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Assessing neighborhoods, wealth differentials, and perceived inequality in preindustrial societies

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Humans often live in neighborhoods, nested socio-spatial clusters within settlements of varying size and population density. In today's cities, neighborhoods are often characterized as relatively homogenous and may exhibit segregation along various socioeconomic dimensions. However, even within neighborhoods of similar social or economic status, there is often residential disparity, which in turn impacts perceived inequality. Drawing on the Global Dynamics of Inequality (GINI) project database, we study housing inequality within a sample of neighborhoods using the Gini coefficient of residential unit area and related measures of inequality. We examine patterns of intra-community inequality within more than 80 settlements from diverse spatiotemporal contexts including some of the earliest cities in Mesopotamia, the Roman Empire, the Classic Maya region, the Central Andes, and the Indus River Basin. Residential disparity differs within and among sectors of these settlements; some neighborhoods exhibit more similarity in residence size, resulting in lower degrees of housing inequality, while other sectors display greater variations in residence size with higher degrees of housing inequality. We observe a meaningful relationship between neighborhood inequality and population size, but not date of foundation or longevity of occupation. The macro-level structural processes associated with varying forms of governance seem to trickle down to the scale of the neighborhood. These findings may help explain why more unequal systems are not necessarily more unstable, as the inequality people experienced in their neighborhoods may generally have been less than that present in the overall settlement.

neighborhoods | inequality | governance | Gini coefficient | spatial analysis

Significance

Neighborhoods are central organizing features of human settlements today and in the past. These place-based communities are primary contexts of social interaction and daily experience, which have measurable impacts on human livelihoods and perceptions of socioeconomic differences. Premodern societies offer diverse contexts to explore how housing inequality was experienced within and between ancient neighborhoods. We observe that residential disparity was commonly lower in neighborhoods compared to the overall settlement and thereby shaped perceptions of inequality for neighborhood residents. Macrostructural processes of governance also play an integral role in local experiences of housing inequality. Our findings highlight the universal complexities of living in diverse and unequal spatial arrangements as well as some strategies humans employ to mediate these differences.

Neighborhoods are fundamental organizing features of urban life for contemporary city-dwellers and preindustrial populations alike (1–4). These place-based communities are primary settings of social interaction shaped by the built environment and influenced by the broader ecological and structural dimensions of human society (5–7). However, neighborhoods are not simple microcosms of their broader political and economic systems, but rather are heterogeneous enclaves that simultaneously reflect the lived experience of their residents and mediate the institutional structures of social life. As such, neighborhoods offer ideal contexts to examine the interaction between a society's macrostructures and the rhythms of daily life (8), providing insights into the impacts of both top–down and bottom–up processes. In this paper, we empirically assess degrees of residential disparity, using residence size as our primary unit of analysis, within and between neighborhoods from a global sample of more than 80 preindustrial settlements (9–11) to better understand how inequality was experienced in these diverse settings. Furthermore, we explore different factors including population size, settlement longevity, and forms of governance that may account for differences in the spatial patterning of housing assets across these communities.

Inequality manifests in many forms, from differences in social and political clout (relational wealth), knowledge and health (embodied wealth), to physical goods and features such as houses and prestige goods (material wealth) (12). Inequality is clearly a multidimensional concept that can vary along these different axes. We use house size metrics to capture these disparities. While the interpretation of residence unit area in socioeconomic terms is complex, evidence presented in other contributions to this Special Feature suggests that it represents a reasonable proxy for household wealth (11) and in some cases may better reflect household income (13). Cross-culturally in ancient societies, residences often reflect economic labor investments with larger households reflecting an individual household's ability to harness power and control over labor and resources to construct a larger physical structure (14). We recognize that house size is not the only metric for measuring

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economic inequality, nor does house size always align with the quality and quantity of material goods associated with the household (see ref. 15). Indeed, access to environmental (land, minerals) and social (networks and trade routes) resources as well as material objects (ceramics, lithics, textiles, and metals) are important forms of wealth; nonetheless, house size is one proxy of economic difference that can be compared easily and replicated across vast geographic regions, temporal periods, and differing spatial scales like neighborhoods, districts, and wards (16, 17).

Urban sociologists have devoted significant attention to the study of neighborhood effects—the notion that spatialized behaviors and local patterns can have systemic and long-term outcomes (18, 19). Various studies of contemporary urban contexts document patterns of racial and economic segregation identifying consequences of these neighborhood-level variations (20–22). More recent work in urban science adds a focus on the generative processes and dynamics that create these localized patterns (23) pointing to the importance of historical processes. These studies have obvious implications for public policy and human development in modern cities (5), but little is known about neighborhood effects in preindustrial contexts, let alone the degree and spatial patterning of heterogeneity within ancient settlements (16, but see refs. 24–26). And yet, built environments continue to face many challenges, so urban designers and city planners are looking to the past for more sustainable models of urban planning (27) as neighborhoods—and the personal interactions they facilitate—become increasingly relevant in our globalized and technologically mediated world (4). If archaeology is to provide reliable insights into contemporary socioeconomic challenges, we need empirical studies that are methodologically robust and reflect the range of variation that existed within human society (28).

Drawing on definitions from archaeology and urban sociology, we define neighborhoods as spatial subdivisions within larger settlements where groups of colocated individuals engage in frequent, face-to-face interactions and share social, architectural, and/or economic traits; these groupings typically consist of ~2 to 25 residential units or less than approx. 500 people (2, 4, 29–31). For much of our sample, neighborhood designations are based on spatial clustering of residences reflective of proximity, topography, or transport infrastructure (streets and paths), rather than shared architectural and economic traits. In a few cases, neighborhoods are defined based on excavated data (*SI Appendix*, Text S1). Although neighborhoods are common in the past and present, archaeologists have only recently begun to investigate the social and spatial significance of these arrangements (26, 31–35). In part, this reflects a move away from the traditional focus on monumental architecture to more comprehensive investigations of past urban experience and quality of life (36, 37). However, most neighborhood studies in archaeology emphasize themes of social integration, immigration, and identity formation in specific urban settings (25, 38, 39). Although studies like these provide rich details about the diverse composition of ancient neighborhoods in specific sites, their specialized focus has limited utility for investigating generalizable patterns and processes across multiple cases. In one of the few comparative analyses, York and colleagues (26) argue that neighborhood clustering is a common phenomenon of cities throughout history and propose several different drivers to understand residential dynamics and the processes responsible for segregation and mixing in urban contexts. But even in that study, detailed empirical cases are lacking.

