 or 30 cm high, means that they would contribute little in the way of area or volume to their owners' architectural assets.

To distinguish which single mounds should be considered part of a household, despite their remoteness from the cluster, from those single mounds which should be excluded from our calculations as solitary "field" structures, we calculated the distance between each solitary (non-clustered) structure and its nearest cluster. We then compiled these nearest distances and, based on the overall distribution of nearest distances, identified 221 m as a threshold. In other words, there appeared to be a natural break in the distribution of distances of solitary buildings from cluster centers at approximately 220 m, suggesting that beyond that distance, solitary structures may have had a different function—that is, non-residential—relative to their closest residential cluster.

Scenarios

We calculated Gini coefficients (see Table 1) using both area and volume measurements as our "inequality metric" for four different analytical units. We did this to see what variations would result using different metrics as well as analytical units. In the first scenario we used only "individual residential structures," as adopted by colleagues in Belize (Thompson et al. 2021b). Only residential structures were used, and among those, only the ones measuring 20–275 m^2 (see Thompson et al. 2023). Single, isolated mounds were included in this scenario. The Gini coefficients were 0.34 for area and 0.59 for volume, with confidence intervals of less than 0.02 (Figure 3). For our second scenario, we aggregated (summed) all the structures within *plazuela* groups (Thompson et al. 2021a). In our case, these *plazuela* groups were the clusters that we had defined earlier, using a combination of HDBSCAN and DBSCAN. The Gini coefficients in this case were 0.44 for area and 0.69 for volume, with confidence intervals of less than 0.06 (Figure 4). A third version of this analysis took as its unit of analysis the entire *plazuela* group, aggregating structures and the basal platform where present. In our case, when our *plazuela* clusters had no basal platform, only the sum of the constituent structures was used (as in Scenario 2). That is, we did not include the area between structure mounds in the Gini calculation; given the irregular nature of many groups in our sample, doing so would have spuriously incorporated a great deal of natural topographic variation. The Gini coefficients were 0.53 for area and 0.69 for volume, with confidence intervals of less than 0.07 (Figure 5).

For our fourth scenario, we return to the issue of single mounds. As noted above, we reasoned that single mounds (20–275 m^2) in close spatial proximity to other multi-building clusters represent true residences. Therefore, in our fourth scenario, we included all single mounds within 221 m of another cluster and excluded all those that fell outside this distance as probable non-dwellings. We chose this distance because the distribution of single structures clustered either within 221 m or far beyond it. This calculation resulted in Gini coefficients that were 0.58 for area and

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Table 1. Gini coefficients of four different scenarios.

		Scenario 1		Scenario 2		Scenario 3		Scenario 4	
		Area	Volume	Area	Volume	Area	Volume	Area	Volume
Data universe		All		All		All		All	
Analytical unit		Individual structures		Basal platform/cluster		Basal platform/cluster		Basal platform/cluster/ individual	
Data source		Structures		Structures		Structures/platforms		Structures/platforms	
Gini coefficient		0.34	0.59	0.44	0.69	0.53	0.69	0.58	0.72
Average		0.46		0.56		0.61		0.65	
Error		0.02		0.03		0.06		0.06	
Descriptive stats	Sample size	3363	3363	985	985	978	978	1319	1319
	Mean	85.02	21.14	304.45	105.37	588.21	154.62	465.04	122.39
	Range	254.89	263.92	3040.13	2356.91	8552.35	5997.74	8559.05	5998
	Standard deviation	54.36	28.81	311.92	226.66	816.92	381.1	736.02	333.95
	Coefficient of variation	0.64	1.36	1.02	2.15	1.39	2.46	1.58	2.73
	Minium	20.02	0.33	17.18	0.64	27.01	0.64	20.31	0.38
	Lower median	45.13	4.62	128.8	15.36	167.57	23.18	105.42	14.73
	Median	67.63	10.18	211.67	37.99	355.63	57.8	223.76	41.49
	Upper median	108.34	24.59	358.48	89.99	699.17	132.36	559.77	101.48
	Maximum	274.92	264.25	3057.31	2357.55	8579.36	5998.38	8579.36	5998.38

