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Compact Section: Ancient Maya Inequality

Beyond house size: Alternative estimates of wealth inequality in the ancient Maya Lowlands

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Abstract

House size provides a comparative measure of household wealth that enables archaeologists to track global trends in inequality across a range of sedentary societies. Such approaches hold particular promise for Maya archaeology given its long history of settlement pattern research and recent applications of LiDAR to map large areas surrounding ancient Maya cities. Estimating dwelling size, however, is not a trivial exercise. This article addresses potential confounds associated with geometric-based estimates (volume and area) and compares traditional house size-based measures of wealth with other estimates of house size and quality of life indicators. Settlement pattern data from the Upper Usumacinta Confluence Zone, recently collected by the Proyecto Arqueológico Altar de Sacrificios, combined with previously published excavation data provide a robust dataset to evaluate alternative measures of wealth beyond house size.

Resumen

El tamaño del hogar proporciona una medida de riqueza conveniente y comparativa de su riqueza que permite que los arqueólogos sigan tendencias en desigualdad a través de un rango de sociedades sedentarias. Tales enfoques son particularmente prometedores para la arqueología maya dada su larga historia de investigaciones en los patrones de asentamiento y recientes estudios de LiDAR para mapear grandes áreas alrededor de ciudades antiguas. Estimar el tamaño del hogar, sin embargo, no es trabajo sencillo. Este artículo discute sobre posibles variables de confusión asociadas a estimaciones de riqueza, basándonos en medidas geométricas (volumen y área) y compara medidas tradicionales de riqueza (con base en la geometría) con otras estimaciones del tamaño de casa e indicadores de la cualidad de la vida. Datos del patrón de asentamientos de la Zona de Confluencias del Usumacinta Superior recientemente recolectadas por el Proyecto Arqueológico Altar de Sacrificios, combinados con datos previamente excavados, proporcionan un conjunto robusto de datos para evaluar medidas alternas de riqueza más allá que el tamaño del hogar.

Introduction

House size is a common measure of household wealth that allows archaeologists to systematically estimate wealth inequality across a wide range of sedentary societies. Recent applications of this metric are used to calculate Gini coefficients, facilitating large-scale comparative studies of wealth disparity in past societies (Kohler and Smith 2018; Kohler and Thompson 2022; Kohler et al. 2017). This method holds particular promise for Maya archaeology given its long history of settlement pattern research, recent applications of LiDAR, and other remote-sensing methods, all producing detailed settlement maps across many regions of the Maya area.

Estimating dwelling size, however, is not a trivial exercise. Several factors affect these measurements, including: the degree of architectural standardization within a settlement or region, the duration of sedentary occupation, the availability of construction materials in different environments, and the estimated number of residents per domestic unit. Formation processes also significantly alter the size and shape of mounded archaeological features, potentially introducing measurement biases. In this article, we calculate Gini coefficients derived from volumetric-, area-, and height-based estimates, drawn from a sample of 417 mounds in the Upper Usumacinta Confluence Zone (UUCZ), to examine the relationship between these metrics and discuss the strengths and limitations of these approaches. In addition, we compare traditional estimates of household wealth with other indicators drawn from burial data to examine

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different aspects of past inequality across multiple scales of analysis. Settlement pattern data recently collected by the Proyecto Arqueológico Altar de Sacrificios (PAALS), combined with previously published excavation data, provide a robust dataset for us to consider alternative measures of inequality beyond house size.

Background

Located in the Western Maya Lowlands, the UUCZ encompasses the region where the Pasión and Salinas rivers join to form the Usumacinta along the modern-day border of Guatemala and Mexico. The landscape is characterized by a low-lying plain of alluvial soils and meandering river channels. Slightly elevated areas surrounding seasonally flooded lagoons and oxbow lakes offer a wide array of lacustrine and riparian resources that attracted people to settle along these waterways, beginning around 3,000 years ago.

Altar de Sacrificios is the largest recorded site in the UUCZ, with its urban core strategically situated on high ground along the southern bank of the Pasión, approximately 2 km from the current confluence (Figure 1). Previous investigations by Harvard University documented the monumental architecture, hieroglyphic inscriptions, and associated deposits in the site core (Smith 1972). Systematic test excavations in all 40 house mounds identified during Harvard's original investigations helped establish a ceramic chronology with permanent occupation from the Middle Preclassic (ca. 950 B.C.) through the Terminal Classic (ca. A.D. 950; Adams 1971).

