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Labor, land, and the global dynamics of economic inequality

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Here, we assess the extent to which land use relating to food acquisition (farming, herding, foraging) and associated value regimes shaped past economic inequality. We consider the hypothesis that land-use systems in which production was limited by heritable material wealth (such as land) sustained higher levels of inequality than those limited by (free) human labor. We address this hypothesis using the Global Dynamics of InequalIty (GINI) project database, estimating economic inequalities based on disparities in residential unit area and storage capacity within sites in different world regions and through time. We find that inequality was significantly greater in land-limited than labor-limited regimes, whether based on residence area or storage capacity, though governance could moderate these differences. Increasing inequality with larger residence and/or site size is associated with underlying shifts from labor- to land-limited economies. Transitions from labor- to land-limited regimes also appear to underlie the development of extended political hierarchies. Increases in inequality after cultivation became common in each hemisphere similarly reflect shifts from labor- to land-limited systems. Land-limited systems in the eastern hemisphere, incorporating animal traction, exhibit an upward trend in inequality over time, while a downward trend in the western hemisphere reflects the lower persistence of land-limited regimes based solely on human labor.

land use | agriculture | wealth | residential area | storage

Significance

Land-use systems create “scarcity” and value regimes that shape economic inequality trajectories. Transitions from labor- to land-limited economies occurred in all major world regions and explain a certain amount of variation in wealth inequality, as gauged from disparities in residence size and storage capacity. Equally, this contribution is often moderated by governance, and there is considerable variation in long-term wealth distribution that reflects other factors, including the interaction of land use with political institutions. This study supports the contention that transitions from labor- to land-limited systems, rather than cultivation and/or herding per se, have contributed systematically to the long-term dynamics of economic inequality.

> *The class which has the means of material production at its disposal, consequently also controls the means of mental production, so that the ideas of those who lack the means of mental production are on the whole subject to it. The ruling ideas are nothing more than the ideal expression of the dominant material relations, the dominant material relations grasped as ideas* (1, p. 67)

It would be difficult to overstate the role that material production and its means have played in consequential philosophical discussion of wealth inequality. Here, we consider means of material production and wealth inequality in deep time. A recent conceptual economic model contrasts labor- and land-limited farming systems (2). In the former, labor is more valuable and more “scarce” than land in an economic sense (that is, the relative marginal product of labor is greater than that of land). Labor-limited systems are correspondingly land-abundant. “Labor” here refers to free labor and is equivalent to relational and/or embodied wealth, of limited susceptibility to intergenerational wealth transfer (3). Unfree labor (forced or slave labor) is a form of material wealth, like land. Where land or some other form of material wealth (traction animals, unfree labor) is of greater relative value than (free) labor, the system is land- (or material wealth-) limited. Land-limited systems are thus relatively labor-abundant. While the labor- versus land-limited model was expressed primarily in arable terms (2), it also applies to herding regimes, hunter-gatherer systems, and forms of land use unrelated to food, such as mining.

Here, we use the labor/land model to interrogate the GINI project database (4), framing comparison of land-use regimes for food acquisition (cultivation, herding, and/or foraging practices). We evaluate the hypothesis that systems limited by land or some other form of material susceptible to intergenerational wealth transfer (3) are associated with higher economic inequality than systems limited by (free) labor. We estimate economic or material wealth inequality using Gini coefficients calculated over residential unit areas and storage capacities within sites (4), interpreting these as proxies for wealth (including income—see ref. 5). We acknowledge that using residential unit sizes and storage capacities as proxies for wealth inequality presents clear limitations. These proxies constrain our focus to sites and phases where sufficient evidence is preserved and to comparisons among residential units. There may also be confounding factors, such as building materials and their preservation

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(6), and variation in storage practices (7). The Gini coefficient values considered here are all calculated at the site(/phase) level, holding confounding variables (such as building materials, storage technologies, and environmental parameters) relatively constant. As discussed in ref. 4, we anticipate that Gini coefficient estimates of wealth inequality based on residential unit sizes tend to underestimate true wealth inequality. Our aim here is to assess whether the hypothesized contrast in wealth inequality (as estimated from residential unit size and/or storage capacity disparities) is observed between labor- versus land-limited systems, despite potential confounding factors.

The GINI project database encompasses regions and land-use regimes far more diverse than the western Eurasian cases considered in ref. 2. Fig. 1 presents an elaborated version of the labor/land model, encompassing world regions without traction. While labor-limited systems ("gardens") are similar whether or not (unspecialized) animal traction is involved, land-limited systems vary in agroecological and political terms depending on the role of specialized animal traction. Extensive systems with specialized traction entail lower inputs and yields per unit area of land than labor-limited systems and achieve large-scale aggregate production through radical expansion (Fig. 1 *A* and *D*). The role of landesque investment (e.g., irrigation systems) depends on the ecological setting; expansive cropping systems in Chalcolithic-Bronze Age southern Mesopotamia, for example, were based on irrigated arable land, while extensive farming in northern Mesopotamia was rain-fed and facilitated by radial field systems (8–11). Land-limited systems with specialized traction require modest human labor year-round but additional seasonal labor at harvest time (12), whether landless workers or migrants from regions with earlier/later harvesting or with other subsistence strategies.