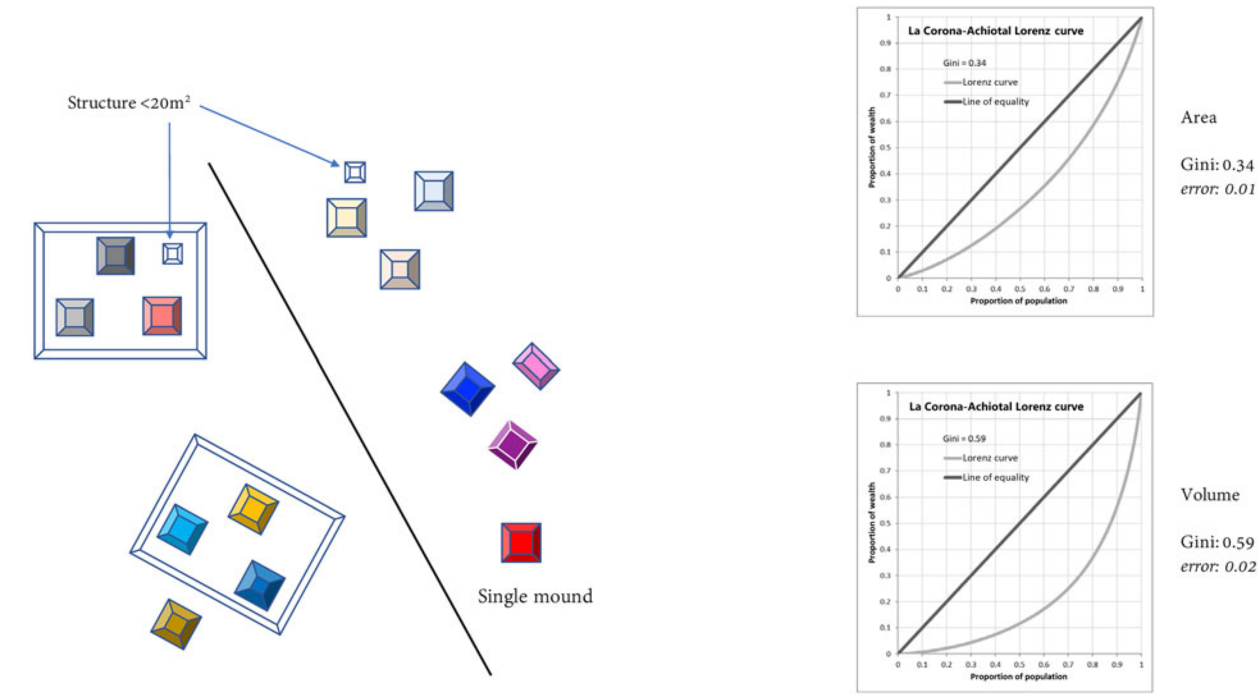

Figure 3. Gini coefficient: individual residential structures (20–275 m^2, sample size: 3,363; Scenario 1).

0.71 for volume, with confidence intervals of less than 0.06 (Figure 6).

Results

These results suggest that the La Corona region had relatively high levels of inequality as measured by the Gini coefficient. However, one note of caution is warranted. Our Gini indices vary notably, from a low of 0.34 for area (equivalent to Canada) to a high of 0.72 for volume (higher than all modern nation states, including South Africa), solely as a function of how we aggregated our data. This variation is no small matter, since we cannot simply favor one measure without good reason.

