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REPORT

Settlement Scaling in the Northern Maya Lowlands: Human-Scale Implications

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Abstract
Settlement scaling theory predicts that higher site densities lead to increased social interactions that, in turn, boost productivity. The scaling relationship between population and land area holds for several ancient societies, but as demonstrated by the sample of 48 sites in this study, it does not hold for the Northern Maya Lowlands. Removing smaller sites from the sample brings the results closer to scaling expectations. We argue that applications of scaling theory benefit by considering social interaction as a product not only of proximity but also of daily life and spatial layouts.

Resumen
Investigadores de relaciones de escala en asentamientos predicen que densidades altas resultan en el aumento de interacciones social, lo cual estimula productividad. Relaciones de escala entre población y área de asentamiento se manifiestan para varias sociedades antiguas pero, como se ve en nuestra muestra de 48 sitios, no se manifiestan para el norte de la Península de Yucatán. Quitando sitios pequeños produce resultados más semejantes a las expectativas de escala. Aplicaciones de relaciones de escala tienen que considerar interacciones sociales como producto no solamente de proximidad sino de la vida cotidiana y patrones de espacio.

Keywords: settlement scaling; daily life; ancient Maya

Palabras clave: relaciones de escala en asentamientos; vida cotidiana; arqueología Maya

A core principle of settlement scaling theory (SST) is that larger, denser cities produce increasing economic returns to scale. When there is more crowding, people are more likely to bump into each other and interact, which is referred to as "social mixing." Such planned and unplanned encounters result in exchanges of information, ideas, and materials; expansion and intensification of social networks; and mobilization of resources, all of which stimulate innovation and other kinds of change (Glaeser 2011; Hannerz 1980; Mumford 1961:96). In short, productivity increases in denser cities.

Based on key assumptions about urban growth and human interactions (Bettencourt 2013:1439; Lobo et al. 2020:736), SST predicts that a settlement's population should grow faster than its settlement area. The primary expectation is that bigger cities should be denser with more localized social interactions. Using a large sample of US metropolitan areas, Bettencourt (2013:1439) found that the slope of the regression line, with the natural log of population as the independent variable and the natural log of land area as the dependent variable, is less than one. Ortman and colleagues (2014) found a similar relationship between population and land area in ancient settlements in the Basin of Mexico. They add that, for every unit of population increase, land area increases to the two-thirds power or, for "networked" settlements with substantial infrastructure such as avenues, to the five-sixths power. Given vast differences between modern cities and ancient Mexico, evidence for similar scaling relationships surprised Ortman and his coauthors (2014:7). They conclude that fundamental processes of human interaction underlie settlements throughout human history.

Yet Smith and colleagues' (2021) recent study of settlements in the Maya and Izapa areas found that sites with larger populations had lower settlement densities. The apparent misfit between the predictions of SST and those recent findings opens up two opportunities that we pursue in this report: assessing SST predictions on a new sample of sites and considering the relation between density and interaction from a human-scale perspective.

Regarding this second approach, several studies show that bringing people into closer proximity neither ensured increased interaction nor the kinds of strong ties that boost well-being (Browning et al. 2017; Hipp and Perrin 2009; Talen 2006). Whether increased density results in the growth of social networks and other scaling effects depends on a variety of mediating circumstances (Kosse 2000), including the specifics of a city's built form and how individuals navigate and interact within those spaces, the existence of shared goals and mutual respect, and the presence of authorities that encourage harmony (Allport 1954; Hutson and Welch 2021; Saitta 2015; Sandercock and Attili 2009). Stated differently, the proposition that settlement density determines interaction rates may not always be correct. We suspect that social mixing made ancient Maya cities attractive (Hutson 2016:21–22), but the literature we cite shows that what people do, where they go in the course of their daily lives, and other considerations, such as gender ideologies that regulate human mobility, affect the rates of interaction. Thus, perspectives that consider spatial form and everyday activities more directly (Robin 2013) can add nuance to settlement scaling analyses by providing a broader context for numerical results.