In the absence of traction, land-limited farming depends on large-scale landesque investment to increase the supply of arable land (e.g., terracing, drainage, irrigation) through mobilization of (abundant) human labor; labor here may be accessible through nucleation in urban centers, for example, and/or unfree/forced/displaced (Fig. 1 *B* and *E*). Labor intensity (per unit area) may be high in both labor- and land-limited systems without traction, which differ instead in the nature/scale of landesque investment. Finally, and irrespective of traction, extreme land-limited scenarios can arise where the physical supply of land is severely restricted, as on small islands, though even here systems may be labor-limited, as in early stages of Polynesian colonization (13).

The labor/land model is distinct from frameworks based on natural resource distribution (14), environmental circumscription (15) and hoe versus plough farming (16), since the assessment of limiting factors is not reducible to natural productivity, physical setting, or technology per se (see also refs. 17–20). The labor/land model also differs from "intensification" [that is, increasing labor inputs per unit area, (21–23)] since the latter does not capture the relevant contrasts in terms of the means of production and their heritability. For example, high inputs per unit area occur (on a small scale) in labor-limited systems, while expansive traction-based systems entail lower inputs per unit area, and expansive systems without traction require high inputs. Rather, the identification of limiting factors requires archaeological, ethnographic, and/or documentary evidence of land use practices to assess the relative value and "scarcity" of labor versus land, albeit shaped by these other considerations.

In regions with traction, where land-use regimes differ primarily in terms of areal inputs, archaeobotanical and zoological data offer the most direct routes of inference, as in western Asia and Europe (2). Archaeological evidence shows that cattle traction was already part of Neolithization in these regions and that it could promote either intensive or extensive systems, depending on sociopolitical conditions (12, 24–27). Direct botanical and/or faunal evidence, including cattle bone pathologies indicative of traction (28, 29), may be underlined by documentary sources detailing, for example, loans of oxen by elite households to share-croppers, as in Bronze Age Mesopotamia (30–32) and Mycenaean Greece (33).

In regions without traction, the most direct archaeological evidence for labor- versus land-limited systems is the nature and scale of landesque investment. There are diverse and spectacular cases of large-scale landesque investment in Mesoamerica, for example, including Aztec chinampas (34–37) and Maya terraced, irrigated,

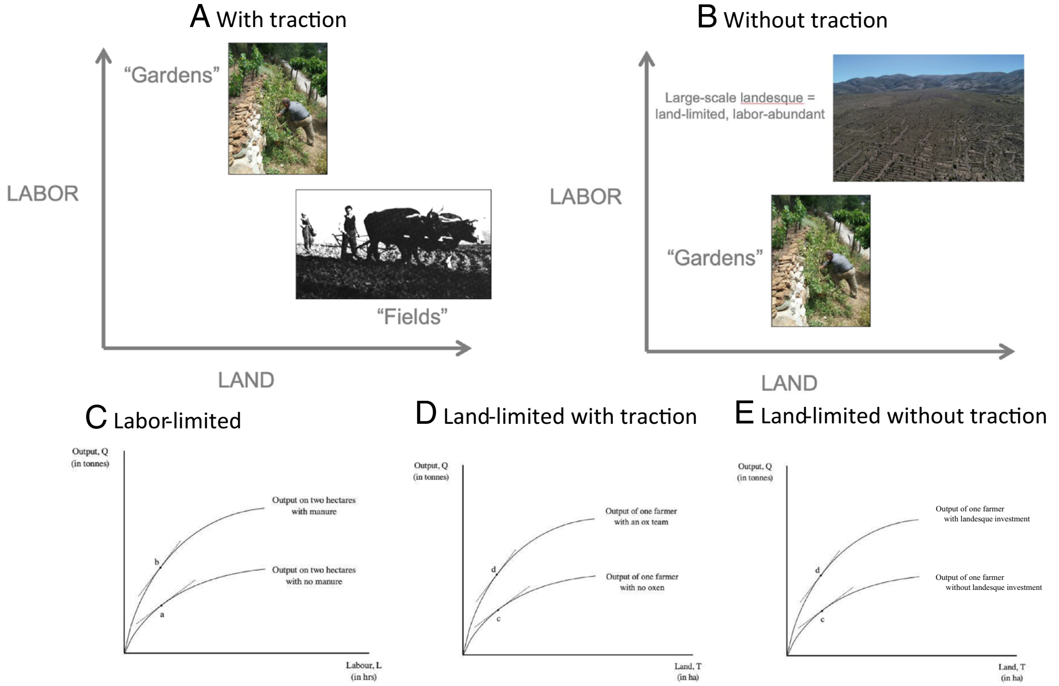


Fig. 1. Schematic visualization of labor- and land-limited agricultural systems (*A*) with traction and (*B*) without traction; effects of (*C*) manuring on output with a given amount of land (labor-limited) and of (*D*) ox-traction and (*E*) landesque investment with a given amount of labor (land-limited).

