Ancient Mesoamerica (2023), **34**, e4, 1–11
doi:10.1017/S0956536123000202

CAMBRIDGE UNIVERSITY PRESS

Research Article

Inequality on the southwest Maya frontier: House size variations in three polities of the Rosario Valley, Chiapas

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Abstract

Being a form of labor investment, house size is frequently analyzed as an index of socioeconomic inequality. However, datasets that lack wide-ranging residential stratigraphic information are not reliable sources of labor investment estimates. This is the case for Late Classic domestic architecture data from three polities in the Rosario Valley (modern-day Chiapas) on the southwest Maya frontier: Rosario, Ojo de Agua, and Los Encuentros. Although the sample's house size inequality generally cannot index period-specific labor investment, it may signify prestige differentiation. For each polity we generated Lorenz curves and calculated Gini coefficients for five variables representing house size (area and volume). Results resemble inequality data from lowland Classic Maya centers. We also demonstrate that the smallest, shortest-lived polity had more equal house size values, likely due to the modesty of its apical elite architecture. In contrast, the two larger, older polities were more unequal because they had substantial palaces.

Resumen

Al ser una forma de inversión laboral, el tamaño de la vivienda se analiza con frecuencia como índice de desigualdad socioeconómica. Sin embargo, los conjuntos de datos que carecen de información estratigráfica residencial amplia no son fuentes fiables de estimaciones de inversión laboral. Este es el caso de los datos del clásico tardío de tres ciudades del Valle del Rosario (actual Chiapas) en la frontera maya del suroeste: Rosario, Ojo de Agua y Los Encuentros. Aunque la desigualdad en el tamaño de las casas de la muestra no puede indexar la inversión laboral específica del período, puede significar una diferenciación de prestigio. Para cada entidad política generamos curvas de Lorenz y calculamos los coeficientes de Gini para cinco variables representativas del tamaño de la vivienda (superficie y volumen). Los resultados fueron similares a los datos de desigualdad de los centros mayas del clásico de las tierras bajas. También demostramos que el asentamiento más pequeño y de vida más corta (Los Encuentros) tenía valores de tamaño de casa más equitativos, probablemente debido a su escasez de arquitectura de élite apical. Por el contrario, los dos estados más grandes y antiguos (Ojo de Agua y Rosario) eran más desiguales porque tenían grandes estructuras palaciegas.

Since McGuire (1983) introduced the Gini coefficient to archaeology, many have assessed the method's accuracy in representing socioeconomic inequality through house size, namely as an index of labor investment (e.g., Fochesato et al. 2019; Kohler et al. 2017; Peterson and Drennan 2018; Smith et al. 2014; Šprajc et al. 2022:25). The Gini coefficient summarizes inequality among a variable's values by measuring the area between the Lorenz curve (percentages cumulatively added from lowest to highest) and a hypothetical line of equality (see more in Analysis methods below). However, while mound-based residential datasets lacking stratigraphic information do not reliably index labor investment, final house dimensions may still represent the relative prestige (*sensu* Drennan et al. 2017) of occupants because structure size is visually impactful (Smith et al. 2014:312). Put otherwise, occupation within large, impressive residences likely confers prestige on inhabitants, irrespective of when the actual phases of construction occur. This is especially salient for societal border zones, where mounded residential structures may result from diverse construction histories. The Rosario Valley, in modern-day Chiapas, was one such frontier, where waves of Maya immigrants from the Lowlands settled new centers or were integrated into pre-existing non-Maya polities (de Montmollin 1995; Pye et al. 2016). This dynamic is similar to other Classic Maya frontiers, such as Copán (Richards-Rissetto 2023).

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Cite this article: Shaw-Müller, Kyle, and John P. Walden (2023) Inequality on the southwest Maya frontier: House size variations in three polities of the Rosario Valley, Chiapas. *Ancient Mesoamerica* **34**, e4, 1–11. https://doi.org/10.1017/S0956536123000202

Our research concerns the Late Classic (A.D. 700–900) house size inequality of three Maya polities in the Rosario Valley: Ojo de Agua, Rosario, and Los Encuentros. We generated Lorenz curves and Gini coefficients for five dimensions of house size across the three polities. Many of the sample's structures were multicomponent, but because we lack data on the degree to which they were constructed in the Late Classic period, we largely take their final forms as indices of prestige differentiation, not labor investment. Our analyses reveal that house size inequality in the region resembled that of contemporaneous Maya lowland cities. Intra-valley differences are also apparent, namely more house size equality for the smallest, shortest-lived polity (Los Encuentros), due mainly to the limited development of its apical elite architecture.