Methods

In this report, we explore the relationship between population and site area in a sample of 48 sites (Figure 1; Table 1) from the Northern Maya Lowlands, where there tends to be higher settlement densities than in the Southern Lowlands (Chase and Chase 2016; Rice and Culbert 1990:19). This area was not part of Smith and colleagues' (2021) sample, which was from two regions in Belize and three regions in Chiapas (two of which—Izapa and the Rosario Valley—are peripheral to the Maya world). Our sample also differs from theirs because ours contains larger sites. Of the 606 sites listed in Smith and colleagues' (2021) supplementary materials, 83% consist of 10 or fewer houses, and 67%

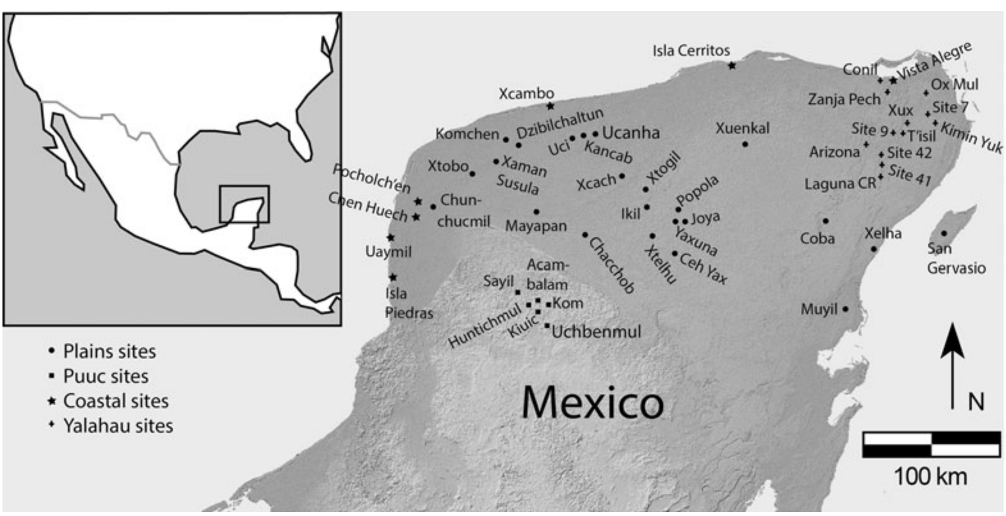

Figure 1. Map of sites included in this study.

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Table 1. Northern Maya Lowland Sites Included in this Study.

Site	Category	Population Estimate	Site Size Hectares	Natural Log of Population	Natural Log of Site Size
Acambalam	Puuc	1,560	91	7.352	4.512
Arizona	Yalahau	137	24	4.922	3.178
Ceh Yax	northern plains	713	109	6.569	4.691
Chacchob	northern plains	211	14	5.350	2.617
Chunchumcil	northern plains	31,415	1,500	10.355	7.313
Coba	northern plains	70,000	7,539	11.156	8.928
Conil	Yalahau	3,773	1,100	8.236	7.003
Dzibilchaltun	northern plains	42,000	1,900	10.645	7.550
Huntichmul	Puuc	4,070	288	8.311	5.663
Ikil	northern plains	256	20	5.545	2.996
Isla Cerritos	coast	78	3	4.357	1.099
Isla Piedras	coast	36	4	3.584	1.386
Joya	northern plains	292	30	5.675	3.401
Kancab	northern plains	1,226	125	7.111	4.828
Kimin Yuk	Yalahau	184	28	5.217	3.332
Kiuic	Puuc	1,610	124	7.384	4.821
Kom	Puuc	2,380	141	7.775	4.945
Komchen	northern plains	2,750	200	7.919	5.298
Laguna Costa Rica	Yalahau	191	22	5.252	3.091
Chen Huech	coast	83	3	4.414	0.916
Mayapan	northern plains	16,000	420	9.680	6.040
Muyil	northern plains	689	26	6.535	3.258
Ox Mul	Yalahau	1,049	60	6.956	4.094
Pochol chen	coast	275	7	5.618	1.974
Popola	northern plains	365	24	5.899	3.178
San Gervasio	northern plains	907	89	6.810	4.487
Sayil	Puuc	5,000	330	8.517	5.799
Site 41 / R. Juarez	Yalahau	495	50	6.205	3.912
Site 42 / Santa Cruz	Yalahau	418	71	6.036	4.263
Site 54 / Zanja Pech	Yalahau	73	8	4.289	2.015
Site 7	Yalahau	1,353	36	7.210	3.584
Site 9	Yalahau	169	5	5.128	1.609
Tisil	Yalahau	4,629	233	8.440	5.451
Uaymil	coast	73	6	4.290	1.792
Ucanha	northern plains	3,028	221	8.016	5.396
Uchbenmul	Puuc	520	28	6.254	3.334
Uci	northern plains	6,733	700	8.815	6.551
Vista Alegre	coast	65	8	4.171	2.079