PAALS was initiated in 2016 to further investigate the history of human occupation and landscape change in the Upper Usumacinta region through extensive settlement survey, household excavations, and geoarchaeological research (Munson and Paiz Aragon 2020; Munson et al. 2019; Paiz Aragon and Munson 2017, 2018). Our team has conducted a set of unmanned aerial system surveys on both sides of

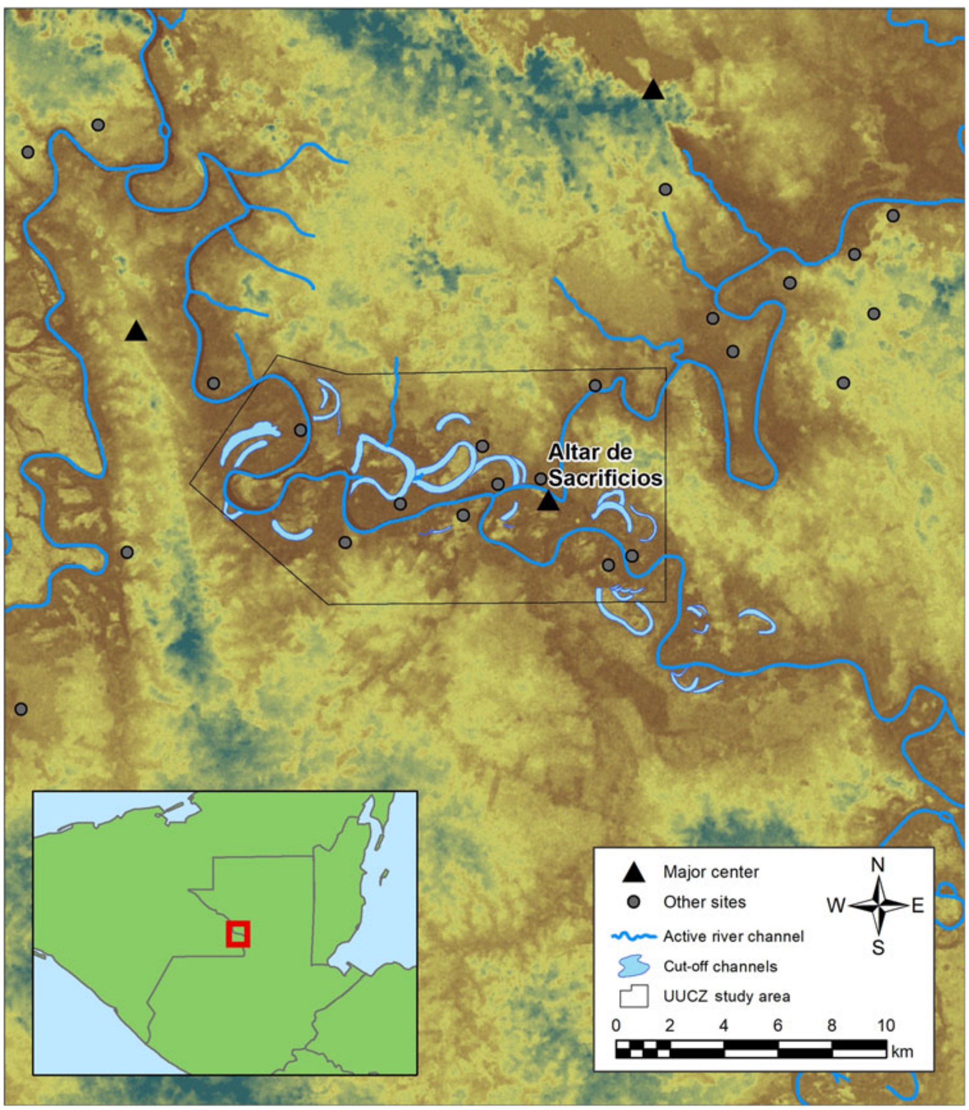

Figure 1. Upper Usumacinta Confluence Zone (UUCZ) study area. Map by the authors.

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the border, covering 52 km^2 to date. Using structure-from-motion, we generated high-resolution topographic models (≤15 cm/pixel) of the landscape to aid in the identification of cultural features (e.g., mounds, depressions, canals, terraces) and the investigation of river channel migration throughout the Holocene.

From these surveys, PAALS has documented a total of 417 mounds to date in the project area, including 339 new structures (Figure 2). Overall, the UUCZ settlement pattern can be characterized as a low-density urban landscape. The compact urban core, located at the eastern edge of the study area, contains temples and ceremonial platforms, multiple plazas, carved stone monuments, a ballcourt, and palace buildings (Figure 3). The surrounding settlement is more dispersed, with variably sized mounds dotting the banks of former river channels. Limestone and red sandstone were used to construct monumental buildings in Groups A and B respectively, but most of the peripheral mounds ground-truthed by our team yield little to no evidence of masonry construction. Rather, these are typically low earthen platforms which provided a level surface for the construction of perishable structures made of wattle and daub. Deposits of alluvial clay and mud offer ample and easily accessible materials for the construction of these platforms.