Dataset background

Ojo de Agua, Rosario, and Los Encuentros were Classic Maya polities in the Greater Rosario Valley, an upper tributary of the Grijalva River, located in southeast Chiapas (Figure 1; de Montmollin 1995:22–23). The Greater Rosario Valley has two upper branches in the east, opening to a wide valley bottom in its west. Before Mayas settled the Rosario Valley, it was inhabited by Mixe-Zoqueans (or "Mizoques"), whose material culture demonstrates clear ties to the Olmec site of La Venta (Bachand and Lowe 2012; Clark 2001, 2016; Clark and Hansen 2001; de Montmollin 1995:36; Lee and Clark 2016; Lowe 1977, 1983; Pye et al. 2016:439).

A major cultural shift occurred in the Late Preclassic (300–50 B.C.), when many settlements containing lowland Maya materials emerged amidst a handful of earlier centers, due to widespread migration from the Peten (Pye et al. 2016:440). After this initial Maya expansion, there was a demographic contraction in the Early to Middle Classic periods (A.D. 200–650; Pye et al. 2016:445). Then the maximum population was reached in the Late to Terminal Classic (A.D. 650–1000), when more Maya immigrants from the Lowlands moved into the region (Agrinier 1983; Pye et al. 2016:450; Wells 2015). This influx resulted in the cultivation of agriculturally marginal hillsides (de Montmollin 1995; Pye et al. 2016:424). The area remained ethnically and linguistically diverse well into Spanish colonial times (Campbell 1988:267–270). Although this wave of immigrants possibly fled the decline of multiple lowland polities (Pye et al. 2016:450), demographic collapse finally swept through the Rosario Valley between A.D. 900 and 1000 (de Montmollin 1995:3–4).

Several archaeological projects contributed to our dataset. Early investigations included limited survey operations in the 1950s and 1960s (Lowe 1959; Lowe and Mason 1965; Shook 1956; Sorensen 1956). Thereafter, surveys and excavations of a 600 km^2 area were conducted along the Grijalva River (Con Uribe 1981; Gussinyer 1973; Martínez Muriel and Navarrete 1978). Another larger survey (area: 2,600 km^2) followed between 1973 and 1983 (Blake et al. 2016; Bryant 1981; Lee 1984). These studies were supplemented by de Montmollin's (1987, 1989a, 1989b, 1995) systematic, intensive, full-coverage pedestrian surveys of the Greater Rosario Valley, specifically in 1983, 1988, and 1990 (survey area: 150 km^2). His data were later digitized for public use (de Montmollin 2018). Among the three polities sampled from this dataset for our study, all residential structures have Late Classic components and we lack information on which have earlier components.

The largest polity and study area (70.11 km^2) was Rosario, which reached its maximum extent in the Late Classic period, but had an Early Classic (A.D. 200–500) component (Agrinier 1983; Pye et al. 2016:445). Its capital, Tenam Rosario, was erected on a hilltop separate from the established settlement (de Montmollin 1989a, 1989b, 1995:220). We sampled 1,565 house groups within the study area (Table 1). Rosario was probably in conflict with the neighboring Ojo de Agua polity (de Montmollin 1995:193), which was located at a lower elevation in the flatter, wider portion of the valley floor to the west. In contrast to Rosario, Ojo de Agua's eponymous capital was occupied from the Preclassic and was surrounded by settlement (de Montmollin 1995:107, 220). Ojo de Agua's survey area was 57.21 km^2 and contained 1,957 sampled house groups. The Los Encuentros polity's study area, immediately to the south of Rosario, was smaller (24.7 km^2) and included 561 sampled house groups. El Zapote was the main civic-ceremonial center of Los Encuentros, and likely purely Late Classic (A.D. 700–900; de Montmollin 1995:220).

The 2018 dataset consists largely of measurements and polygons for all recorded structures. Although house group quantities for each "site" were noted, these clusters were originally not denoted on maps, and many of them contained dozens of structures. Consequently, and to assure consistency with others in this Compact Special Section, we designated our own house groups (Table 1), placing a point for each group according to structure location and other contextual data, then assigning structures to these points via nearest neighbor analysis (*sensu* Thompson et al. 2022). These groups likely represent households (Hammond 1975). House groups were typically supported by *plazuelas*, which are artificial patio surfaces (Ashmore 1981a). Because house groups were identified remotely, we approximated *plazuela* areas by generating convex hulls that encompassed the structures of each group (Figure 2).