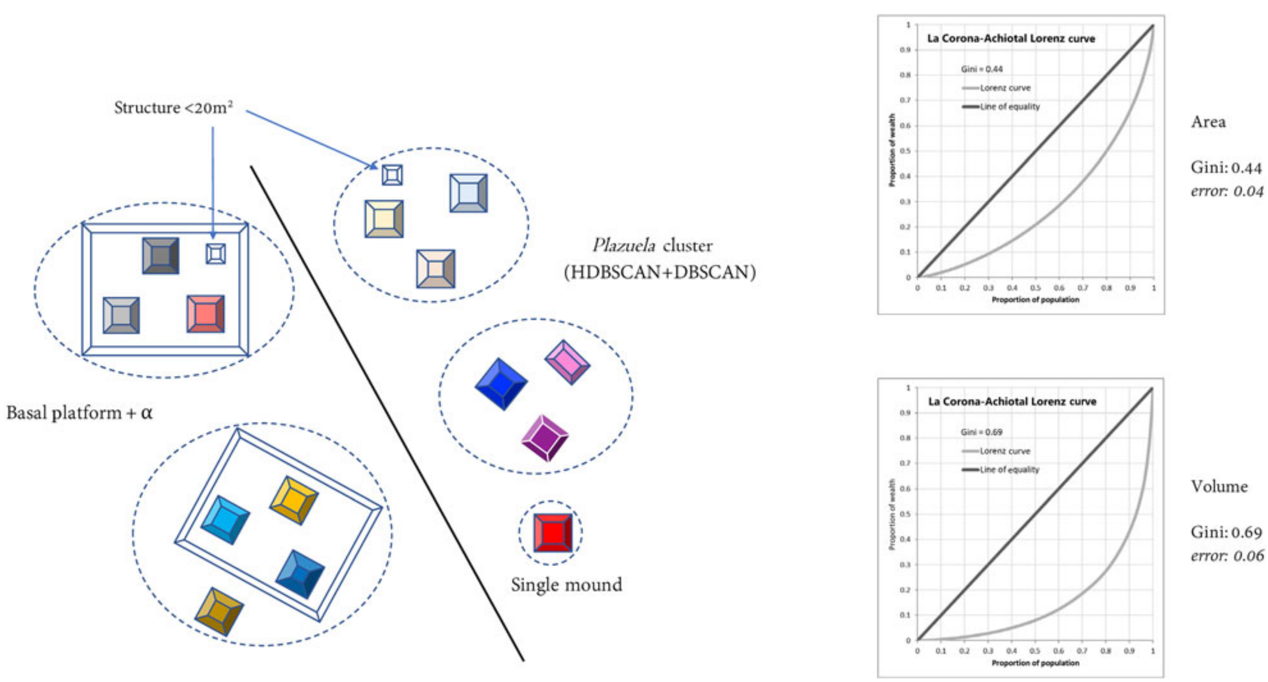

Figure 4. Gini coefficient: structures in *plazuela* groups (sample size: 985; Scenario 2).