(*Continued*)

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Table 1. Northern Maya Lowland Sites Included in this Study. (*Continued.*)

Site	Category	Population Estimate	Site Size Hectares	Natural Log of Population	Natural Log of Site Size
Xaman Susula	northern plains	288	20	5.663	2.996
Xcach	northern plains	2,025	295	7.613	5.687
Xcambo	coast	281	7	5.637	1.946
Xelha	northern plains	518	26	6.251	3.258
Xtelhu	northern plains	510	43	6.235	3.761
Xtobo	northern plains	1,247	57	7.128	4.043
Xtogil	northern plains	770	124	6.646	4.820
Xuenkal final	northern plains	3,172	300	8.062	5.704
Xux	Yalahau	685	35	6.530	3.555
Yaxuna	northern plains	5,000	800	8.517	6.685

consist of five or fewer houses. In contrast, our sample contains only one site with fewer than 10 houses and none with fewer than five houses. The average site population in the 2021 sample—assuming five people per house and an 81% correction factor for contemporaneity—would be 71 (median of 16) compared to the average population of the sites in our sample of 4,566 (median of 701). The sites in Smith and colleagues' dataset also have extraordinarily high settlement densities (see the later discussion).

Our study calculated regression equations using the natural log of site area as the dependent variable and the natural log of population as the independent variable (see Supplemental Table 1 and Supplemental Text 1 for determination of the population and land area). To account for the heterogeneity in our sites, we performed separate regressions to account for three subsets of our sample—coastal, Puuc, and Yalahau—based on specific environmental conditions. Coastal sites can have substantially higher densities because of population circumscription. Puuc sites exist in an environmentally distinctive subregion partially made up of hill slopes that are generally devoid of settlement. Yalahau sites, in northern Quintana Roo, are often close to wetlands. We also performed separate regressions to account for chronology.

Results

The slope of the regression line for all 48 sites is 0.988, with a 95% confidence interval between 0.889 and 1.087 (Figure 2). This result differs from the expected slope of between 0.667 and 0.833 (pertaining to powers of two-thirds and five-sixths, respectively) predicted by SST. It also differs from the super-linear slope (1.3) documented by Smith and colleagues (2021). It is interesting to note that when they analyzed only the 36 sites in their sample that had 40 or more houses, they found a slope similar to ours: 0.98. Such a scaling relationship means that site area grows in proportion to population growth, with little change in density. In other words, sites with hundreds of residents tend to be just as densely settled, on average, as sites with thousands of residents. This relationship is uncommon but has also been documented for dispersed sites in the Basin of Mexico (Ortman et al. 2020:Table 1).