The Harvard project identified the majority of these low earthen constructions as "house mounds," based on their dissociation from the ceremonial core, simple form, and relatively small size, as well as the nature of the refuse recovered from their excavations. Harvard's investigations recorded few details of the domestic architecture, but our more extensive excavations have documented the remains of walls, postholes, clay floors, and pit features associated with domestic activities from the Late Preclassic through Terminal Classic (ca. 300 B.C. to A.D. 950). PAALS is developing a database of residential architecture, material possessions, and burials in ongoing excavations to further investigate long-term changes in Maya household inequality.

Gini results for house size

A total of 390 mounds are classified as residential in our study area (Table 1), based on published descriptions of architectural types documented by the earlier Harvard project (Smith 1972:117–127), our team's ground verifications, as well as considering the slope and surface area of mounds not accessible by the other two methods. Volumetric estimates were obtained for 253 (64.9 percent) of the classified residential mounds, using a three-dimensional semi-ellipsoid to approximate the shape of the mound, after filtering methods were applied to minimize noise introduced by vegetation before rendering the final digital elevation model (DEM; Mejía Ramón 2017, 2018, 2019). We also record the basal area and height of residential mounds as

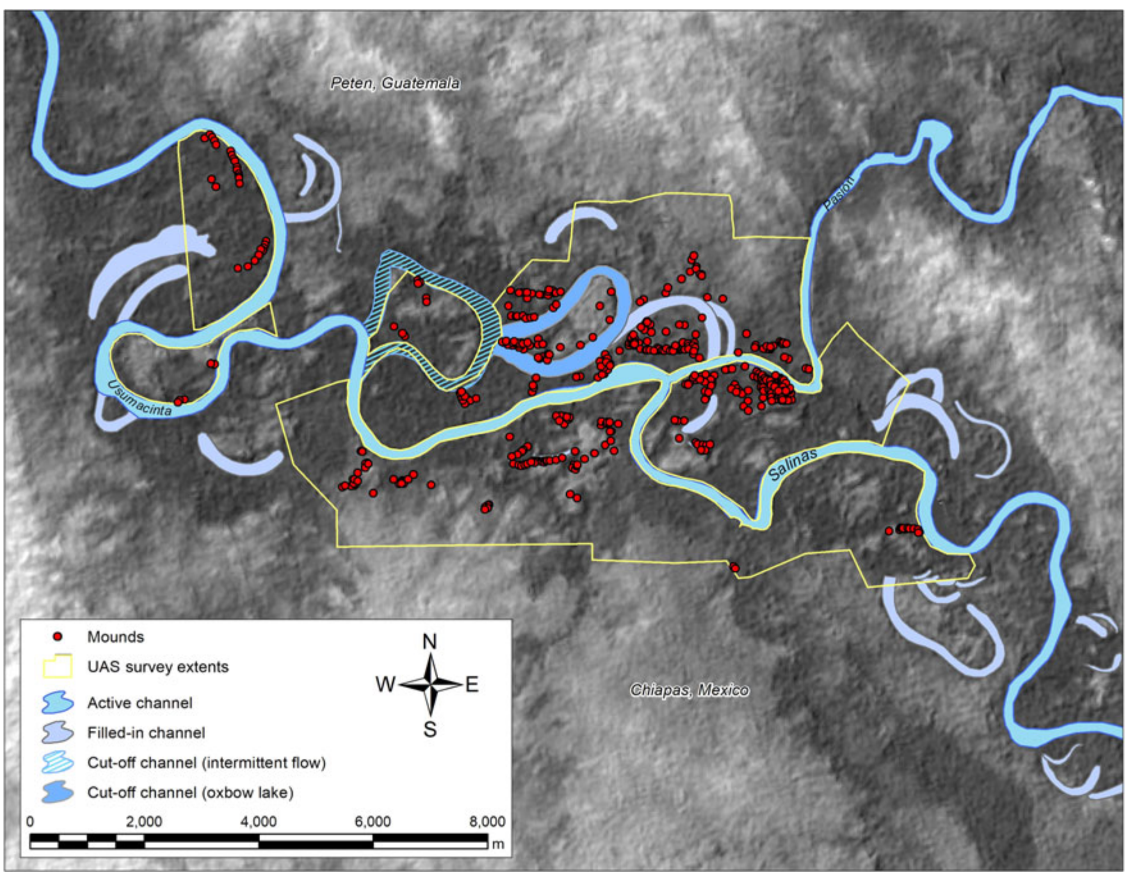

Figure 2. Mounds recorded by the Proyecto Arqueológico Altar de Sacrificios (PAALS). Credit by Jessica Munson.