Analysis methods

We share our inequality analysis methods with all authors in this Compact Special Section (Chase et al. 2023). Lorenz curves represent the inequality of a sample by cumulatively adding values (as percentages), arranged from lowest to highest to form a curve, plotted relative to a hypothetical line of equality. The Gini coefficient summarizes inequality as the area between the line of equality and Lorenz curve: the higher the value, the more unequal (Peterson and Drennan 2018). We ran these analyses for the following variables, sampled at polity- and valley-wide scales: individual structure area; total area of structures per house group; *plazuela* area; individual structure volume; and total volume of structures per house group. We could not estimate the volumes of *plazuelas*.

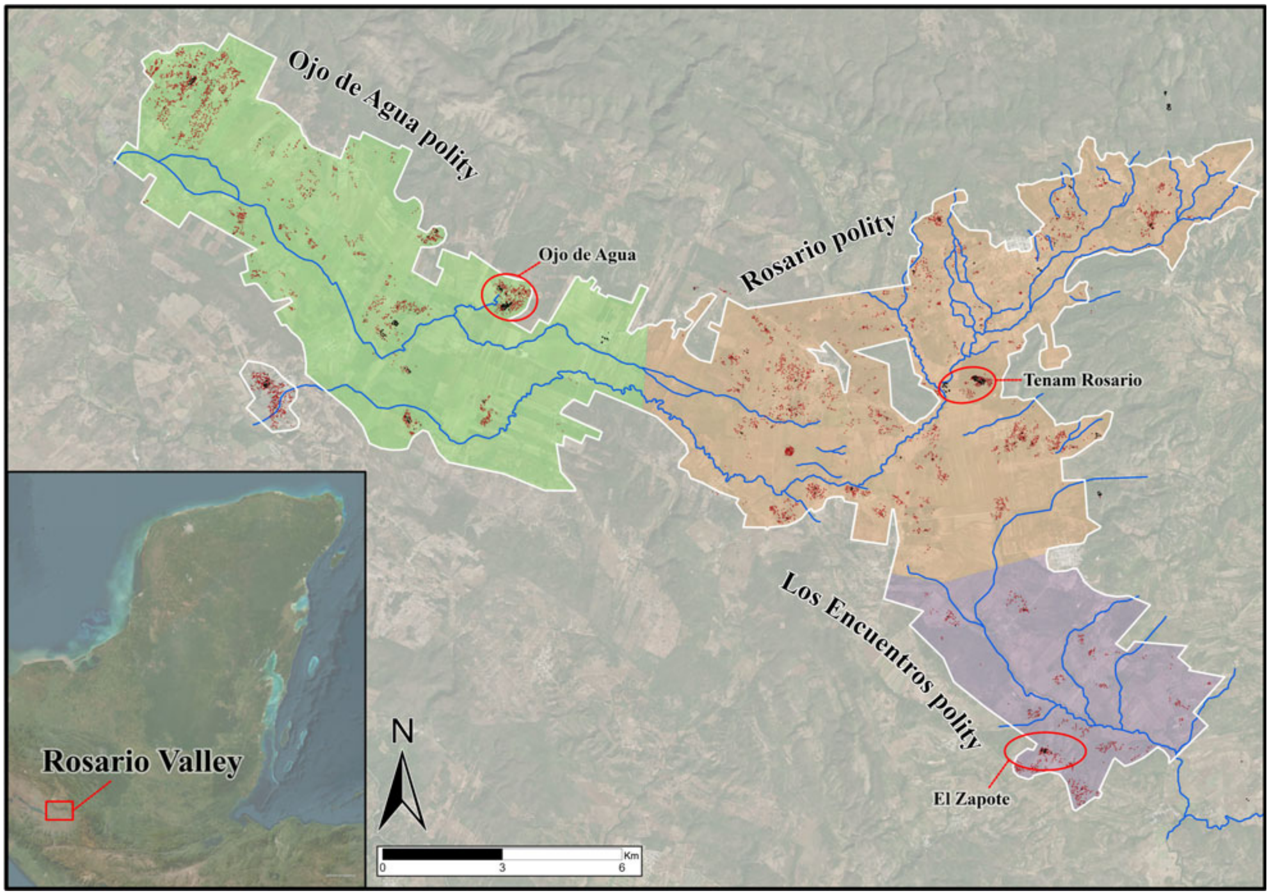

Figure 1. Map of the Rosario Valley; the sampled Late Classic Maya polities with de Montmollin's survey boundaries in white, house group points in red, and structure outlines in black. Sources: ArcGIS Pro "Imagery" basemap, Maxar; de Montmollin 2018.