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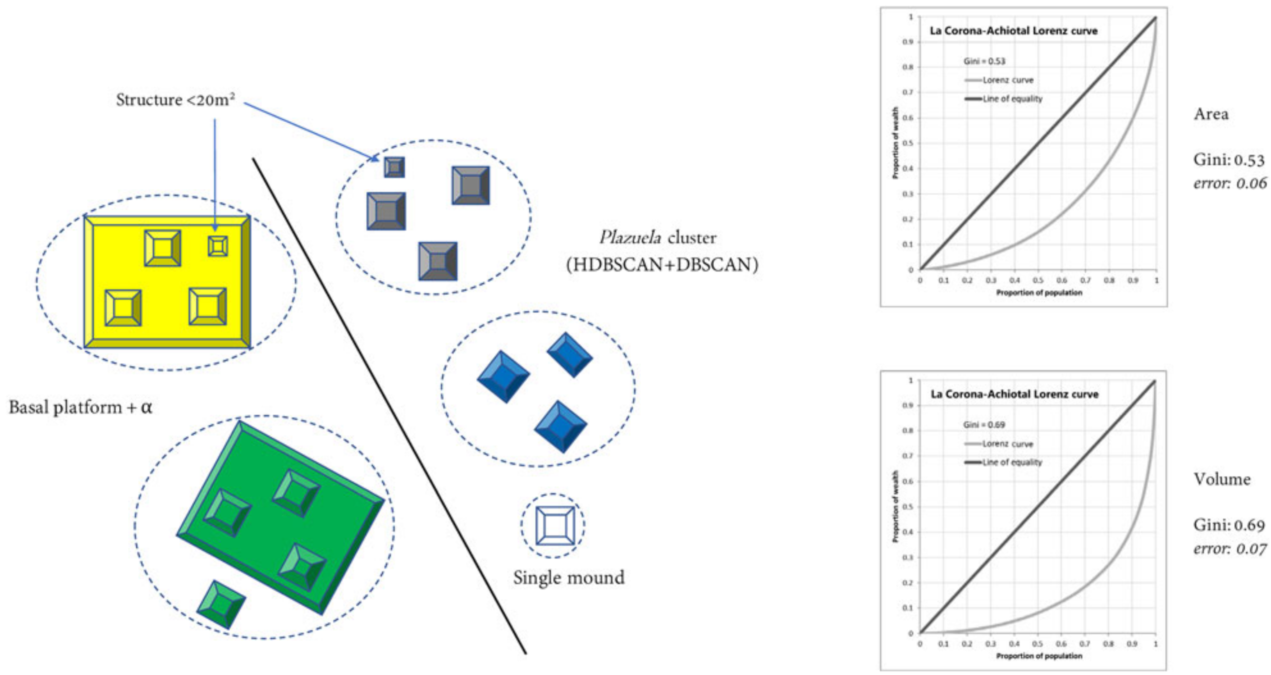

Figure 5. Gini coefficient: *plazuela* group, including basal platform (sample size: 978; Scenario 3).

We begin with the differences produced by area- and volume-based measurements. These are *significant* (see Table 1; see Thompson et al. 2023). We find that volumes may be far more inaccurately measured than areas, especially given uncertainties (vertical error, misclassified points, etc.) in the LiDAR-derived DEM and further uncertainties introduced by the estimation of a pre-architectural, "natural" surface beneath digitized buildings (see Hutson et al. 2023; Munson et al. 2023). However, because volume provides a critical dimension of information that cannot be ignored, we are not willing to discard it entirely. For this reason, we suggest calculating both area and volume, and then reporting a *Gini coefficient range* (see Oka et al. 2018, for alternative approaches to developing composite coefficients). A second source of significant Gini coefficient variation is the aggregation of different features. Thus, to