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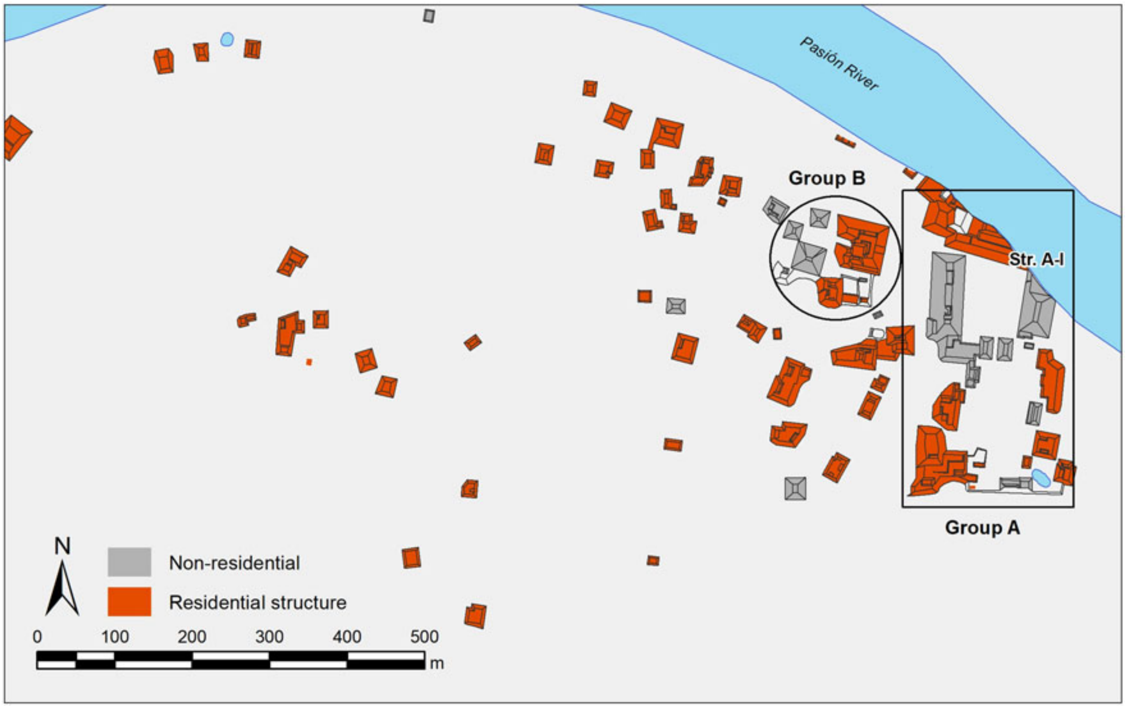

Figure 3. Altar de Sacrificios' ceremonial core and surrounding house mounds, originally mapped by the Harvard Project (Smith 1972).

additional estimates of house size to examine multiple proxies of wealth inequality in the past.

Using standardized methods (Chase et al. 2023), we computed the Gini coefficient for each of the house size variables described above. To account for potential bias due to small sample size, this method calculates a "corrected" or unbiased Gini, which is reported in Table 2 along with the standard Gini coefficient. For volumetric house size estimates, the standard and "corrected" Gini coefficient is 0.59 (Table 2), which is close to the median for the total sample of sites reported in this Compact Special Section (see Chase et al. 2023). Examining the Lorenz curve (Figure 4) also aids in the interpretation of this result. In this case, about half of the accumulated household wealth is concentrated in the top 15 percent of the population. We also calculated Gini coefficients using structure area and mound height. These house size estimates yield significantly lower Gini coefficients of 0.45 and 0.32 respectively (Table 2, Figure 4), which is consistent with the other sites included in this Compact Special Section. However, the dissimilarity in magnitude between these values raises questions about different house size-based measures of wealth. If comparative analyses of Maya household inequality are to be pursued, we need to critically evaluate techniques for estimating house size and consider the underlying assumptions of these geometric variables to avoid misleading interpretations.

Table 1. Mound counts.

	n	%
Total mounds recorded in UUCZ	417	–
Classified residential mounds	390	93.5
Residential mounds with volume estimates	253	64.9
Residential mounds with area estimates	390	100.0
Residential mounds with height estimates	332	85.1

Estimating household wealth inequality from mound volume and height

House size is approximated by archaeologists in a number of different ways depending on data availability and research traditions across regions (Table 3). For many Mayanists, the preferred method is mound volume. This metric accounts for all structure platforms, remains of superstructures, and area between structures, thus approximating the labor required to modify hilltops for residential construction (see Thompson et al. 2021). For estimating household wealth, the underlying assumption is that larger mound volumes equate with wealthier households or those with greater access to the resources and labor that enabled them to build big. Calculating mound volume is easily facilitated by high-resolution DEMs, made available from recent LiDAR and other remote-sensing surveys. However, such metrics can be difficult and time-consuming to generate from legacy datasets, regardless of the detail and precision of the original settlement maps (see Richards-Rissetto 2023). Volume, as a preferred univariate proxy for household wealth, is potentially problematic given that it directly correlates with both surface area and height. Gini coefficients calculated from living area will almost always be

Table 2. Gini coefficient summary statistics.