Here, we investigate the heterogeneity and economic segregation of neighborhoods drawn from a global sample of preindustrial settlements, representing the largest systematic comparative study of neighborhood inequality to date. Our basic unit of analysis is the residence, which we define as the primary dwelling that houses the most fundamental social, economic, and spatial units of human society (40). Residences vary cross-culturally (41) and although there is substantial variation in the form and composition of residential units across the archaeological record, this variation has a larger impact on the mean residence size than on the statistical variance or range of residence sizes in relation to the mean residence size within a given community (13). Ultimately, groupings of residential units may form neighborhoods, which can be found in large urban centers but also in semi-urban and rural settlements that may have only been occupied on a temporary or periodic basis (3). The GINI Project database (10, 11) includes settlements that ranged from small rural hamlets to densely populated ancient cities located in a wide variety of environments (*SI Appendix*, Table S1), offering a unique opportunity to investigate a global sample of preindustrial settlements to examine patterns of heterogeneity, inequality, and economic segregation in ancient neighborhoods. Although different methods for measuring inequality exist, the Gini coefficient has gained popularity among archaeologists in recent years as a standardized metric for measuring and comparing residential disparity (14, 42). The Gini coefficient is formally defined as half the average absolute difference between all pairs of observations, standardized by the population mean (43), and thereby assesses the unevenness in the distribution of a sample (44). Absent negative wealth, the resulting values vary from 0 to 1, representing perfect equality and perfect inequality, respectively. Here, we evaluate the degree of neighborhood economic inequality within settlements of varying size and longevity using estimates of residence size. Our sample is drawn from the GINI Project database (10, 11) and includes more than 80 preindustrial settlements from around the world representing over 19,500 residential units divided into some 800 neighborhoods (*SI Appendix*, Fig. S1).

We examine several interrelated questions about neighborhood inequality, considering macrostructural factors along with individual-level perceptions and experiences of wealth differences in the past. We ask the following questions: What characteristics of urban sites are associated with neighborhood inequality? Second, what is the relationship between neighborhood-level inequality and site-level inequality and how does this relationship potentially result in different perceptions of inequality across a settlement? Third, what is the relationship between productivity and heterogeneity within settlements and how did these factors potentially impact peoples' daily experience of inequality in the past? Last, how do different systems of governance impact the degree of inequality within neighborhoods from more collectively versus more autocratically organized societies?

In answering these questions, we highlight our broader findings with examples from four sites: two from the Western Hemisphere and two from the Eastern Hemisphere. These sites exhibit differences in settlement density, temporal occupations, and governance. Comparative examples from the well-documented and spatiotemporally diverse archaeological sites of Mohenjo-daro (Indus Urban Phase, ca. 2600–1900 BCE), Pompeii (Early Roman Empire, 31 BCE–79 CE), Tastil (Southern Andes, Late Intermediate period, 1250–1450 CE), and Tikal (Late Classic Maya, 600–900 CE) are discussed throughout the paper and used to visualize our results. Neighborhoods were modeled at these four sites by regional specialists using a variety of methods including geospatial cluster analysis plus considerations of topography (Tikal), previously reported neighborhoods based on the street network (Pompeii), spatially discrete platforms composed of numerous households and supported by excavation data (Mohenjo-Daro), and sectoring of residential units spatially delimited by a network of paths (Tastil). In general, several patterns allude to the intentional arrangement of settlements, wherein residential units of similar size tend to cluster near each other. This pattern may be a by-product of coercion or convention in some cases, but it seems likely that, in others, it is the result of free locational choices by households. Although these residences are more similar in size to each other than to others outside of their neighborhoods, residential unit size within neighborhoods is not identical; some differences in residence size within neighborhoods persist. Overall, we observe that the rhythms of daily life in neighborhoods and overarching governmental systems likely resulted in varying perceptions and experiences of inequality in the past.

Results

We draw inferences about the disparities between residential sizes through various approaches based around differing applications of the Gini index. We explore the relationship between a number of social attributes and the observed Gini index using ordinary least-squares regressions, while group effects and perceived inequality are measured through a novel decomposition approach (45, 46). The GINI project database variables appear in brackets below (e.g., [CountHH]) and are defined in *SI Appendix*, Text S2. Additional derived metrics are defined in the text below and in the corresponding supplemental text.

Residential Diversity and Spatial Patterning of Neighborhoods. We find residential disparities within ancient settlements, with neighborhoods (defined by at least two houses) having a wide range of Gini values (*SI Appendix*, Fig. S1 and Table S1; see also refs. 16, and 17). For example, at Pompeii, the 78 neighborhood Gini coefficients range from 0.05 (N = 3 residential units) to 0.76 (N = 8 residential units), revealing neighborhoods composed of similarly sized residences and great disparity in residence size, respectively. This pattern is observed across the dataset, reflecting the wide range of residence sizes and residential disparity ($\overline{\sigma} = 0.12, \sigma_\sigma = 0.07$). Nonetheless, most (78.0%) of the neighborhood-level Gini coefficients are less than what is exhibited at the site level (mean error = –0.13). For example, at Tastil, the site-level Gini coefficient is 0.22, and 22 of the 27 neighborhoods have lower Gini coefficients than the site overall. Within our sample, this pattern seems to hold true regardless of location or polity type.