The total volume and area metrics for house groups include most domestic structures in de Montmollin's (2018) dataset, in addition to two acropolis complexes from Ojo de Agua and Tenam Rosario. Acropolises are large, monumental platform complexes that contained civic-ceremonial structures and apical elite residences (de Montmollin 1995:70). Although these complexes were multifunctional, with many component structures serving domestic and public-facing purposes, they were predominantly elite residences (Folan et al. 2001; Inomata 2001:341; de Montmollin 1995:70, 93). Structures with incomplete area, volume, or height data were excluded from house group samples, where relevant. The *plazuela* area variable consists of convex hull areas for each house group and acropolis. Due to de Montmollin's dataset (2018) only containing total area and volume for each acropolis (not for constituent structures) these complexes were not included in the individual structure samples. Relatedly, the platform volumes of acropolises could not be excluded from the total volumes of structures on these platforms, whereas comparable *plazuela* volumes could not be estimated for all other house groups; therefore, the house group volume Gini coefficient is inherently inflated. Finally, for consistency with other authors in this Compact Special Section (see Thompson et al. 2023), we excluded structures smaller than 20 m^2 in area from the single structure analyses. This is because mounds of 20 m^2 or less may not have been standalone residences, instead serving ancillary domestic functions (Ashmore 1981a:47, 1981b:369; Hammond 1975; Webster and Gonlin 1988; Wilk 1983). Given these differences, sample sizes varied widely according to variable (see Tables 2 and 3).

Table 1. Summaries of each polity.

Polity name	Sample area (km^2)	House group count	Temporal component(s)	Capital name
Rosario	70.11	1565	Early Classic–Late Classic	Tenam Rosario
Ojo de Agua	57.21	1957	Late Preclassic–Late Classic	Ojo de Agua
Los Encuentros	24.7	582	Late Classic	El Zapote

https://doi.org/10.1017/S0956536123000202 Published online by Cambridge University Press

Figure 2. Maps of each polity's capital, with civic-ceremonial structures (not sampled) in grey, *acropoleis* in red, and surrounding house groups (opaque structures and semi-transparent *plazuela* convex hulls) distinguished by unique colors. Sources: ArcGIS Pro "Imagery" basemap, Maxar; de Montmollin 2018.

https://doi.org/10.1017/S0956536123000202 Published online by Cambridge University Press

Table 2. The quantities and proportions of total mapped structures for each polity.

Polity name	Total mapped structures	Structures lacking complete area and volume data	House group area & volume	Individual structure area	Individual structure volume
Rosario	4639	728	74.76%	50.10%	42.63%
Ojo de Agua	4041	42	95.32%	57.63%	57.34%
Los Encuentros	1315	20	96.96%	54.68%	53.38%
Rosario Valley	9995	790	85.99%	61.18%	56.90%

Results

Confidence intervals (CIs) for corrected Gini coefficients in all samples varied widely, ranging between small intervals for individual structure areas (0.017) and massive intervals (0.300) for house group volumes (see Figure 3). Although the larger samples tend to have smaller CIs, the exceptionally large total structure volume CIs for Ojo de Agua and Rosario are due mainly to the inclusion of *acropoleis*. These palaces numbered only one per polity, dwarfing the next largest house groups.

Overall, results show that Ojo de Agua and Rosario have the most unequal house size distributions, while those of Los Encuentros are more equal (Table 4 and Figure 3). The house group volume variables for Rosario and Ojo de Agua generated the highest Gini coefficients (0.68 and 0.63

Table 3. Sample sizes and descriptive statistics for each variable.

		Individual structure areas (m^2)	Total structure areas (m^2)	*Plazuela* areas (m^2)	Individual structure volumes (m^3)	Total structure volumes (m^3)
Rosario	Sample size	2324	1565	1565	1978	1565
	Mean	34.40	49.14	108.12	28.99	50.01
	Median	30	37.5	69.06	19.25	20.25
	Maximum	150	3,850	3,850	308	23,870
	Minimum	20	1.5	1.16	4	0.3
Ojo de Agua	Sample Size	2329	1957	1957	2317	1957
	Mean	40.87	58.25	110.46	27.97	46.68
	Median	34.45	43.57	74.2	18.9	21.9
	Maximum	408.5	2,600	2,600	490.2	20,020
	Minimum	20	2.55	3.14	4	0.64
Los Encuentros	Sample size	719	582	582	702	582
	Mean	34.56	52.05	142.61	23.51	32.49
	Median	31.5	44.84	109.99	16.97	22.5
	Maximum	115.8	205.36	932.99	150.66	220.26
	Minimum	20	3.4	3.57	4.18	0.68
Rosario Valley	Sample size	6115	4104	4104	5687	4104
	Mean	37.31	53.89	114.12	27.27	45.94
	Median	32	41	76.42	18.27	21.16
	Maximum	408.5	3850	3,850	490.2	23,870
	Minimum	20	1.5	1.16	4	0.3

https://doi.org/10.1017/S0956536123000202 Published online by Cambridge University Press