	Volume	Basal area	Mound height	Height (Late Preclassic)	Height (Late Classic)
Gini	0.59	0.45	0.32	0.42	0.23
"Corrected" Gini	0.59	0.45	0.32	0.44	0.24
Sample size	253	390	332	22	34
Mean	1449.32	878.14	2.37	1.09	2.49
Range	16196.83	5931.91	9.86	3.00	4.60
Standard deviation	2085.25	871.24	1.44	0.84	1.03
Coeff. of variation	1.44	0.99	0.61	0.78	0.42
Lower Gini (CI)	0.548	0.425	0.299	0.362	0.183
Higher Gini (CI)	0.642	0.487	0.352	0.548	0.310

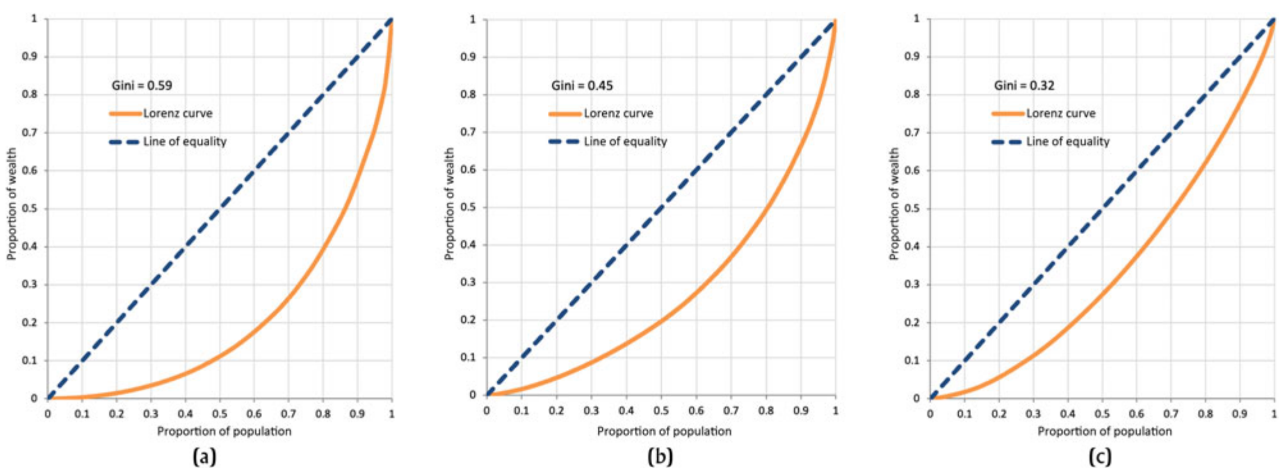

Figure 4. Lorenz curves for the UUCZ, based on house size estimates for (a) mound volume, (b) area, and (c) height. Credit by Jessica Munson.

Table 3. Sample of house size estimates by region.

House size metric	Region	Citations	Considerations
Area	Global	Chase 2017; Kohler et al. 2017; Thompson et al. 2021	Cross-cultural comparisons possible with adequate sample
Floor/dwelling/ roofed area	American Bottom, US Southwest, Oaxaca, Pacific NW	Betzenhauser 2018; Ellyson et al. 2019; Feinman et al. 2018; Pailes 2018; Prentiss et al. 2018	Requires detailed excavation or ethnographic data; better preservation conditions apply
Storage area (+ living area)	US Southwest, N. Mesopotamia, SW Germany	Bogaard et al. 2018; Kohler and Higgins 2016	Requires detailed excavation or ethnographic data; better preservation conditions apply
Construction costs	US Southwest	Abbott et al. 2021	Requires detailed excavation data; diachronic analysis possible
Volume	Maya Lowlands	Chase 2017; Thompson et al. 2021	Different methods, whether to measure individual structures, all structures, or include entire *plazuela*
Mound height	Maya Lowlands	Munson et al. 2023 (this study)	Simple to measure; can be estimated from modern ground surface or stable buried surface; enables diachronic analysis

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less than those calculated from volume, given that the former increases with the square of displacement and the latter with the cube. Therefore, differences between the two should not be surprising. Area is also of limited utility unless paired with the number of residents per domestic structure. Alternately, mound height is perhaps the simplest and most uniformly collected metric on house size across the widest range of cases. Regardless of the metric used, we argue that some type of ground verification is needed to classify structure function and chronology and assess post-abandonment conditions in order to make appropriate use of these data, especially for comparative purposes. We also argue that too many confounds make volume and surface area questionable singular proxies, and emphasize the need to evaluate multiple, independent estimates of household wealth using comparative approaches across a wide variety of cases.