What urban characteristics are associated with intra- and inter-neighborhood heterogeneity? We found that more populated settlements and neighborhoods tend to have higher residential disparity, but that settlement persistence does not correlate with neighborhood inequality. First, we evaluated population size. In a case study of more than 400 preindustrial societies, increases in population size were associated with more acute social hierarchies (see also refs. 13, and 47). Does this macroscale pattern manifest at the scale of neighborhoods? We found that the $\log_{10}$ of the number of residential units in each neighborhood ([CountHH], as a proxy for neighborhood population) accounts for 25.69% of the variability in the neighborhood Gini coefficient (N = 859, R^2 = 0.256, coeff = 0.20, P <0.01; *SI Appendix*, Fig. S2), meaning that neighborhoods with more residential units tend to have higher residential disparity and that on average a 10-fold increase in population results in an increase of Gini value by 0.20. This trend holds true for the estimated population size of the entire settlement ([MaxHH], (N = 752, R^2 = 0.184, coeff = 0.119) (*SI Appendix*, Fig. S3 and Table S1). We also investigated whether longer-lived settlements resulted in greater wealth disparities through the intergenerational transmission of wealth, observing no meaningful temporal trends in the degree of residential disparity present among neighborhoods [GiniNeib] and the site foundation date [BeginDate] (N = 861, R^2 = 0.01, coeff = 1.4×10^{-5}, P < 0.01; *SI Appendix*, Fig. S4), nor duration of site occupation $\log_{10}$ [EndDate – BeginDate] (N = 861, R^2 = 0.05, coeff = 0.059, P < 0.01, *SI Appendix*, Fig. S5), indicating that there is no evidence that settlements occupied for longer periods of time inherently result in greater differences in neighborhood wealth based on residence size metrics (see also ref. 48).

To assess spatial patterns of inequality within ancient settlements, we conducted spatial autocorrelation and hot spot analyses of our four case study sites (*SI Appendix*, Text S3). We observe that some settlements exhibit spatial clustering of neighborhoods with higher and lower residential disparity (*SI Appendix*, Table S3). For example, at Pompeii, using the neighborhood Gini coefficient [GiniNeib] neighborhoods are clustered, with greater residential disparity near the central Forum and lower disparity near the amphitheater and gymnasium in the southeastern sector of the city (Fig. 1*A*). The median total house area [MED_TAH] of Pompeii neighborhoods is also clustered. Comparing the neighborhood Gini value and the median residence size illustrates the notion that residential disparity can be low, even when median residence sizes are large, and that a single residence alone is not contributing to the increased median total house area value. Other neighborhoods in the southeastern sector have both low Gini coefficients and low median residence sizes. Combined with a hot spot analysis, we observe that there are clusters of adjoining neighborhoods with similarly sized residences. The neighborhoods near the amphitheater have low residential disparity but cluster together with large residences—averaging over 750 m^2. In contrast, the neighborhoods near the Forum have high residential disparity, yet their median residence size is smaller, around 100 m^2. In comparison, Tastil's neighborhoods have generally lower residential disparities, with both high (red outlines, Fig. 1*C*) and low (blue outlines, Fig. 1*C*) clusters of median residence size. These maps also help visualize the impact of residence size for residential disparity. For example, at Pompeii, there are several neighborhoods with high residential disparity but generally low median residence size, shown in the red polygons with blue outlines (Fig. 1*A*), meaning that most residences were small, and one was larger. At Tikal, there was high degrees of residential disparity but also, spatial clustering of apparent wealth as evidenced by the red outlines around darker red polygons (Fig. 1*D*). These spatial analyses suggest that there may be an intentional economic segregation in settlements, as is the case of Pompeii, but also highlight the diversity in human behaviors including settlement composition as well as potential perceived and experienced inequality.

Perceived Inequality Within and Between Groups. Perceived inequality refers to the way individuals perceive differences in how wealth and other resources are distributed among the members of a group, which may deviate considerably from the actual measured extent of inequality within the society (49). One way to capture these differences is to consider the relative contribution of each residential unit to the amount of inequality within each neighborhood in relation to the total inequality measured at each site. Others have proposed reformulated methods for computing the Gini coefficient as a measure of experienced inequality on a complete social network (50). The approach we take is based on a decomposition technique outlined by Mejía Ramón and Munson (45) and Crema et al. (46). This method effectively measures how much inequality an observation, or single residence, perceives in its local neighborhood by comparing every other observation (residence) in its neighborhood to the mean residence size of

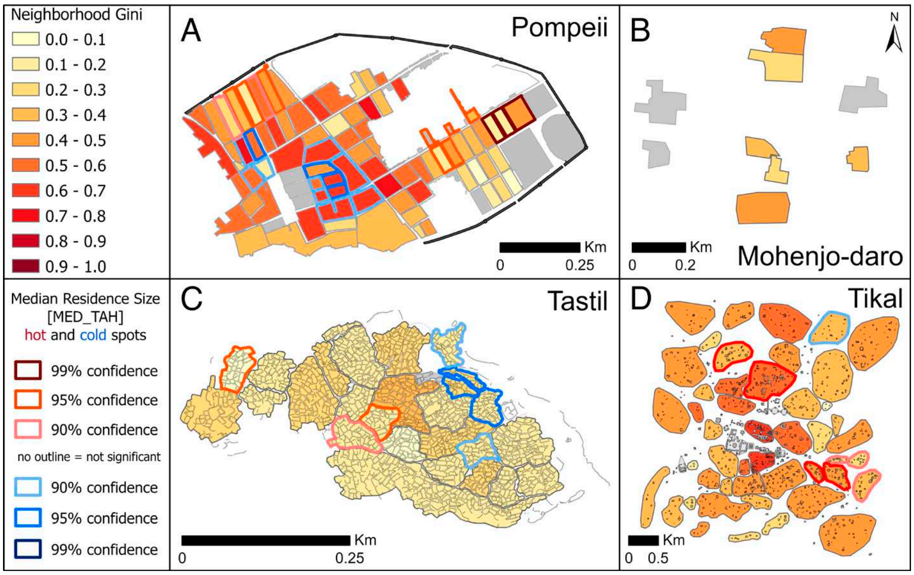

Fig. 1. Examples of neighborhood inequality around the world. Neighborhood Ginis are displayed for four case studies from different spatiotemporal contexts. Neighborhood-level Gini coefficient is displayed on the map representing neighborhoods of low (light yellow) and high (dark red) residential disparity. The median total house area [MED_TAH] neighborhood hot spot results are outlined in red and blue. Clockwise from top center to bottom left: Pompei (Roman, 200 BCE–79 CE, [*A*]); Mohenjo Daro (Indus, 2600–1900 BCE, [*B*]); Tastil (Late Intermediate Period, 1250–1450 CE, [*C*]); and Tikal (Late Classic Maya; 600–900 CE, [*D*]). Site and neighborhood shapefiles created by authors.

its neighborhood. Then one assesses its local (within-group) inequality in relation to the total (out-group) inequality observed among all other residences at the settlement. This method employs an abstracted form of the Gini index that standardizes measures of the average error from an expected value, representing half the fraction of how much richer (or poorer) an observation (residence) would be if there was absolute equality within its group, across its group, and in the total system. In this way, we can evaluate the extent to which inequality is structured within a settlement (*SI Appendix*, Text S4).