and/or drained landscapes (38–40). In South America, there are pre-Inka examples in the coastal zone of the central Andes (41, 42) as well as Inka terrace/water conservation systems (43–45). In some regions, large-scale land-limited systems of landesque investment can be contrasted with small, family-scale systems: in the southern Andes, for example, Inka terraced field systems of monumental stone walls contrast with family-scale terraces of fieldstones in pre- and post-Inka periods in the Intersalar region of southern highland Bolivia (46). The Inka case also offers an example informed by documentary sources, detailing the *mitmaqkuna* (or *mitmaq*) system of forced/displaced (agricultural and military) labor (44, 45, 47–49). Eastern hemisphere examples of landesque investment at varying scales include irrigation works (50, 51), terracing (52, 53), and field systems (54–56) in varying combinations, including bunded rice paddies (57, 58).

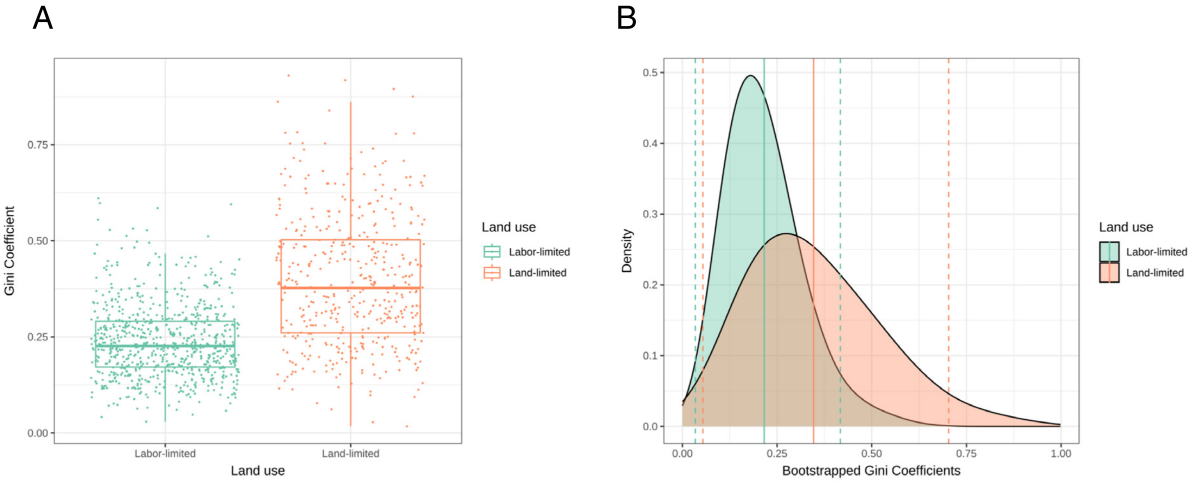
Other sources of evidence relevant to the classification of cases in the GINI project database are ethnographies/ethnohistories and spatial/GIS-based approaches. The former include evidence for labor-limited systems in Melanesia, with notable emphasis on the importance of "strength" in numbers for defense as well as land use (59), and wealth-in-people perspectives in sub-Saharan Africa (60, 61). Spatial approaches to (physical) land scarcity include simulation modeling of farming niches in the Indus River Basin and American Southwest to gauge diachronic change in land pressure (62, 63).

Using land-use classifications of 1,267 sites (Dataset S1) in the GINI project database (4), we consider the hypothesis that land-limited systems tend to sustain higher levels of economic inequality than labor-limited systems. For the most part, classifications simply distinguished "labor-limited" and "land-limited", but there are exceptions; in Europe, sufficient information was available to attempt a four-point ordinal scale from labor- to land-limited, while in other regions without traction and lacking extensive landesque investment evidence, an intermediate category of "more land-limited" resulted in a three-point ordinal scale (*SI Appendix*). In the analyses that follow, we mostly use the two-point scale (labor- or land-limited, the database field [Twoscale] in ref. 4).

In testing the heuristic model, we aim not only to gauge its general relevance but also to identify exceptions, where the model's expectations are overturned, and possible factors involved. A second aim is to assess how far mean residential unit area, total site area, maximum residence count, and related site-level quantitative variables corroborate labor- versus land-limited distinctions based on the independent lines of evidence summarized above, thus providing a means of estimating gradations of labor- versus land-limitation. Third, we investigate how labor- versus land-limited regimes relate to polity structure and contribute to relationships between site hierarchies and housing inequality. Fourth, we compare the eastern and western hemispheres in terms of the emergence of labor- and land-limited systems through time. The absence of traction animals in the western hemisphere allows us to consider the hypothesis that land-limited systems based exclusively on mobilization of human labor were less persistent than those based (at least partly) on animal traction.