Volumetric estimates of house size are subject to simplistic assumptions about occupational history and the uniform accretion of mound construction (see Canuto et al. 2023; Hutson et al. 2023). House size estimates are calculated using measurements of the modern ground surface, which do not account for differential formation processes that may have significantly altered the physiognomy of mounds during their occupation and post-abandonment phases. The problem is akin to the "Pompeii premise," addressed long ago by behavioral archaeology (Binford 1981) and more recent practice-based approaches for interpreting stratigraphy (McAnany and Hodder 2009; Munson 2015). Specifically, estimating mound size from the modern ground surface potentially makes two false assumptions: (1) that every mound was occupied during the same time period and (2) the size of mounds observed today is the same as they were in the past. Even if we can incorporate chronological estimates for mound occupation based on data from surface collection, these estimates would not account for differential growth and expansion of mound size over long periods of time. In the case of Altar de Sacrificios, we have detailed stratigraphic records from Harvard's test-pitting program and our ongoing excavations that document these architectural changes, which we use to address these limitations and evaluate alternative house size estimates.

Formation processes

The first factor to consider is the taphonomic processes that transform the archaeological record (see also Walden et al. 2023). The local rivers in the UUCZ have shifted considerably throughout the Holocene, evidenced by the numerous oxbows and filled-in channels that cut across this dynamic fluvial landscape (see Figure 2). Alluvial deposits and floods may bury some archaeological mounds, while erosional processes have eliminated the vestiges of others, including at least half of Structure A-I, which formed part of the Late Classic acropolis and palace. Most parts of our study area are also under active cultivation with mechanized plows. Plowing has quantifiable effects on mound size, impacting any subsequent analysis relying on measurements of the modern ground surface (Figure 5). Using data collected in 2017 and 2018, we found that mound heights decreased by 16 cm on average, representing an average annual volumetric loss of 262 m^3 (or 15 percent) for each mound (Mejía-Ramón 2017, 2018). However, erosional processes are not uniformly distributed. Soil loss and erosion caused by plowing have a greater impact on smaller, lower mounds, since the tractor cannot pass over steeper mounds or those more than about 3 m high. Thus, the size disparity between small and large mounds is likely exaggerated, which would result in an inflated Gini coefficient calculated from mound volume. In addition to erosional processes, we have also documented a few instances of post-abandonment deposition, which *increases* the apparent size of mounds, thus further confounding volumetric measurements of mound size. While the impacts of formation processes may be particularly acute for earthen mounds located in alluvial floodplains and undergoing active cultivation, archaeologists must be aware of the local effects of formation processes in their specific study areas.

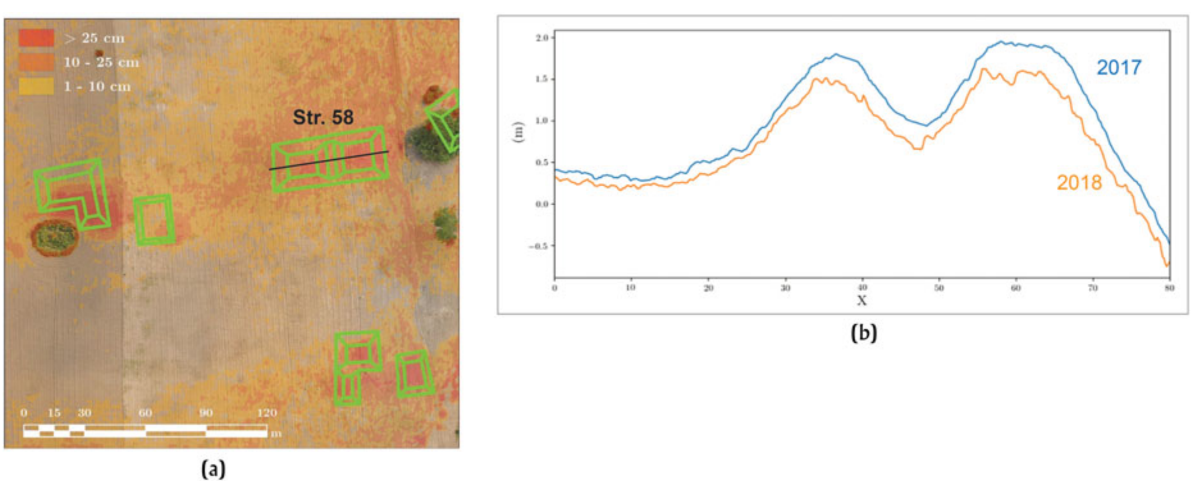

Figure 5. (a) Quantified soil loss due to mechanized plowing; (b) east–west cross-section of Structure 58, showing the recorded soil loss between 2017 and 2018. Credit by Andrés G. Mejía Ramón.