We found that inequality within neighborhoods is generally less than the level of inequality observed outside of the neighborhood within each settlement. Fig. 2 shows how inequality within neighborhoods (i.e., in-group inequality, the average standardized pairwise difference between members of a neighborhood) compares to inequality between neighborhoods (i.e., out-group inequality, the average standardized pairwise difference between members of a neighborhood and all remaining residences outside of the neighborhood within a settlement). In most cases (67.1%), the total out-group inequality is significantly larger than the in-group neighborhood inequality; at the neighborhood-to-site level, these results are complementary to findings by Crema et al. (46) who document similar trends at the site-to-region scale of analysis. Together, these results reveal an important phenomenon: In human societies, spatial patterns in socioeconomic properties exhibit a degree of scale invariance. Within- and between-group inequality is significantly different from what would be expected due to chance in all cases. There is an even split between settlements with significant out-group equality (Fig. 2*A*, teal points) and inequality (Fig. 2*A*, red points), while a slight majority (62.4%) of settlements demonstrate significant in-group inequality (Fig. 2*A*, yellow). Four settlements (Inka La Huerta; Mid-Late Classic Mitla Fortress; Kachemak SAS; and Late Roman Silchester) have neighborhoods with residential units more similar to each other within each neighborhood versus the pooled inequality of all other residences outside each respective neighborhood (Fig. 2*A*, purple points) than would be expected due to chance, suggesting a degree of wealth segregation. These patterns complement the finding that neighborhood-level Gini coefficients tend to be lower than site-level Gini coefficients, discussed in more detail below. Some settlements exhibit lower-than-expected neighborhood inequality but overall higher-than-expected inequality between neighborhoods, which we interpret as a form of economic segregation, wherein residences within a neighborhood are more like each other than they are to the overall site. Interestingly, most of these sites are either parts of less complex social systems or are lower-level sites within more complex polities (Fig. 2*B*). Conversely, the sites found to have high in-group and out-group inequality represent sites with more heterogeneous neighborhoods but that nevertheless have significant inequality between groups; this is similar to the finding that sites with greater residential disparity have wide ranges of neighborhood-level Gini coefficients (*SI Appendix*, Table S1). In most cases, these are sites within more complex arrangements (empires and archaic states), but also appear at apex settlements [WhichLevel = NOfLevels] within less complex systems (11, 51).

We also analyze the degree of residential segregation within settlements by examining variation in the distribution of residential unit sizes alongside in-group and out-group inequality. Our findings highlight the heterogeneity that existed within preindustrial settlements. We plotted the relationship between perceived in-group neighborhood inequality and the total out-group inequality for each measured residential unit within a settlement. Despite the number of settlements with low–low inferences, a finding that settlements have more out-group inequality than would be expected due to chance does not imply that wealth segregation is completely absent. In archaeological contexts, an example of this is Tastil, a Late Intermediate Period (1250–1400 CE) site located in the southern Andes, where road networks connect residential units and simultaneously delineate clusters of residences (52). As a whole this settlement experiences low in-group inequality but contains a few observations that perceive high in-group inequality (Fig. 2*D* and *SI Appendix*, Fig. S85). At the other extreme, Pompeii, which has 78 neighborhoods (53), provides an example of a settlement with more heterogeneous household wealth within and between neighborhoods. The variable combinations of low–high (N = 604), high–low (N = 558), low–low (N = 632), and high–high (N = 210) inequality indicate