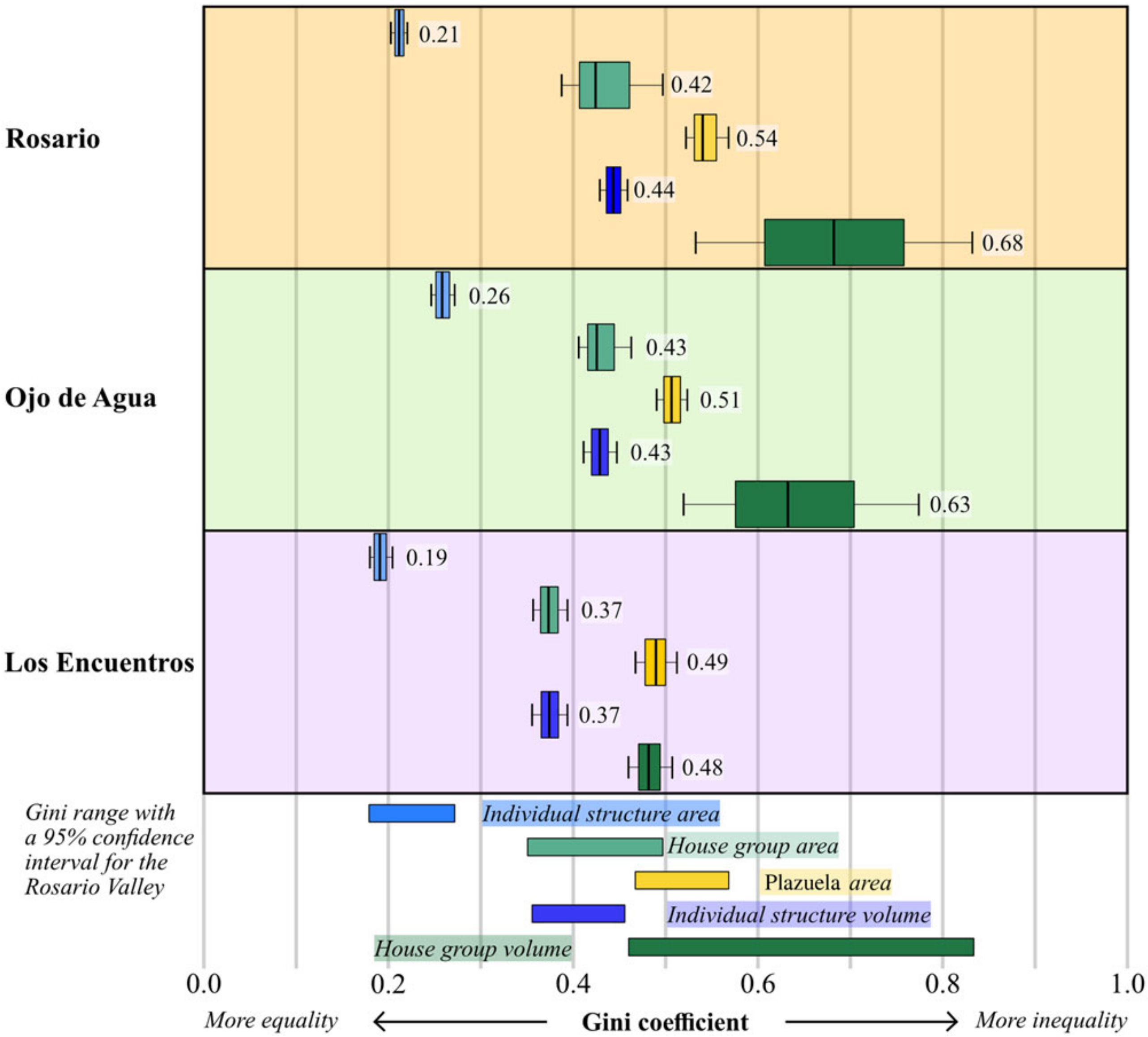

Figure 3. Box-and-whisker plots for each polity-scale Gini coefficient. Created by authors.

respectively). As explained in the section above, these high values for house group volume were inflated by the inclusion of acropolis platforms. Rosario and Ojo de Agua's area-based samples also yielded higher Gini coefficients (0.21–0.54) than those of Los Encuentros (0.19–0.49). The exception is *plazuela* area, where Rosario's higher value (0.54) has no CI overlap with that of Ojo de Agua (0.51) or Los Encuentros (0.49).