Results

Fig. 2 summarizes the comparison of site-level Gini coefficients for labor- and land-limited groups based on residential unit areas. Labor-limited regimes tend to be associated with lower Gini coefficients than land-limited ones, though there is considerable overlap (Fig. 2 *A* and *B*). These differences are statistically significant taking the uncertainty of Gini coefficient estimates into account (Fig. 2*C*). We observe similar differences between labor- and



C

	Number of observations		Gini coefficient		
Region	**Labor Limited**	**Land Limited**	**Average Gini (Labor Limited)**	**Average Gini (Land Limited)**	**Perm p-value**
Global	734	442	0.239	0.394	<0.001
Africa	13	2	0.261	0.543	<0.001
North America	276	2	0.231	0.376	0.035
Asia	212	53	0.247	0.417	<0.001
Europe	191	194	0.237	0.349	<0.001
Oceania	6	18	0.259	0.464	<0.001
Mesoamerica	1	154	0.278	0.423	0.097
South America	35	19	0.239	0.488	<0.001

Fig. 2. Comparison of Gini coefficients based on residential unit areas for sites classified as labor-limited (n = 734) and land-limited (n = 442): (*A*) boxplots; (*B*) probability density functions, including uncertainty of the bootstrapped Gini coefficients, where solid lines show the means and dashed lines the 95% CI; (*C*) permutation tests at the global and [BigRegion] level.

land-limited regimes in all major world regions (Fig. 2*C*). Labor- and land-limited sites can be compared at smaller regional and subregional scales where both are well represented (*SI Appendix*, Figs. S4–S7 and Tables S2–S4). Similar contrasts occur in the southern Andes (*SI Appendix*, Fig. S6*A* and Table S3), for example, and in south-east Europe and Britain (*SI Appendix*, Fig. S4*A* and Table S2). Within western Asia, Anatolia and Mesopotamia exhibit the expected contrasts, while in the Levant the two groups are similar, though land-limited Gini coefficients are more variable (*SI Appendix*, Fig. S7*A* and Table S4). In North America, an intermediate land-use category (more land-limited) coincides with a slight uplift in Gini coefficients (*SI Appendix*, Fig. S3*A*), whereas in East Asia it is associated with slightly higher Gini coefficients in Japan but not in Shandong, China (*SI Appendix*, Fig. S7*A*).

We also compared site-level Gini coefficients of labor- and land-limited systems based on storage areas or proportions (*SI Appendix*, Figs. S10–S14) in order to isolate patterning most directly linked with land use (2, 64). Storage data are far patchier than residential unit areas across the GINI project database; nevertheless, the Gini coefficients of labor-limited sites are significantly lower than those of land-limited sites, whether based on storage areas or proportions (*SI Appendix*, Figs. S10 and S11). Similar contrasts, as well as exceptions, are apparent at smaller regional scales (*SI Appendix*, Figs. S12–S14).

We considered the overall impact of governance (collective versus autocratic, [PolitGov]) on the labor-/land-limited contrast (*SI Appendix*, Figs. S15–S18). While there is no pervasive effect globally, at a regional level, collective governance appears to moderate the contrast in western Asia, South Asia, Europe, and South America, where collective land-limited Gini coefficients are lower than noncollective. In Mesoamerica and North America, comparison of collective and noncollective land-limited cases shows no difference or the opposite trend.

Fig. 3 shows relationships between residential unit and/or site size with Gini coefficients, coded by labor- versus land-limited systems and major world regions. Linear regressions are performed using the ordinary least squares method, with interaction terms to assess relationships between Gini coefficients and measures of size for labor- and land-limited groups separately (see also *SI Appendix*, Tables S7–S10). We make several observations. First, there is a shift from labor- to land-limited economies with increasing residential unit size and site size: labor-limited sites tend to have few/small residences, while land-limited sites tend to have many/large ones. Though there is overlap, settlement morphology appears to reflect gradations of labor versus land limitation. This observation is not surprising but does provide indirect support for land-use classifications. Second, with increasing residential unit and/or site size, land-limited sites tend to become significantly more unequal, whereas labor-limited sites disappear at larger residence- and site-size scales and show weaker, insignificant, or even negative relationships between size and inequality. The implication is that increases in productivity with scale (5) are associated with an underlying shift from labor- to land-limited regimes. Put another way, larger residential unit size does not necessarily translate into greater inequality; it depends on the nature of the labor- versus land-limited economy. The relationship between site size and the Gini coefficient also helps to explain why some land-limited sites have relatively low values, including sites in the Bronze