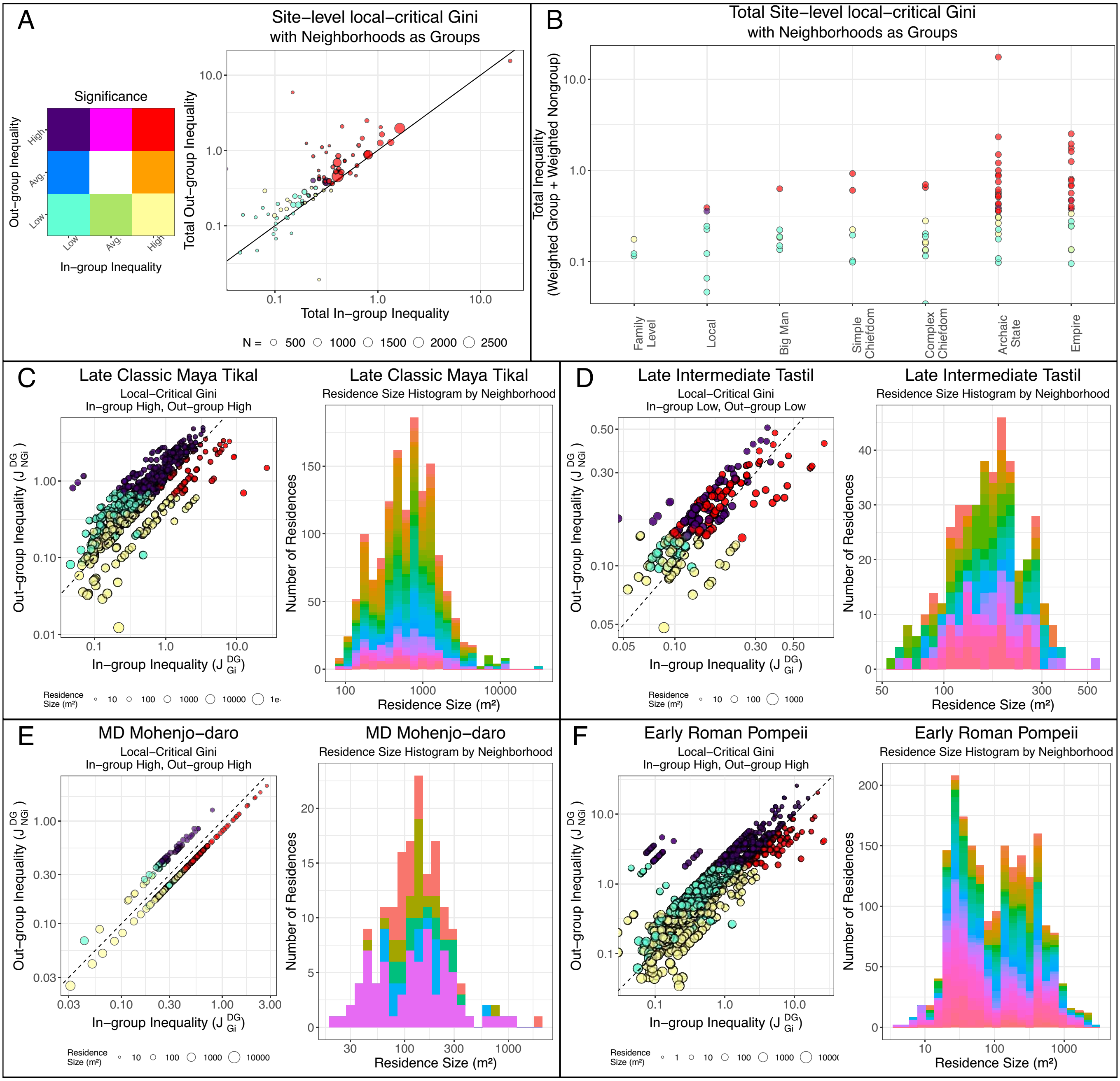

Fig. 2. Summary of decomposition analysis. Results by site, with the value decomposed into the total group and nongroup components (*A*) and the total value versus organizational complexity of a society (*B*). Results by neighborhood for four representative sites (*C*–*F*). Scatter plots show the decomposition of the total value by observation into perceived in-group and out-group inequality. Histograms are of the residence sizes with each unique color representing an individual neighborhood. See also *SI Appendix*, Text S4 and Figs. S18–S102.

that neighborhoods are mixed with regard to the degree of inequality perceived locally in relation to the rest of the settlement, bolstering the argument above (Fig. 2*F* and *SI Appendix*, Fig. S73). Overall, most residences perceived less inequality within their neighborhoods compared to the rest of the settlement (low–low and low–high) than would be expected by random chance as indicated by the teal and purple points (Fig. 2*A*). However, enough households perceive high levels of inequality within their neighborhoods compared to the total settlement (high–low, yellow points and high–high, red points) such that the site organization results in a high amount of total site level inequality. In contrast to the more segregated patterning of neighborhood wealth based on median residence size at Tastil (Fig. 1), Pompeii appears to have a more heterogeneous distribution. In total, our findings reflect the heterogeneity of neighborhood and settlement composition, wherein some settlements contain neighborhoods that are subject to segregated patterning (low–high), while others exhibit high perceived inequality with heterogeneous neighborhood composition (high–high). *SI Appendix*, Table S4 and Figs. S18–S102 summarize the results for all sites with more than one neighborhood.

Scalar Effects of Productivity and Heterogeneity. Next, we investigated inequality at nested scales of analysis. First, we asked: How does residential disparity at the neighborhood level compare to the overall residential disparity of the settlement? Based on population- and nested-scalar effects noted by other scholars (46, 54), we expected that neighborhood-level Gini coefficients would be lower than the total site-level Gini coefficient. To assess this, we conducted several independent analyses including regressions of neighborhood vs site Gini coefficients, neighborhood vs site productivity, and the measured difference between neighborhood Gini coefficient and site Gini coefficients, denoted as δ-inequality by Crema et al. (46). Our findings highlight that, in most cases (78.0%), neighborhood-level inequality is lower than site-level inequality regardless of geographic region ([Region] in the GINI database) or polity type ([Politytypdesc] in the GINI database) (*SI Appendix*, Text S5 and Fig. S6). However, if one estimates the relative productivity of a neighborhood using the mean-log of residence area (13), mean neighborhood productivity is often very similar to overall site level productivity (RMSE = 0.29) (*SI Appendix*, Text S5 and Fig. S7). In other words, residence size disparities are typically lower in neighborhoods than across sites, but neighborhood-level residence sizes themselves are similar to site-level residence sizes (Fig. 3). This suggests residents in neighborhoods experienced typical levels of productivity across the larger community to a greater extent than they experienced the actual level of inequality. This is an important finding in that it suggests that people generally experience the effects of productivity change (i.e., increasing residence sizes) to a greater extent than they experience the effects of inequality change (i.e., increasing residential disparities).

Next, we evaluated the difference between each neighborhood-level Gini coefficient and their respective site-level Gini coefficient, or δ-inequality (46), compared to a) estimated settlement population and b) the site Gini coefficient. There is no significance in the relationship between δ-inequality and population in terms of households (N = 104, R^2 = 2.3 × 10^{-3}, $\log_{10}$ coeff = −0.008, P = 0.625; *SI Appendix*, Fig. S8). However, we found a meaningful relationship between δ-inequality and site-level Gini coefficient. Overall, as residential disparity increases, δ-inequality decreases, accounting for 37.2% of the variation (N = 133, R^2 = 0.372 coeff = −0.449, P < 0.01; *SI Appendix*, Fig. S9). While these results seem to suggest homophily within populations, the range of neighborhood level Gini coefficients among most settlements alludes to the diverse composition in neighborhoods rather than the low variation often encountered in suburbs today. To further test this finding, we simulated randomized differences in δ-inequality, which would allow us to see whether these patterns hold true or are a result of our neighborhood clusters (*SI Appendix*, Text S6). None of our 1,000 simulated neighborhood findings are as extreme as those of our observed neighborhoods (*SI Appendix*, Fig. S10). This implies that the findings from the observed neighborhood data are in fact due to the specific groupings of residence sizes within neighborhoods, suggesting that lower neighborhood Gini coefficients are due to homophily, or the tendency of more similar people to live nearer to each other (*SI Appendix*, Text S6). Although numerous factors contribute to why people opt to live in obviously unequal systems (55), the fact that neighborhood inequality seems to be intrinsically lower than settlement inequality may help to explain why highly unequal social formations can develop and persist in the first place; namely, that the representative individual in such societies experiences a lower level of inequality in their local interactions than actually exists in their overall socioeconomic network.