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Contemporaneity and chronological issues

Contemporaneity is another important issue that should be addressed for comparative studies of household wealth inequality (see Canuto et al. 2023). While it might be safe to assume that the end of the Classic period marks the latest occupation at most lowland Maya settlements, it is difficult to assess the degree to which all mounds were occupied during this phase without excavation or other forms of ground verification. Some mounds may have been abandoned already or fallen into disuse, such as the buildings in Altar's Preclassic ceremonial center, Group B (see Figure 3). Without chronological controls attached to settlement data, it is difficult to estimate the size of contemporaneous populations. Moreover, volumetric estimates of house size make simple assumptions about the uniform accretion of mound construction which contradicts what we know about the superposition and energetics of Maya architectural practices (Abrams 1994). With refined chronological controls, we may be able to address the contemporaneity issue, but we are still left with the problematic synchronic and geometric fallacies.

Alternative estimates of mound size

At Altar, mound construction began in the Middle Preclassic and continued through the Terminal Classic period—a duration of some 1,500 years. Using stratigraphic information from Harvard's test-pitting program and our own excavations, we measured mound height above sterile soil as an alternative estimate of house size for our Gini calculations. In this case, our sample was restricted to those mounds on the peninsula that were excavated and identified as having Late Preclassic or Late Classic occupation surfaces (see Figure 3)—the two periods with the highest population estimates (Smith 1972). We used Harvard's reported elevations of these occupation surfaces to estimate mound height above sterile soil for each occupation period. These measurements were then used to calculate Gini coefficients for each time period to examine diachronic trends in household wealth inequality. Interestingly, the Gini results show a significantly higher disparity in household wealth during the Late Preclassic in comparison to later Classic times (Table 2, Figure 6). Not surprisingly, these Gini coefficients are also closer in value and more consistent with the Gini based on mound height measured from the modern ground surface when compared to volumetric measurements. The advantages of this alternative house size metric address the two critical issues outlined above: (1) it avoids the pitfalls of formation processes as the occupation surfaces we measured are buried and unaffected by modern land-use practices; and (2) it includes chronological controls that enable diachronic analyses and examination of the intergenerational transmission of household wealth. Moreover, mound height is the simplest and most straightforward metric of house size to obtain and can be easily calculated using standardized methods across the widest number of cases. Of course, this kind of analysis would not be possible without excavation and detailed stratigraphic records, which may limit the overall sample sizes included. It is also true that this method cannot discriminate between houses with the same platform height and different areal extents, but additional material wealth indicators will prove useful in these cases, as discussed below. There is room to explore different measures of house size that may capture more precise details for a smaller number of sites, as well as reliable, yet less precise estimates that facilitate broader comparisons. As we pursue more collaborative and comparative frameworks in Maya settlement studies, we argue for the need to thoughtfully consider our choice of economic proxies.

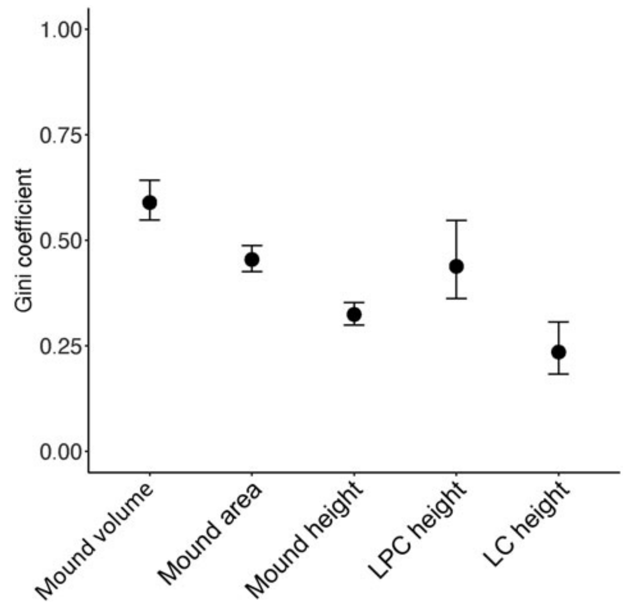

Figure 6. Comparison of Gini coefficients based on mound volume, area, height from modern ground surface, and from excavated subsamples (LPC = Late Preclassic, LC = Late Classic). Credit by Jonathan Scholnick.

Multiple dimensions of wealth inequality

Another advantage of Gini coefficients is the opportunity to compare household wealth with other dimensions of inequality across different scales of analysis. House size is one source of information that archaeologists use to approximate household wealth. Other types of data commonly include household artifacts and burials (Haviland 1981; Rathje 1983; Smith 1987), which provide access to different aspects of past inequality. We recently outlined an approach that considers not only material forms of wealth, but other noneconomic factors that contribute to an individual's overall wellbeing (Munson and Scholnick 2022). These three dimensions of quality of life (i.e., material wealth, social wellbeing, and embodied wellbeing) comprise a framework for examining a wider range of structural inequities that existed at different points in the past. We developed a set of proxy indices to estimate different forms of wealth and wellbeing using previously published burial data from Altar. Since these data and our refined, chronologically controlled house size estimates are drawn from the same population, we can reliably compare Gini coefficients across these categories and through time (Figure 7).