Regarding chronology, the slope for the 16 sites that peak in the Preclassic is 0.861, whereas the slope for the 29 Classic period sites is 1.047. Isolating just the 13 sites that likely have a substantial Terminal Classic component yields a slope of 1.082. Thus, we find a trend toward less dense sites over time, though the difference is not statistically significant at the 95% confidence level (see also Ortman et al. 2020:13). Regarding ecology, seven sites on or near the coast are circumscribed by water or wetlands (Xelha is not circumscribed). These sites are small, covering less than 10 ha, and they have significantly higher settlement densities than the other 41 sites (averaging 2,381 versus 1,471 people per km^2, respectively) with between 36 and 287 residents (e.g., small populations in

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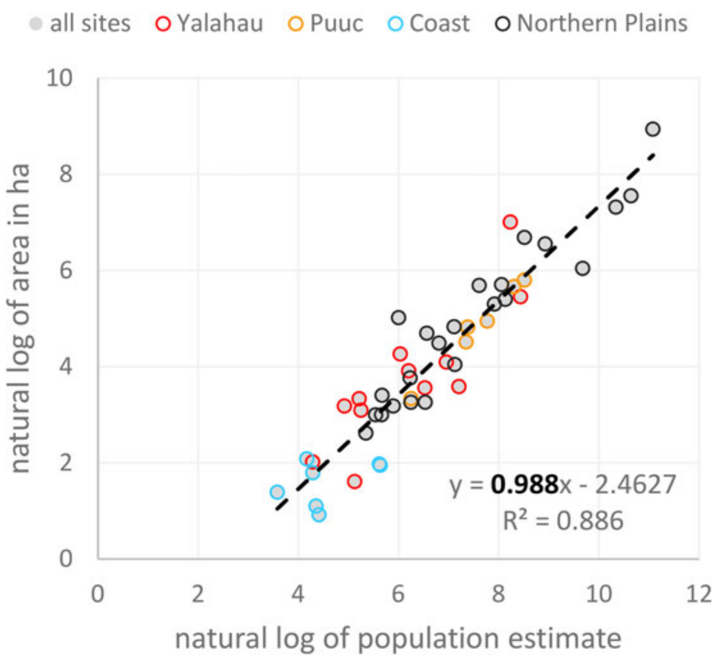

Figure 2. Regression of 48 sites from the Northern Maya Lowlands. (Color online)

even smaller spaces). If we remove these seven sites, as well as the two other sites that cover less than 10 ha, the slope for the remaining 39 sites is 0.905 (Figure 3), with a 95% confidence interval between 0.784 and 1.027. The slope that SST posits for networked settlements—0.833—falls within the 95% confidence interval, yet few of our sites are networked. Removing the 12 Yalahau sites also reduces the slope for the remaining 36 sites ($\beta = 0.925$, with a 95% confidence interval between 0.831 and 1.008).

The Puuc Hills are topographically distinct from the plains that host the other sites in the sample, and the slope of the regression line of the six Puuc sites is 1.09 (Figure 4), with a 95% confidence interval between 0.899 and 1.281. The slightly lower settlement densities of Puuc sites (see Table 1) account for this pattern, but these lower densities do not equate to less crowding within sites. Rather, the densities are lower because the larger Puuc sites in the Bolonchen region incorporate hills whose steep gradients cannot support settlement (93.6% of settlement is found on terrain with slopes of less than 12°; terrain with slopes of 12° or greater accounts for 21.5% of the survey region). The Puuc sites have little effect on the overall scaling relationship for the Northern Lowlands dataset; removing them from the sample of 48 yields a slope of 0.983, with a 95% confidence interval between 0.868 and 1.098.

Discussion and Conclusion

The relationship between the natural logarithms of site population and site area for 48 sites in the Northern Maya Lowlands is directly proportional (slope of 0.988); larger sites did not have substantially higher settlement densities. We found a nonsignificant trend toward lower density in later periods. Removing the smallest sites, most of which are surrounded by water or wetlands, produces a slightly "sub-linear" slope of 0.905. This slope suggests that settlement density increased with population growth in larger sites, theoretically allowing more social interactions in smaller areas.