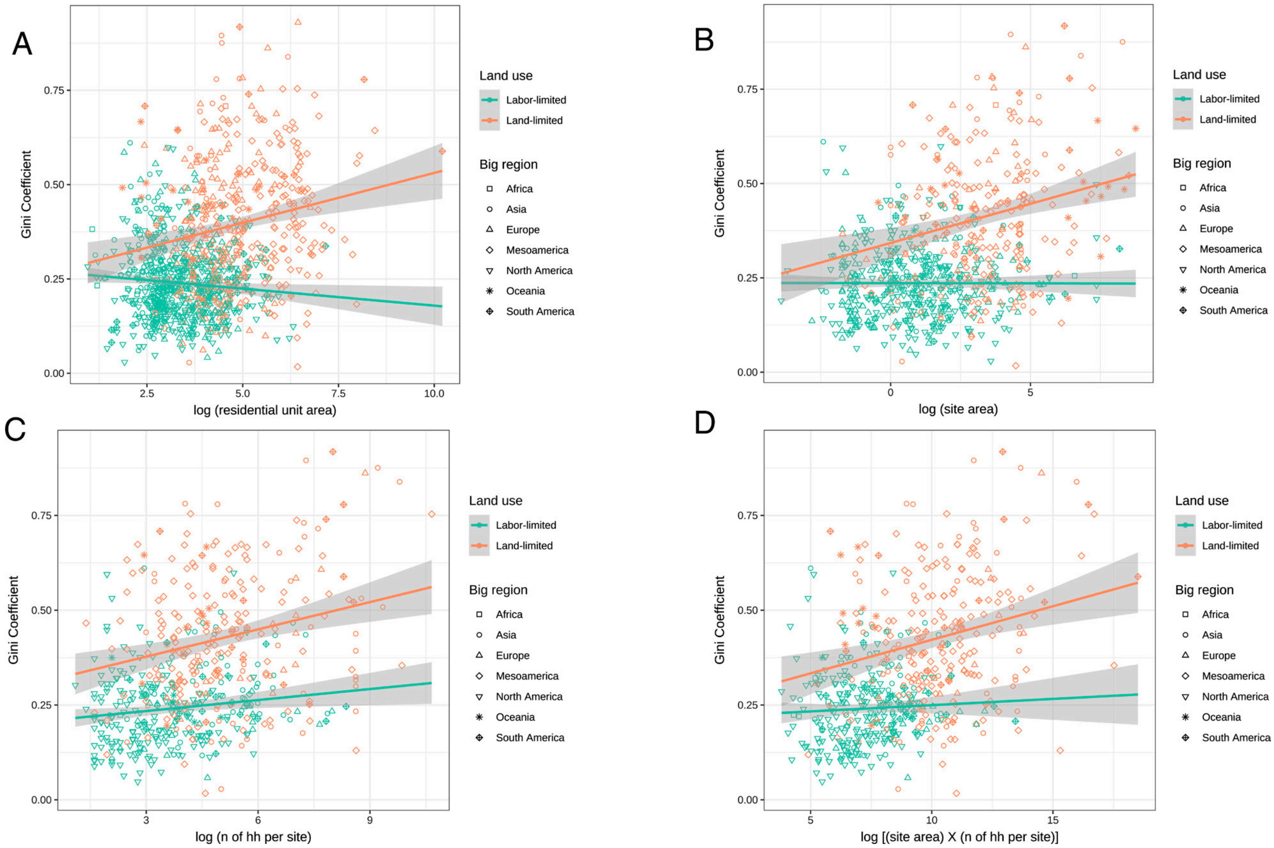
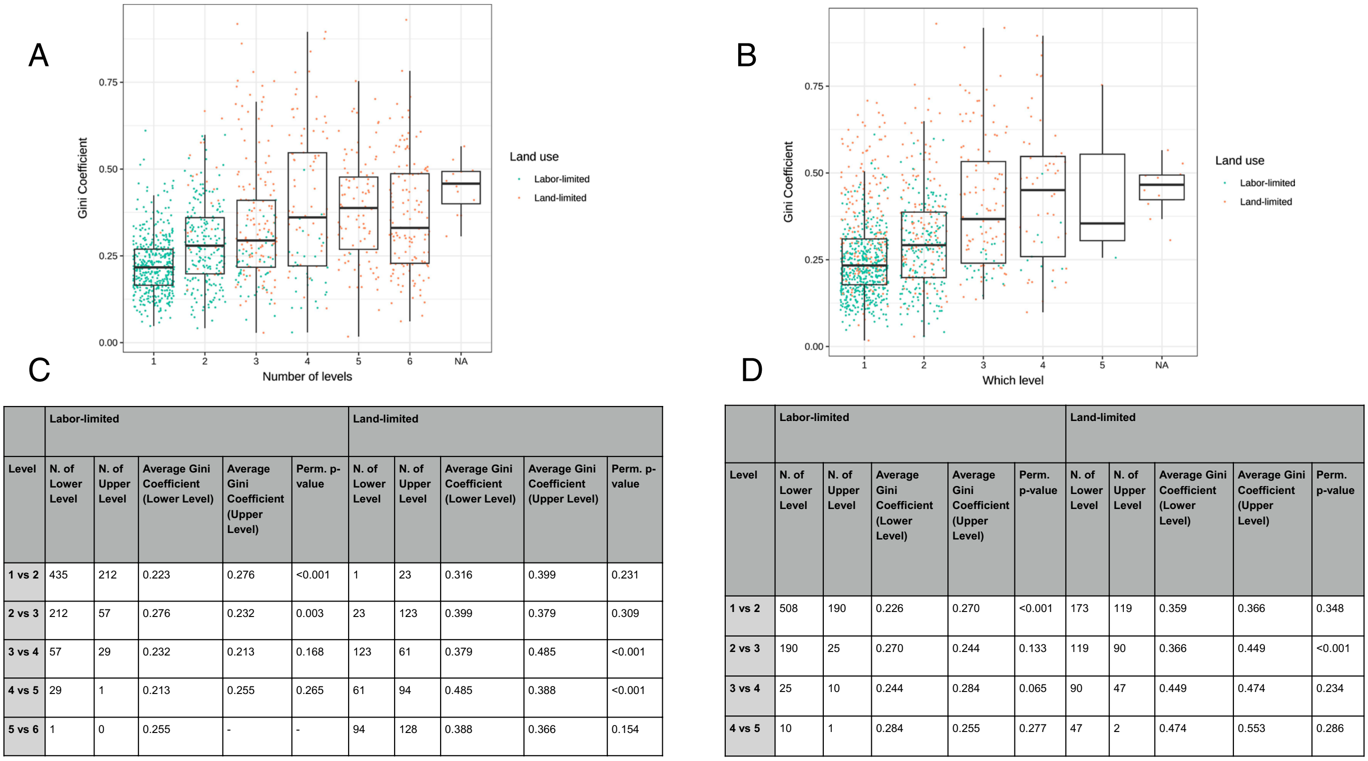