Finally, all Lorenz curves (Figure 4) were smooth, with no inflection points, except near the end. The biggest such jumps are visible in the Lorenz curves for house group volume. This pattern parallels the univariate plots that also show few substantial jumps in value, except towards the end of each curve. We have compiled our inequality data and house group polygons in an online dataset (Shaw-Müller and Walden 2023).

Discussion

Before comparing and interpreting our results, it bears explaining what architectural inequality means in this context. Because we lack stratigraphic sequences for most domestic structures, their final, Late Classic forms only provide a snapshot of architectural inequality. Therefore, from an energetics perspective (Abrams 1994), their volume or area totals cannot represent labor investment and consequent socioeconomic inequality during specific periods. Yet the final Late Classic sizes of these structures still probably indexed prestige—that is, "esteem or respect in the non-economic sphere of social relationships" (Drennan et al. 2017:54) for those inhabiting them, regardless of when they were predominantly constructed. Indeed, the height of domestic structures had a "visual effect" (Smith et al. 2014:312) that probably communicated prestige differentiation more than the labor necessary to build them. Furthermore, ethnoarchaeological evidence from Southeast Chiapas demonstrates that Maya residential architecture quality not only correlates with economic status, but also with social status (Blake 1988:51–54).

Irrespective of whether house size variables represent social status or wealth (as labor investment), our results still resemble existing Lowland Classic Maya inequality data. The lack of inflection points in the Lorenz curves corroborate prior claims that class-based social divisions were not prominent among Rosario Valley residences (de Montmollin 1995:293). That is, in keeping with lowland Maya samples, house sizes varied along a gradient, not according to distinct social ranks (Brumfiel 1994; A. Chase 2017:35–37, 2021:249–250; D. Chase 1986:362; Chase and Chase 1996, 2011; Fash 1983; Freidel 1981; Hutson 2016:167, 2020:409–412; Masson and Pereza Lope 2005; Pohl and Pohl 1994).

Another pattern for the Rosario Valley Gini coefficients is that the volume-based values (0.37–0.68) are higher than their area-based counterparts (0.19–0.54). Volume-based Gini coefficients are also high at other Classic Maya sites, ranging between 0.54 and 0.62 for Chunchucmil, Caracol, Uxul, Uxbenká, and Ix Kuku'il (Barnard 2021:144; Chase 2017:37; Hutson and Welch 2021:820; Thompson et al. 2021:14). Copán yielded even higher volume-based Gini coefficient values than the Rosario polities, ranging between 0.65 and 0.85 (see Richards-Rissetto 2023). In contrast, area-based Gini coefficients, such as those for *plazuela* area (0.34) at Caracol (Chase 2017:37), house lot area (0.34) at Chunchucmil (Hutson and Welch 2021:820; Magnoni et al. 2012), and individual structure area (0.44) at Palenque (Brown et al. 2012:318), are notably lower. Therefore, a key question is whether area-based or volume-based Gini coefficients more accurately reflect prestige differentiation.

In a region such as the Rosario Valley, where property sizes cannot be estimated (e.g., through houselots), area-based Gini coefficients are likely less reliable indicators of prestige and wealth differentiation. For example, ethnoarchaeological evidence from Chanal, a Maya community in southeast Chiapas, demonstrates that although the lowest- and highest-status households tend to have the smallest and largest area houses on average (respectively), this relationship is not linear for the rest of the sample (Blake 1988:54). That said, single structure area Gini coefficients were exceptionally low (0.19–0.26) for Rosario samples, with very tight confidence intervals, possibly, in part, for this reason and because they lacked *acropoleis* and small structures (less than 20 m^2). Even if outliers were included, single structures would probably not represent household prestige differentiation because ancient Maya residences typically consisted of multiple structures, such as storage buildings, ancestral shrines, and kitchens (Hammond 1975; McAnany 2013; Sheets et al. 1990; Thompson et al. 2021). Indeed, among modern Maya communities in southeast

Table 4. Gini coefficient results.