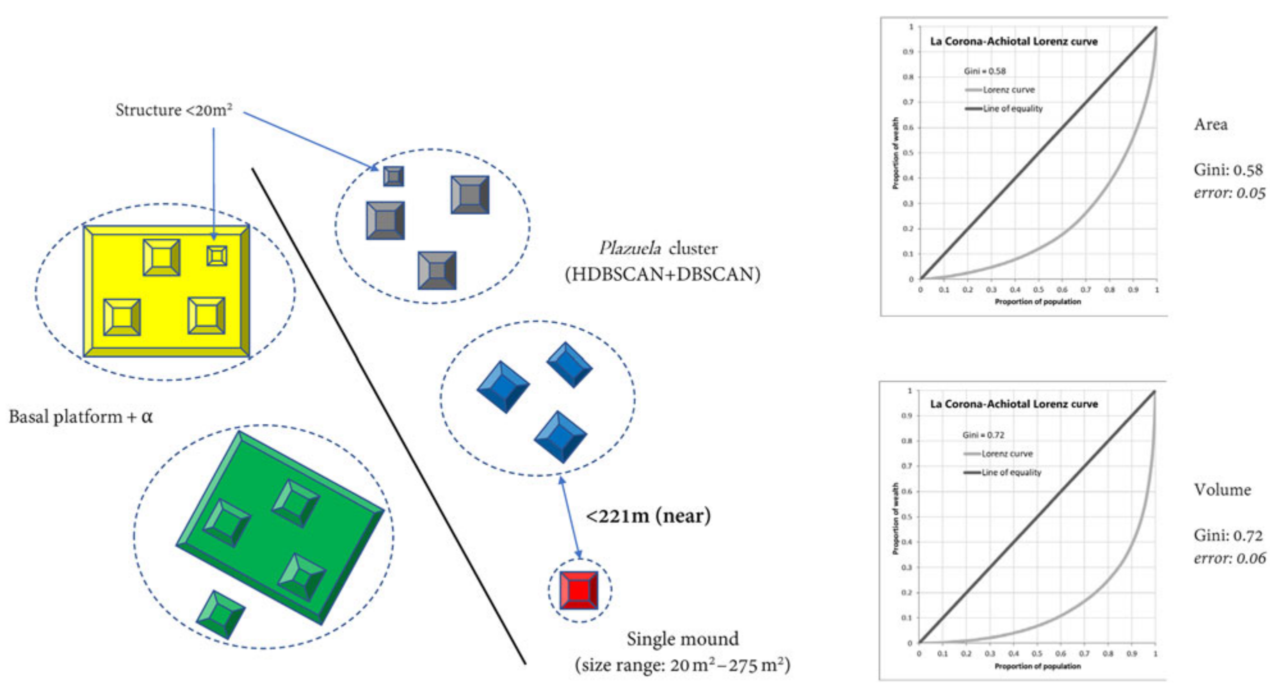

Figure 6. Gini coefficient: *plazuela* group, including basal platform and nearby single structures (sample size: 1,319; Scenario 4).

Table 2. Gini coefficients of four different data subsets.

		La Corona "polity"		La Corona "monumental core"		A La Corona "rural community"		Achiotal "polity"	
		Area	Volume	Area	Volume	Area	Volume	Area	Volume
Analytical unit		Basal platform / cluster / individual		Basal platform / cluster / individual		Basal platform / cluster / individual		Basal platform / cluster / individual	
Gini coefficient		0.54	0.66	0.61	0.78	0.56	0.69	0.63	0.79
Average		0.6		0.69		0.63		0.71	
Error		0.09		0.16		0.24		0.07	
Study area (km^2)		189.1		3.0		1.3		ca. 340.0	
# of residential groups		688		175		60		578	
# of residential structures		1988		551		166		1559	
Time period		Late Classic		Late Classic		Late Classic		Late Preclassic	
Descriptive stats	Sample size	688	688	175	175	60	60	578	578
	Mean	495.98	131.74	491.85	140.82	554.46	156.62	389.38	101.67
	Range	7960.83	5997.74	7962.17	5997.73	5730.77	2926.58	8559.05	3979.13
	Standard deviation	731.32	334.09	905.88	501.44	858.46	391.86	673.57	305.31
	Coefficient of variation	1.47	2.54	1.84	3.56	1.55	2.5	1.73	3
	Minium	20.97	0.64	19.63	0.64	75.19	12.03	20.31	0.38
	Lower median	145.02	26.84	114.61	12.64	172.03	22.14	75.53	7.77
	Median	269.31	54.85	224.84	37.11	297.55	51.31	138.12	19.36
	Upper median	578.98	117.49	502.95	80.67	532.86	134.92	454.71	70.26
	Maximum	7981.79	5998.38	7981.79	5998.38	5805.96	2938.6	8579.36	3979.51

choose among our four scenarios, we suggest that the one which produced the tightest range between area and volume indices is likely to be the most robust. In our case, Scenario 4—the measurement of the entire *plazuela* group, including nearby single mounds—results in the smallest range of values between area and volume. For this reason, we suggest that the most accurate measurement of inequality in the Corona region would be a Gini coefficient of 0.65 +/−0.06 (Table 1).