Fig. 3. Relationships between measures of residential unit and/or site size and the Gini coefficient, with data points coded by labor- versus land-limited site classifications and by world region: (*A*) mean log residential unit area (n = 734 labor-limited, n = 442 land-limited), (*B*) mean log site area (n = 470 labor-limited, n = 262 land-limited), (*C*) log maximum residence count (n = 289 labor-limited, n = 246 land-limited), and (*D*) log (residential unit area × site area) (n = 289 labor-limited, n = 246 land-limited). The lines show the estimated linear models of the Gini coefficients on each measure of residential unit and/or site area by land use and the interaction term between the two variables. The gray areas show the 95% CI of the estimated linear models. See *SI Appendix* for the regression results and further robustness checks accounting for possible confounding factors.

Age-Iron Age Levant which are all smaller than 10 ha and likely part of larger polities (see below). Third, major world regions vary in residential unit size (5), such that those in Oceania tend to be small, for example, while those in the Americas tend to be large. Additional linear regressions (*SI Appendix*, Tables S7–S10) show that among land-limited sites, there is a significant increase in inequality with residential unit and/or site size also when controlling for hemisphere and time.

Fig. 4 shows the distribution of labor- and land-limited sites in terms of the number of levels in site hierarchies, the database variable [NOfLevels], and the level at which individual sites sit, [WhichLevel]. There is a clear trend from labor-limited economies in site hierarchies with 1 to 2 levels, to land-limited economies in site hierarchies with >2 levels (Fig. 4*A*). Similarly, labor-limited sites dominate the lower levels of site hierarchies, while land-limited sites dominate the upper levels (Fig. 4*B*). The implication is that increases in Gini coefficients with [NOfLevels] and [WhichLevel] (65) reflect shifts from labor- to land-limited regimes. There are statistically significant increases in site Gini coefficients at lower values of [NOfLevels] for labor-limited sites, and at higher values of [NOfLevels] for land-limited sites (Fig. 4*C*); similarly, labor-limited sites show a significant increase in Gini coefficients from [WhichLevel] 1 to 2, while land-limited sites show a significant increase for [WhichLevel] 2 to 3 (Fig. 4*D*). These results suggest that flows of surplus sustain site hierarchies in both labor- and land-limited economies but that these flows are more extended in the latter. This makes sense given “normal surplus” (66); labor- and land-limited economies differ in the scale of surplus. Labor-limited sites at relatively high [WhichLevel] (≥3) include sites in Chalcolithic (Trypillia) Ukraine and Moldova, Late Neolithic Shandong, medieval Zimbabwe, and the Southeastern United States (*c.* 900 to 1300 AD) including Cahokia. Among land-limited sites, those at low [WhichLevel] and with a tendency to relatively low Gini coefficients may be producers for wider polities; these include, for example, a number of the Bronze Age-Iron Age Levantine sites of restricted size noted above. Those at [WhichLevel] ≥3 with relatively low Gini coefficients (<0.40) are more striking as exceptions. These include urban centers such as Monte Albán, Teotihuacan, and some Aztec sites (such as Tlaxcallan, Yautepec, and Jilotzingo) in Mexico, Mohenjo-daro in the Indus River Basin, classical sites such as Athens, Olynthus, and Thorikos in Greece and Roman Wroxeter, Cirencester, and Silchester in Britain. Of these, Teotihuacan (67–69), Tlaxcallan (70), Mohenjo-daro (71), Athens, and other classical sites (70) are associated with collective governance.