For the Late Preclassic, we see significant overlap in the Gini coefficients for all forms of material wealth inequality and disparities in social wellbeing that we measured. Such

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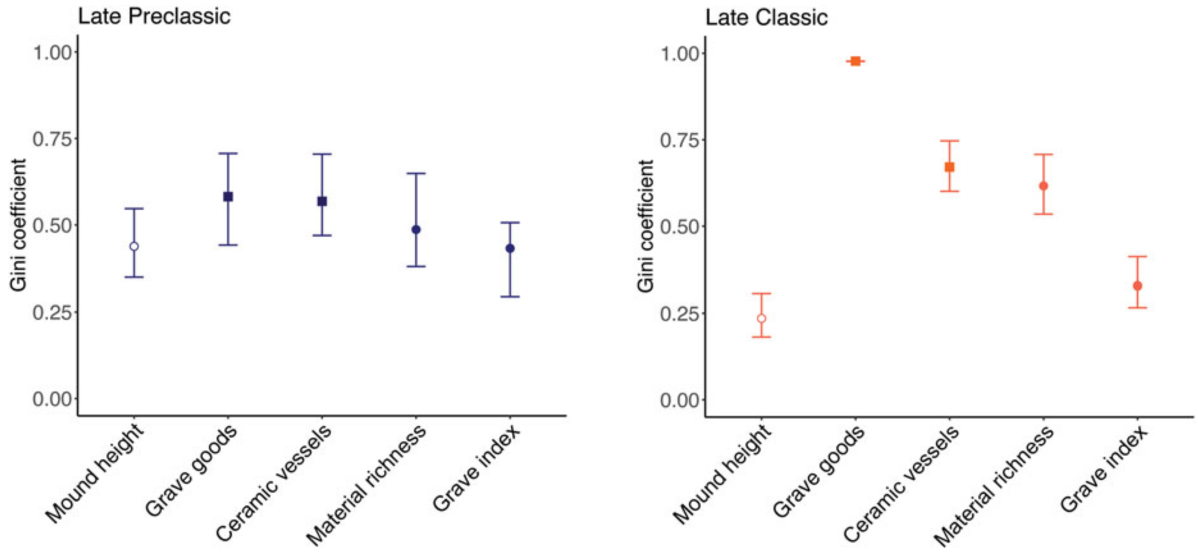

Figure 7. Comparison of Gini coefficients for household wealth (open circles), material wealth (filled squares), and social wellbeing (filled circles). See Munson and Scholnick (2022) for definitions of wealth and wellbeing indicators. Credit by Jonathan Scholnick.

internal consistency suggests a degree of robustness in these aggregated estimates. In contrast, during the Late Classic, house size-based estimates of wealth diverge significantly from wealth estimates measured from grave goods. The high Gini for material wealth based on burial goods may be explained partially by the inclusion of royal burials located in nonresidential structures not included in the house size-based estimates. The Gini for household wealth is also surprisingly low, which might suggest greater investment in material goods and grave construction by some segments of society relative to residential structures during the Late Classic. More research is needed to better understand changes in inequality between these two periods of cultural apogee in the Maya Lowlands, as well as how they relate to changing forms of governance and economic exchange (Feinman and Carballo 2018).

Conclusions

Although Gini coefficients are commonly used to analyze wealth distributions, it is important to keep in mind that the Gini is not inherently a measure of economic inequality (Peterson and Drennan 2018). When applied to noneconomic data, Gini coefficients can be a powerful technique for measuring disparities across a wide variety of domains that archaeologists would like to compare. Indeed, one advantage of calculating Gini coefficients is the ability to conduct large-scale comparative studies of inequality in past societies, as illustrated by the case studies in this Compact Special Section. However, in order for these analyses to be reliable, we need to ensure our methods are consistent, systematic, and rigorous.

Volumetric-, area-, and height-based measurements of mound size from the modern ground surface are coarse estimates of house size that are subject to differential post-abandonment formation processes, and limited in their ability to address diachronic change in household inequality. We recognize that it may be difficult to overcome these limitations in the absence of excavation data. However, in the case of Altar de Sacrificios, we demonstrate how alternative estimates of house size can expand on the basic analysis of area and volume and provide more detailed analyses of inequality over time and across different economic and social dimensions. As we collectively seek to understand the distribution of household wealth across the Maya Lowlands, we hope that future work will consider a broader range of factors beyond house size.

Data availability statement. The data that support the findings of this study are available from the corresponding author (JM) upon reasonable request.

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Competing interests declaration. The authors declare none.

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