		Individual structure area (m^2)	House group area (m^2)	Plazuela area (m^2)	Individual structure volume (m^3)	House group volume (m^3)
Rosario	Corrected Gini	0.21	0.42	0.54	0.44	0.68
	Gini lower boundary	0.20	0.39	0.52	0.43	0.53
	Gini upper boundary	0.22	0.50	0.57	0.46	0.83
Ojo de Agua	Corrected Gini	0.26	0.43	0.51	0.43	0.63
	Gini lower boundary	0.25	0.41	0.49	0.41	0.52
	Gini upper boundary	0.27	0.46	0.52	0.45	0.77
Los Encuentros	Corrected Gini	0.19	0.37	0.49	0.37	0.48
	Gini lower boundary	0.18	0.35	0.47	0.36	0.46
	Gini upper boundary	0.20	0.39	0.51	0.39	0.51
Rosario Valley	Corrected Gini	0.23	0.42	0.52	0.43	0.64
	Gini lower boundary	0.23	0.40	0.51	0.42	0.53
	Gini upper boundary	0.24	0.45	0.53	0.44	0.74

https://doi.org/10.1017/S0956536123000202 Published online by Cambridge University Press

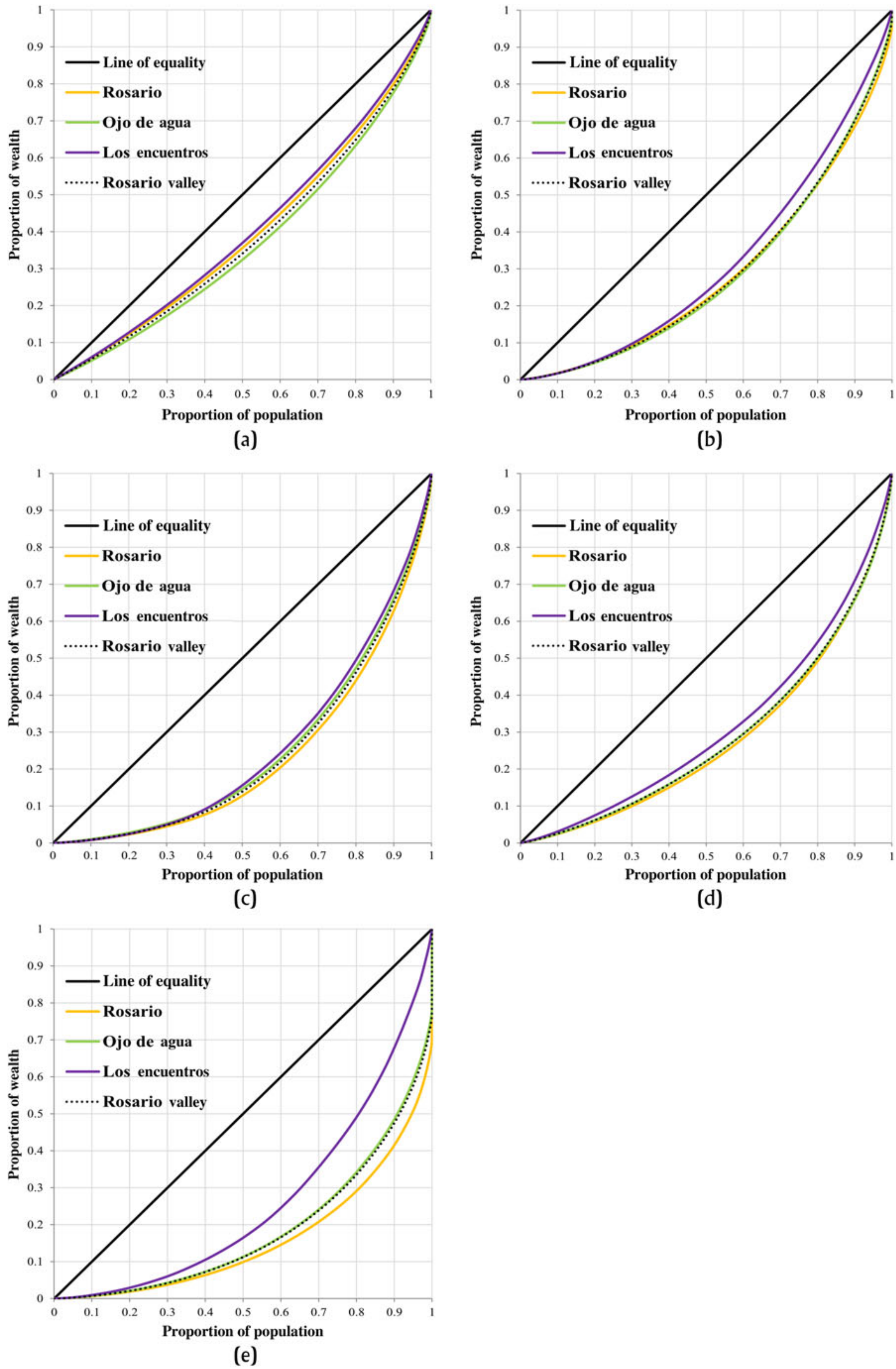

Figure 4. Lorenz curves for each variable: (a) structure area; (b) house group area; (c) *plazuela* area; (d) structure volume; and (e) house group volume. Created by authors.