Given that our region is likely composed of two different settlement systems—a Late Classic one around La Corona to the west and a Late Preclassic one around Achiotal in the east—we divided our data to calculate separate Gini indices for these two times and sites (Table 2; see Montgomery and Moyes 2023; Shaw-Müller and Walden 2023). For the Late Classic La Corona polity, using our preferred measure, we see an overall Gini coefficient of 0.6 +/−0.09 (Figure 7). Frankly, we were surprised by this high value, given the secondary, satellite, or, more simply, modest nature of the site and its settlement. To drill down a bit further, we decided to isolate the settlement within two settlement clusters in order to determine the extent to which this degree of inequality varied within separate sectors of the same polity (see Marken 2023).

We first isolated the polity core (ancient Sak Nikte') and found a Gini coefficient of 0.69 +/−0.16—a value likely higher than the polity average. We then chose the largest cluster of "rural settlement" and calculated a Gini coefficient of 0.63 +/−0.24. While lower than the polity core, this value had such a wide margin of error that it is difficult to conclude anything with certainty. It nevertheless seems plausible this "rural cluster" and other smaller ones would likely demonstrate progressively less inequality. The basic takeaway here is that there was no place in the Corona polity where inequality would be sensed and perceived more acutely than in the polity core. This makes sense, as the most conspicuous architectural feature of the entire region is the La Corona palace: a huge residence in the middle of the polity core.

Surprisingly, however, these values are eclipsed by our results in the Achiotal sector of our dataset, where the settlement is predominantly Late Preclassic. Of 43 stratigraphically tested buildings in the region, all but three (93 percent) produced evidence of Late Preclassic occupation. This region produced a Gini coefficient of 0.71 +/−0.07 (Figure 8). This striking level of inequality is primarily down to a single complex: the palace at Achiotal, which dwarfs any other residential architecture in the region. To go by architecture and all the resources it indexes, it seems that the Late Preclassic was every bit as "unequal" as the Classic period in this region—indeed, likely more so.

To further nuance this comparison, we compared the median residential sizes of both the La Corona and Achiotal polities. The data (see Table 2) demonstrate that the median residence in the La Corona polity (269.31 m^2/54.58 m^3) was two to three times larger than that of the Achiotal polity (138.12 m^2/19.36 m^3). Although the Achiotal polity exhibits a somewhat higher degree of inequality, this difference does not fully explain the disparity in median residential size. Consequently, we propose that the disparity also suggests that Late Classic households were both sociologically larger and more complex, as well as