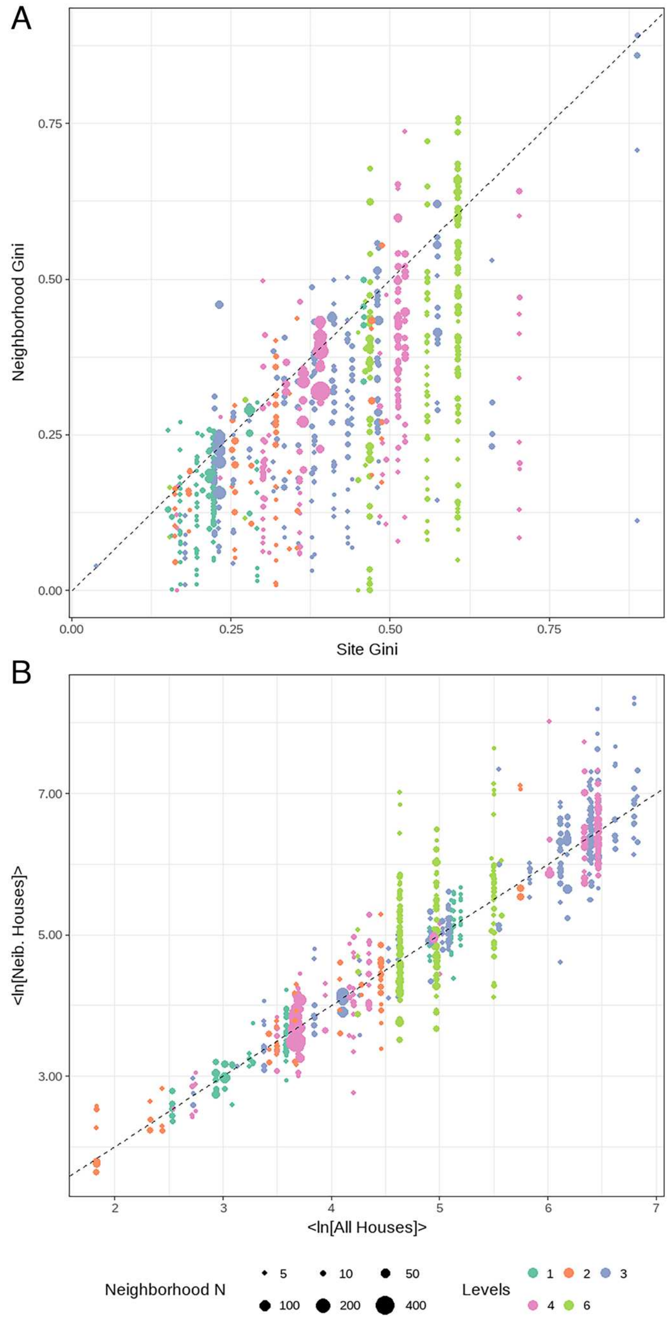

Fig. 3. Inequality vs productivity. Relationship between site-level Gini coefficient and neighborhood-level Gini coefficient, by neighborhood (*A*); relationship between the mean-log of all residences vs. the mean-log of neighborhood residences, by neighborhood (*B*). Point colors reflect the number of levels in the settlement system of the society in which each settlement was embedded, and point size reflects the number of residences in the neighborhood. Neighborhoods associated with a single residence size measurement are excluded from the plot. Dashed lines reflect an equivalent value at the site and neighborhood level. Note that mean neighborhood inequality is systematically lower than settlement-level inequality, but mean neighborhood productivity is systematically equivalent to settlement-level productivity. See also *SI Appendix*, Text S5 and Figs. S6 and S7.

Governance Impacts Neighborhood Inequality. Based on previous scholarship that shows more collective societies had lower residential disparities compared to more autocratic societies (16, 51, 56, 57), we expected this pattern to emerge at the neighborhood level as well. Leadership regimes in more collectively governed sites typically rely on their local populace for economic underpinnings (58), where goods are internally produced and therefore, wealth is more widely distributed across the community, resulting in lower degrees of residential disparity, even at the neighborhood scale. Among more autocratically governed societies, leadership regimes monopolize resources through external trade, resulting in fewer people having access to wealth and prestige goods, resulting in visible residential disparities (59, 60). To further evaluate the impact of macro-level structural processes on residential disparity, we examined the distribution of residence size and how it articulates with governance using ordinal scale variables for more and less collective regimes as discussed in ref. 51. We found that neighborhoods in more autocratic settlements tend to have greater variation in both the mean and variance of residence size than is the case in settlements with more collective forms of governance.

These trends are visible in Fig. 4, where the range of variation in neighborhood properties is reflected in the diameter of the black ellipse. Sites with a greater dispersion of residential values tend to have higher governance scores, as seen in the more autocratic systems of Tikal and Pompeii. Tikal, a Classic Maya (250–800 CE) kingdom with detailed dynastic histories carved into stelae (61), was one the most powerful Maya kingdoms of its time with connections to vast sociopolitical and trade networks across the Mundo Maya (62, 63). Although the elite monopolized these trade networks, they may have provided concessions to intermediate elites within local neighborhoods through the distribution of goods (64). These social patterns may result in the wide distribution of residences within neighborhoods (Fig. 4). Sites with more clustered neighborhood residential values tend to have lower governance scores as represented by the more collectively organized settlements of Mohenjo-daro and Tastil. Mohenjo-daro is one of the Indus civilization's largest cities (ca. 2600–1900 BCE). Its citizens built massive platforms to support its neighborhoods (65) and constructed public goods such as drainage networks and public buildings (66, 67), which required substantial labor inputs from thousands of people to establish and maintain. And yet, the city has no evidence of a ruling class—no palaces, exclusionary temples, ostentatious burials, or individual-aggrandizing art; in other words, the city was conspicuously egalitarian (68). Governance at Mohenjo-daro was therefore remarkably collective (69). However, this is not always the case, as seen with Xochicalco (Mexico), which is collectively governed yet exhibits significant residential disparity across neighborhoods (*SI Appendix*, Fig. S11). While this trend holds for the autocratically governed sites in Europe (*SI Appendix*, Fig. S12), South America (*SI Appendix*, Fig. S13), and Mesoamerica (*SI Appendix*, Fig. S11), the densely occupied tell sites of SW Asia do not follow this trend (*SI Appendix*, Fig. S14). In SW Asia, autocratically governed sites display both wide variation and great similarity in neighborhood disparity. However, at the collectively governed sites in SW Asia, all neighborhoods had little variation in residential unit sizes within the neighborhoods, suggesting both lower residential disparity and more similarity between neighborhoods of the same community compared to autocratically governed settlements. This pattern does not hold for the North American sites, where there is high variation in residential disparity within neighborhoods of some collectively governed sites, such as Cerro Prieto and Oryavi, while others have lower variation, such as Gb-To-78 and also less variation in residential disparity among more autocratically governed sites, such as the John H. Faust site (*SI Appendix*, Fig. S15).