Finally, we consider the occurrence of labor- or land-limited sites since cultivation became common (ΔCult) in the western and eastern hemispheres (Fig. 5). In both hemispheres, Gini coefficients for labor-limited sites remain low, including after cultivation becomes locally common, hovering around values of *c.* 0.25 (Fig. 5 *B* and *D*). There is no significant increase in Gini coefficients with Δyears when controlling for land-use regime and hemisphere (*SI Appendix*, Table S13). Labor-limited economies reappear in both hemispheres after *c.* 3,000 Δyears (eastern hemisphere examples are early Saxon England and medieval Zimbabwe; western hemisphere examples include Andean and Postclassic Maya sites) but do not persist in the eastern hemisphere beyond *c.* 5,500 Δyears. As a result of these trends, Gini coefficients show an overall downward trend in the western hemisphere and an upward trend in the eastern (Fig. 5 *A* and *C*). Linear regression analyses performed using the ordinary least squares method (*SI Appendix*, Tables S11 and S12) confirm that the western hemisphere followed an inverted U-shaped time trend, while the eastern hemisphere exhibits a positive linear trend over Δyears. These observations support the hypothesis that land-limited systems based purely on human labor mobilization, as in the western



	Labor-limited					Land-limited				
Level	N. of Lower Level	N. of Upper Level	Average Gini Coefficient (Lower Level)	Average Gini Coefficient (Upper Level)	Perm. p-value	N. of Lower Level	N. of Upper Level	Average Gini Coefficient (Lower Level)	Average Gini Coefficient (Upper Level)	Perm. p-value
1 vs 2	435	212	0.223	0.276	<0.001	1	23	0.316	0.399	0.231
2 vs 3	212	57	0.276	0.232	0.003	23	123	0.399	0.379	0.309
3 vs 4	57	29	0.232	0.213	0.168	123	61	0.379	0.485	<0.001
4 vs 5	29	1	0.213	0.255	0.265	61	94	0.485	0.388	<0.001
5 vs 6	1	0	0.255	-	-	94	128	0.388	0.366	0.154

	Labor-limited					Land-limited				
Level	N. of Lower Level	N. of Upper Level	Average Gini Coefficient (Lower Level)	Average Gini Coefficient (Upper Level)	Perm. p-value	N. of Lower Level	N. of Upper Level	Average Gini Coefficient (Lower Level)	Average Gini Coefficient (Upper Level)	Perm. p-value
1 vs 2	508	190	0.226	0.270	<0.001	173	119	0.359	0.366	0.348
2 vs 3	190	25	0.270	0.244	0.133	119	90	0.366	0.449	<0.001
3 vs 4	25	10	0.244	0.284	0.065	90	47	0.449	0.474	0.234
4 vs 5	10	1	0.284	0.255	0.277	47	2	0.474	0.553	0.286

Fig. 4. Relationships between site hierarchies and Gini coefficients: (*A*) boxplot showing labor- (n = 734) and land-limited (n = 430) sites per [NOfLevels] (the number of levels in the site’s hierarchy); (*B*) boxplot showing labor- (n = 734) and land-limited (n = 431) sites per [WhichLevel] (the level at which the site sits); (*C*) [NOfLevels] permutation tests; and (*D*) [WhichLevel] permutation tests.