Because our results do not conform to the slope expectations (0.67–0.83) of SST, we follow Ortman and colleagues (2020:21) in attempting to explore the reasons for the discrepancy: they propose that the settlements in Smith and colleagues' (2021) sample, which also do not fit SST expectations, "consist of residences interspersed with agricultural land [infield agriculture], centered on a smaller civic area. As a result, the area enclosed within a settlement boundary expands much faster than the area over which the people inside actually interacted socially." We agree that a sample with many large, less dense, primarily infield agricultural sites would inflate the slope, as noted by Chase and Chase

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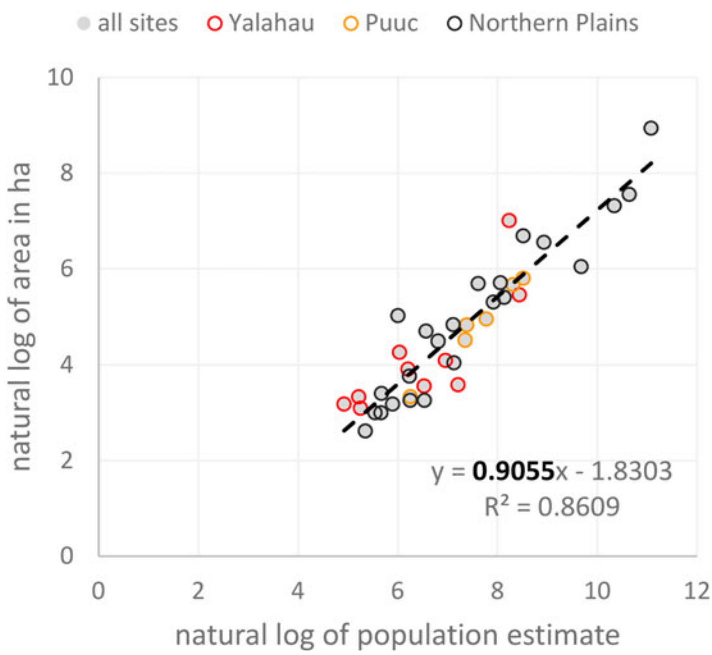

Figure 3. Regression of settlements larger than 10 hectares. (Color online)

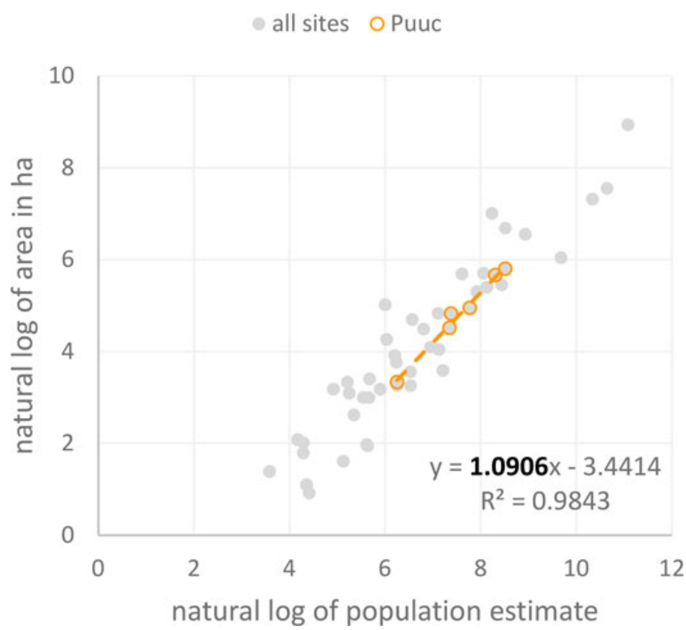

Figure 4. Regression of Puuc sites. (Color online)