Chiapas, at least 80 percent of households have separate kitchen structures (Blake and Blake 1988:40). Individual structure volume Gini coefficients are likely unrepresentative for similar reasons.

Likewise, *plazuela* area Gini coefficients (0.49–0.54) for the Rosario polities probably do not represent wealth or prestige differentiation. The Rosario polity has the highest *plazuela* area Gini coefficient value (0.54) because it has the largest area acropolis (3,850 m^2) and smallest average *plazuela* areas. Ojo de Agua's *plazuelas* are just slightly larger, while those of Los Encuentros are much larger on average (Table 3). It bears emphasizing that because our *plazuela* area metric consists of convex hulls, it represents architectural size less well than estimates inferred from LiDAR or pedestrian mapping. Assuming convex hulls are accurate, however, the likeliest cultural explanation for the more spacious *plazuelas* of Los Encuentros is that, as multifunctional areas for everyday activities (Thompson et al. 2021:9; Vogt 2014:89), they benefit from more space to some extent, but there is a point at which *plazuelas* do not need to be larger to fulfill their social functions. Los Encuentros *plazuelas* could be so spacious and equal because many households simply had the room to expand their patios to socially useful maximums, whereas Rosario and Ojo de Agua residents did not. Therefore, the differences between Rosario Valley *plazuela* area statistics are probably not socially meaningful.

Of all variables, total structure volume by house group appears to yield Gini coefficients best reflecting prestige differentiation. Rosario and Ojo de Agua have much higher degrees of architectural inequality (with Gini coefficients for total structure area and volume ranging between 0.42 and 0.68) than Los Encuentros (0.37–0.48). Total house group volume is especially representative because it takes height into account (Smith et al. 2014:312). Rosario and Ojo de Agua are more unequal for this variable (Gini coefficients: 0.68 and 0.63 respectively) than Los Encuentros (0.48) because their samples include acropolises, which are immense outliers that cause wide CIs. Furthermore, we can account for lower Gini coefficients at Los Encuentros by reference to its short-lived, strictly Late Classic settlement, where labor investments can be more reliably estimated. While Los Encuentros yielded the highest median value for total house group volume (22.5 m^2), it also had the lowest mean (32.49 m^2); therefore, most inhabitants probably grew their houses faster because they were not involved in monument-construction projects as ambitious as those of Rosario and Ojo de Agua. De Montmollin's (1995:222) own analyses corroborate this hypothesis, demonstrating that Los Encuentros had the lowest proportion of elite architecture of the three polities.

Conclusion

The Gini coefficients and Lorenz curves for five dimensions of house size in the Rosario Valley samples demonstrate remarkable continuity with other Late Classic Maya polities: namely, a smooth gradient of architectural inequality and house group size Gini coefficients comparable to major Classic Maya centers in the Lowlands. Although the inequality of these three polities' house size metrics is but a snapshot of architectural variability in the Late Classic, and so may only represent prestige differentiation in that period alone, aspects of economic inequality (via labor investment) can be gleaned from the Los Encuentros settlement, because it is a single component. Its sample yielded the most equal distribution of domestic architecture size in the valley, while also having the largest median for house group volume, probably because its apical elites levied less labor for monument construction. Therefore, political differences likely did exist between this short-lived Late Classic polity and the larger, well-established centers of Tenam Rosario and Ojo de Agua, for which labor investment data are more ambiguous. Relatedly, the diverse settlements of these older polities were probably characterized by more dramatic differences in household prestige, as reflected especially in the high Gini coefficient values of their visually impactful residential volume variables.

Acknowledgements. We thank Olivier de Montmollin for making the Upper Grijalva Basin dataset publicly available through the University of Pittsburgh's Comparative Archaeology Database. Likewise, we owe our gratitude to Alexander J. Martín, Hugo Ikehara, Weiyu Ran, and Faith Ruck for their work in designing and digitizing the dataset. As for the article itself, we are grateful to the three anonymous reviewers who generously offered insightful comments, improving both our analyses and prose. Finally, we are very thankful to Adrian Chase and Amy Thompson for organizing the 2022 SAA symposium in Chicago that led to this Compact Special Section, for providing the resources and guidance necessary to undertake these analyses, and for offering extensive feedback on this article.

Competing interests declaration. The authors declare none.

Data availability statement. All data will be made available through a publicly accessible online database (Shaw-Müller and Walden 2023).

Funding statement. Our research was made possible through funding from the University of Toronto, specifically for conference travel, stipends, and software licensing.

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