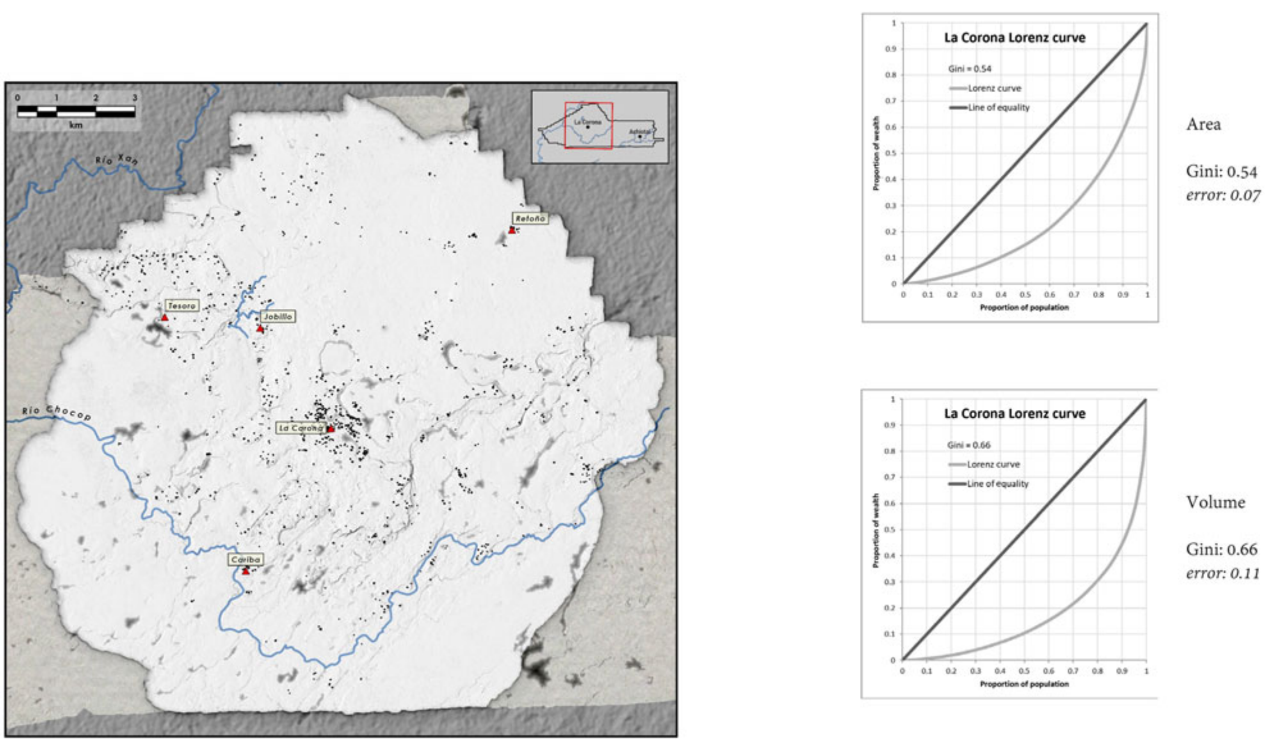

Figure 7. La Corona polity: *plazuela* group and nearby single structures (sample size: 688), Gini coefficient.

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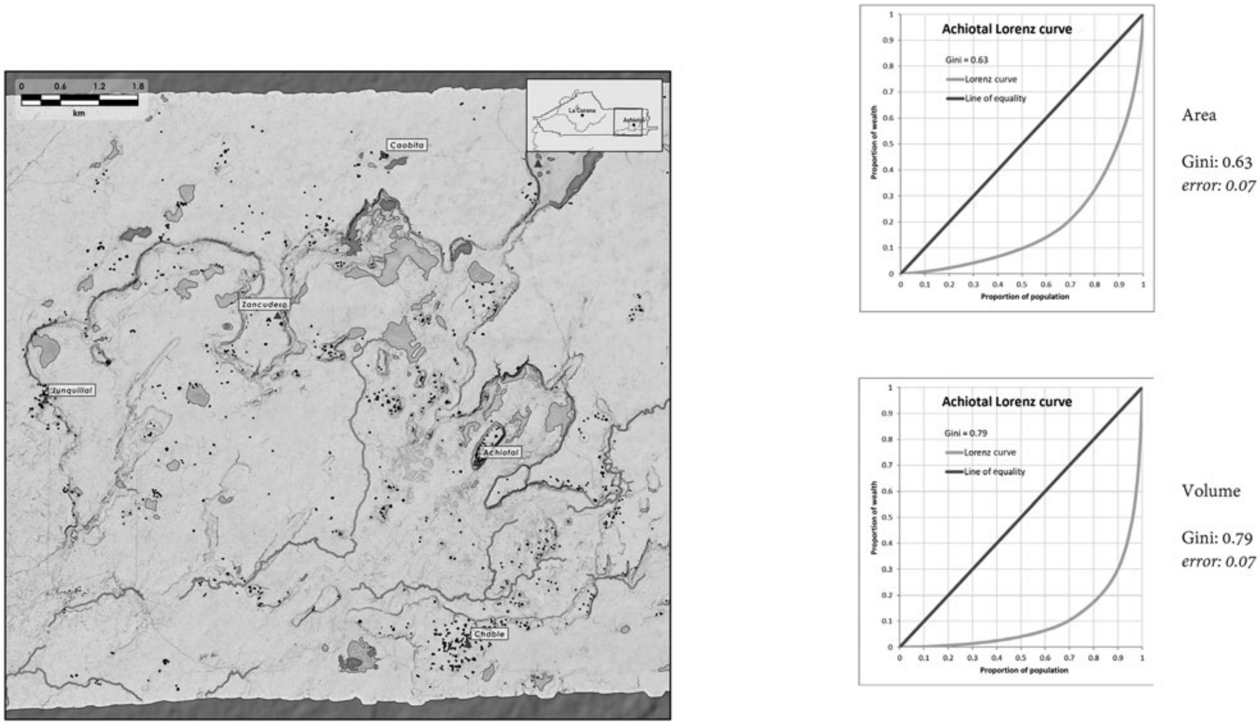