(2016). However, the average settlement density for the 455 Lowland Maya sites (excluding the Izapa and Rosario sites) in Smith and colleagues' sample is extremely high: 23,526 people per km^2 (median of 11,739). With such tight packing of people, residences could not have been interspersed with agricultural land. Such abnormally high densities result from the abundance of very small sites in their sample. The eight Lowland Maya sites in their sample with 40 or more houses have a lower average settlement density—2,839 people per km^2—but this density is still too high (five times the exemplar of infield agricultural, Caracol) to accommodate significant infield agriculture. In our Northern Lowland sample, some sites are known to have had kitchen gardens and infield agriculture. But

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because occasional gardens and infields also characterize ancient settlements in regions with sub-linear slopes, and given that all our settlements would have relied heavily on outfield agriculture or trade, infield agriculture is unlikely to be the only cause for a non-sub-linear slope.

Smith and colleagues (2021) invoke occasional events at civic architecture to argue that mixing may still occur in regions that do not exhibit sub-linear slopes. We suggest that consideration be given to how the specific rhythms of daily life and particular spatial layouts affect social interactions in settlements. Regarding daily life, tropical lowlanders spent much time outdoors, putting neighbors in each others' sound- and viewsheds. Being outdoors boosts interactions, particularly in the Northern Lowlands where settlement densities are higher than in the south (Rice and Culbert 1990:19). Ortman and colleagues' (2020) attention to agriculture has the salubrious effect of considering the activities that people pursued and that led them to interact with others. When larger and smaller settlements have about the same population density (the same degree of proximity between residences), as is the case in this sample, people in larger settlements may nevertheless have had more opportunities for social interaction on a daily basis. Proximity alone does not determine the number of interactions: interaction occurs because day-to-day activities get people moving within and beyond the settlement. They crossed paths with others while fetching water, firewood, and other raw materials; visiting kin, affines, and officials; playing ball; exchanging gossip and goods; attending ceremonies; and more. Large Maya sites often had craft specialists and marketplaces that were sometimes not present at small sites, leading to even more opportunities for interaction. Furthermore, because of larger settlement sizes, inhabitants of the big sites needed to move around more (take longer walks outward to milpas, hunting grounds, and raw material sources, and inward to site cores), which increased the possibility of social interaction. Without doubt, relatively dense ancient Maya cities attracted people from less dense rural areas (Hutson 2016). Though Maya people in these denser cities may not have organized their settlements to maximize the cost-benefit relationship of social mixing and travel effort, their lifeways stimulated daily circulation and social interaction.

Regarding spatial layouts, we lack actual circulation patterns for most Maya cities. Nevertheless, movement patterns can sometimes be inferred (see Richards-Risetto and Landau [2014] for least-cost pathways). At Chunchucmil, one of the few Maya sites where stone alignments delimited pathways, such pathways channelled people into and through closely delimited spaces (see also Campiani 2019; Hare et al. 2014), including the spaces of the paths themselves. This increases the potential for social interaction. Chunchucmil also features an abundance of informal open spaces (as opposed to formal ceremonial plazas, of which there were also many), where people could have congregated (Hutson and Solinis Casparius 2022).

In sum, ancient Maya people's daily activities put them on the move, which gave them many chances for social interactions. Spatial layouts amplified these chances, even if the scaling relationship between population and total area differs slightly from expectations. To be clear, we never doubted that higher settlement densities in Maya cities led to advantages not found in rural areas. Yet because these cities thrived even with lower densities than predicted by SST, we suggest that settlement dynamics and social interaction also respond to factors other than residential density.

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Data Availability Statement. All relevant data are in Table 1 and the Supplemental Material.

Competing Interests. The authors declare none.

Supplemental Material. For supplemental material accompanying this article, visit https://doi.org/10.1017/laq.2022.103.
Supplemental Table 1. Site Population Estimates.
Supplemental Text 1. Methodological Details.

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