In general, the neighborhood Gini coefficients among more collectively governed sites are lower than those among autocratically governed sites (*SI Appendix*, Fig. S16). Collectively governed sites such as Mohenjo-daro tended to invest in more public goods and services, which often served to redistribute resources and reduce impediments to domestic wealth accumulation thereby underpinning less residential disparity than in autocratically governed communities. In contrast, leaders of more autocratic regimes such as Tikal's kings often garnered wealth through the monopolization of trade links and the import of prestige goods with few incentives to share or redistribute (60, 64, 70). These patterns align with increasing residential economic disparities of neighborhoods in the United States and their implications (22). In our sample, among more autocratically governed societies ([Gov_I] = 2 and 3), the average neighborhood-level Gini coefficient was generally higher than the average neighborhood-level Gini in more collective sites ([Gov_I] = 0 and 1). Nonetheless, we found that the average site-level Gini coefficient is almost always greater than the average neighborhood-level Gini coefficient, regardless of governance score, a finding that echoes those discussed above.

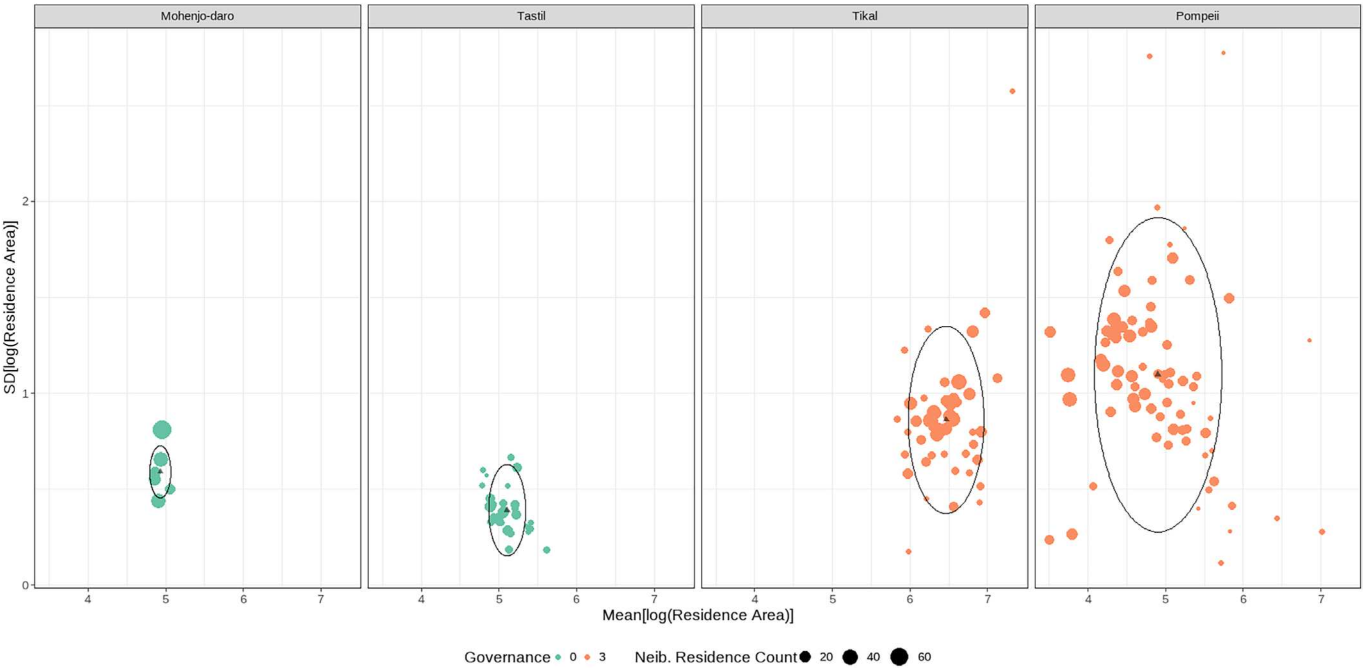

Fig. 4. Governance [Gov_I] and neighborhood disparity based on the SD of the log of the mean residential unit area per neighborhood. The site-level mean residential unit area is represented by the black triangle for settlement. Generally, more collective forms of government have less variation in residential unit size within a neighborhood (smaller circles for the green graphs, Mohenjo Daro and Tastil) compared to the variation in residential unit size within neighborhoods in more autocratic forms of governance (larger circles and wider distributions in the orange graphs, Tikal and Pompeii). See also *SI Appendix*, Text S4 and Figs. S18–S102.

Discussion: Unpacking Inequality

Persisting and developing social concerns about spatial and economic inequality, the rise of the 1%, and gentrification (6, 71) are not novel aspects of globalization and megacities (72). Our work highlights the long-term existence of neighborhoods in both urban and rural settlements with varying patterns of wealth and status. In a subsample of our data, we show that spatial variability of neighborhood inequality has existed for thousands of years. These findings have broad implications for sustainability, policy, and differential access to public services (sensu refs. 5, and 73). Today, neighborhood effects have bundled social impacts on differential access to health care, varying birth and death rates, and education levels, among others (7). Future analyses incorporating additional lines of evidence from residential construction materials, burials, and household possessions may further elucidate how neighborhood inequality, residential disparity, and economic segregation affected the residents of neighborhoods in the past (36).