Figure 8. Achiotal polity: *plazuela* group and nearby single structures (sample size: 578), Gini coefficient.

materially wealthier, than their Late Preclassic counterparts. Whether this difference holds true across the entire Maya Lowlands will depend on the analysis of a much larger dataset.

Conclusions

Our initial foray into these analyses provides some simple takeaways that we hope will inform our continued application of this index in our efforts. First, we suggest that isolated buildings have a small, but still important effect on Gini calculation, and we need a unified strategy for dealing with these buildings. Moreover, given their ephemeral nature, we must ensure that their inclusion is buttressed by robust field verification efforts to reduce the possibility of including false positives or ignoring false negatives.

We also conclude that the La Corona region has high levels of economic inequality, particularly when the palace—a residence—is not arbitrarily excluded. In contrast, the Gini for the Late Preclassic settlement around El Achiotal is even higher than for Late Classic La Corona. This suggests that for this region, inequality did not grow with time, even though overall material wealth and household complexity apparently did. We suggest the possibility that the common factor between the extreme Gini indices for La Corona and Achiotal is that they were both "frontier" polities in their respective heydays, each dependent to some degree on relations with a foreign hegemonic power. We suspect that these values reflect the juxtaposition of a rural subsistence farming population, with essentially intrusive elite classes drawn to the region for its strategic importance. We maintain that this inequality was an expression of socioeconomic disarticulation throughout the region. In other words, this inequality may have been "felt" differently by the populations in the two areas, given the sharp divergence in overall sociopolitical complexity and differences in the relationship between ruling houses and political subjects.

Furthermore, this comparison between La Corona and Achiotal demonstrates how we *should expand* our analyses beyond the level of "the polity," however we choose to define it. Although our example does not compare two contemporaneous polities, it is important to appreciate that ancient Maya people would not have assessed inequality or prosperity only at the level of an individual kingdom, but could also have compared a place like Tikal or Caracol to a place like La Corona. To put it prosaically, would the richest family at La Corona have been able to afford Tikal? It is therefore instructive for us to aggregate data—perhaps by region—so that these interregional differences can be identified and interpreted; and that the further we extend our comparisons, the more likely our values will reflect an ancient reality.

These last points bring us to our final thought. While this coefficient may bring some empirical order to our observations regarding architectural differentiation within an area, we caution against the accepting *prima facie* notion of "inequality" (see Munson and Scholnick 2022). We cannot assume how any of these degrees of inequality were salient, if at all, to the ancient Maya. In fact, was "inequality" even a phenomenon of degree or was it seen only in absolutist terms? Perhaps inequality was understood only as a function of a "moral order" (e.g., Houston et al. 2003)? We should proceed cautiously when leveraging our understanding of these inequality indices to develop economic or sociopolitical models that inevitably touch upon indigenous notions of freedom, indebtedness, prosperity, and power.

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