Across the archaeological record, the lived experience of inequality for most people was generally less pronounced than was the reality across the entirety of settlements. In contrast, we also observe that the lived experience of productivity reflected the fortunes of settlements overall. This second regularity may be a simple by-product of the central limit theorem—the fact that the mean of subsamples of a (log) normal distribution will provide a close estimate of the mean across the population. Nevertheless, this systematic and apparently intrinsic difference between the lived experience of inequality and productivity may help explain why people live within and accept systems of extreme inequality—within their neighborhoods, they experience less extreme versions of inequality because people who are dramatically richer or poorer than the average neighborhood resident are often not nearby.

On the other hand, people engage in nested social networks and social mixing at varying scales. Through movement and communication, residents must have developed some sense of the inequities that existed within their larger social systems. These interactions influence people's perception of inequality as some may experience more in-group (neighborhood-level) interactions, while others may participate in more out-group exchanges, frequenting other parts of their community and beyond (49). To us, these seemingly contrasting views do not exist in isolation, rather it may mean that people set aside these differences for myriad reasons and particular circumstances. The complexity of these social interactions and their impacts on human experience are persistent features of existing in an unequal world.

Four key findings from this study of neighborhood inequality, derived from more than 800 neighborhoods in settlements spanning approximately 10,000 y from across the world, are as follows. First, we observe that neighborhoods are characterized by residential units of varying size, reflecting diverse neighborhood composition in preindustrial societies. Using spatial analyses and our four case studies, we show that low degrees of residential disparity can result from both low and high median residence size within neighborhoods, even within the same settlement (*SI Appendix*, Fig. S17). Second, both within- and between-group inequality is significantly different than would be expected if households were randomly distributed for all societies within our dataset. Generally, significant equality tends to dominate in all but the most highly ranked settlements of state- and imperial-level societies while significant housing inequality tends to be present in all but the most highly ranked settlements of state- and imperial-level societies and apex settlements in less-complex systems. Thus, one potential consequence of the dynamics of wealth accumulation is that disparities in the sizes of neighboring residences generally emerge regardless of the settlement's spatial and economic organization at its foundation. Third, we find neighborhood-level residential disparity is generally lower than that of the overall settlement, suggesting that the average person may have experienced or perceived lower levels of economic inequality in their local interactions than is reflected in the totality of the settlement. Finally, we find that neighborhood-based residential disparity is itself more variable among more autocratic societies than it is among more collective societies, consistent with patterns found at the site level (see ref. 51).

Within the context of the GINI Project and beyond, the implications of our findings are integral to understanding the effects of residential disparity within ancient communities and why individuals may opt to continue to reside within systems that are seemingly unfair when viewed from a distance. This may be due, in part, to our findings that even within an unequal settlement, occupants may not perceive the degree of inequality in which they reside based on their day-to-day interactions proximate to their homes and neighborhoods. This is particularly evident for settlements with more autocratic governance.

Materials and Methods

We conducted our analyses of residential unit size data on over 800 neighborhoods associated with more than 80 settlements from across the world (*SI Appendix*, Fig. S1), spanning 8000 BCE through 1981 CE. This dataset is a subset of the larger GINI Project database (*SI Appendix*, Text S7), which contains residential information from sites in Asia, Central America, Europe, North America, Oceania, and South America, and represents the largest comparative study of preindustrial neighborhoods published to date. For all statistical analyses, we used neighborhoods with at least two houses and a minimum of three neighborhoods within each settlement except for the decomposition analysis where we used all residences and neighborhoods of any size to evaluate perceived in-group and out-group inequality.

We acknowledge the spatial limitations of this dataset, in which we have a relatively small sample from Africa (see ref. 11) and few neighborhoods from Asia due to limited GINI project house size data from those regions. Geographically, sites in the neighborhood dataset come from diverse environments ranging from the high *altiplanos* of the Andes to the lush neotropical forests of the Mundo Maya, alluvial floodplains in the dry Indus River Basin, and the temperate Mediterranean climate, among other settings (*SI Appendix*, Text S1). Our sample also derives from systems with varying levels of social organization, from family-level communities in the North American Great Plains and Southwest to imperial systems, including the Inka and Roman empires (*SI Appendix*, Table S3). Neighborhoods were defined by the GINI project regional specialists based on geospatial clustering, excavation data, and natural and anthropogenic landscape features such as topography, rivers, and roads contemporary to the settlement (*SI Appendix*, Text S1). Neighborhoods vary in size from 2 to 409 residential units and vary substantially in residential density (*SI Appendix*, Table S1). The results from our diverse sample elucidate variations in neighborhoods as well as larger trends in multiscalar social communities within ancient and modern settlements (46).

The occupational sequences (foundation date and longevity) of the sites vary, but individual neighborhood chronologies are not incorporated in our analyses. Rather, we use a "snapshot in time" approach–that is, what was the degree of inequality within a neighborhood during its final phase of occupation, when we assume most houses were occupied. More recent sites, such as the modern (1980s) Big Man sites from New Guinea represent a two-year timespan, while others represent hundreds or thousands of years of occupation from the initial establishment of the site through its final phases of occupation, such as the Classic Maya centers near the Usumacinta that were occupied for 1,800 y prior to abandonment. In our dataset, diachronic analyses often resulted in too few houses within neighborhoods to provide meaningful results due to a dearth of temporal data from individual houses, which requires extensive household excavations. While much of our sample derives from robust pedestrian survey data, several sites, and their modeled neighborhoods are based on excavation data, including Pompeii and Mohenjo-daro.

While neighborhoods contain facilities, services, and institutions (1, 4, 30, 33, 74), we focus our neighborhood models on the concept of place. Given the differences in population density, architecture, landscapes, environments, and cultural norms, a one-size-fits-all model was not applied in the modeling or creation of neighborhoods (31). Rather, contributors delineated neighborhoods using a variety of methods based on the best practices for their regions (*SI Appendix*, Text S1 and Table S1). Some relied on spatial modeling and cluster analyses (e.g., Maya region, Near East), while others relied on previous studies of neighborhoods (e.g., Oaxaca, Roman), and others still that integrated artifacts, architecture, and location based on excavation data (e.g., Pompeii and Mohenjo-daro). This approach provides flexibility in the modeling of neighborhoods based on cultural and environmental nuances.

Data, Materials, and Software Availability. All raw data and R scripts for replicating the analyses and reproducing main and supplementary figures are provided on tDAR: https://core.tdar.org/project/496853/the-global-dynamics-of-inequality-gini-project (75).

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