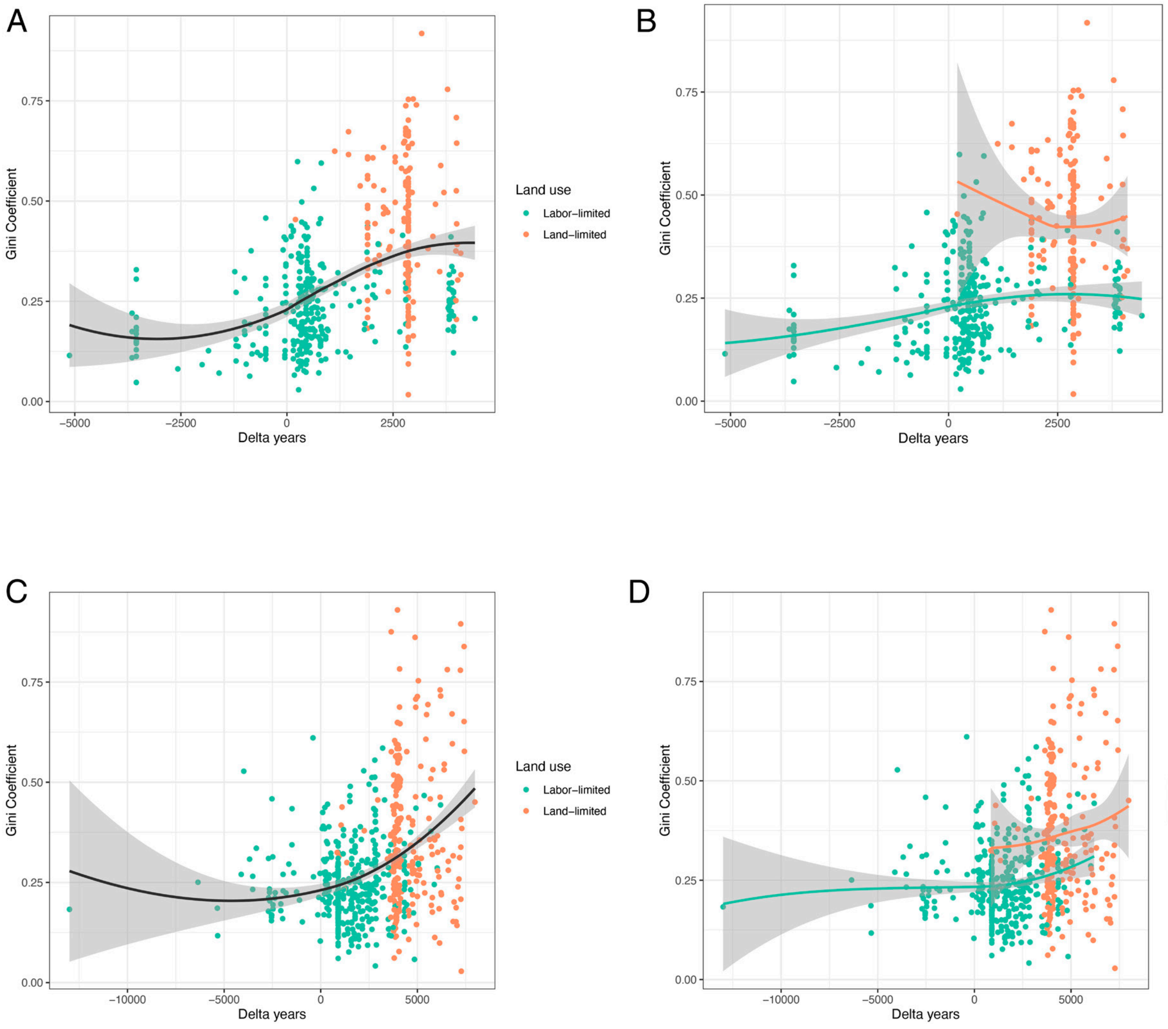


Fig. 5. Relationships between site ΔCult dates (Δyears) and Gini coefficients by hemisphere, with data points coded by labor- versus land-limited: (*A*) the western hemisphere (n = 487) with the LOESS trend line; (*B*) the western hemisphere with the LOESS trend lines per land-use regime (n = 312 labor-limited and n = 175 land-limited); (*C*) the eastern hemisphere with LOESS trend line (n = 665); and (*D*) the eastern hemisphere with LOESS trend lines per land-use regime (n = 416 labor-limited and n = 249 land-limited). Oceania, which spans both hemispheres, is excluded.

hemisphere, are less persistent than land-limited systems based (at least partly) on traction, as in the eastern hemisphere.

Discussion

Based on our analyses, disparities in residential unit area and storage capacity are shaped by associated land-use regimes and the relative scarcity and value of labor versus land. Despite confounding factors, we find significant differences in these proxies of material wealth inequality between (relatively equal) labor- and (relatively unequal) land-limited settlements in diverse settings, including world regions without traction animals.

Measures of social scale including residential unit area, settlement area, and combinations of these variables are positively correlated with wealth inequality in land-limited systems but not in labor-limited ones. The underlying nature of the economy determines these relationships between scale and inequality (5). Although there are many exceptions, there is a tendency for large-scale settlements to be land-limited, underpinning a general link between land-limited inequality dynamics and urbanization (72).

Labor- to land-limited contrasts also appear to underlie differences among sites in polity structure, the development of extended site hierarchies and the social advantages they harbor for apex sites (65). Our findings highlight the importance of social scale and coordinated effort for increasing production, and of signaling success through material culture such as residential unit size (20). They are also consistent with the roles of institutional change (17) and demographic expansion, and with conceptual modeling that predicts an increase in population size and in the variance of well-being following shifts to more productive forms of subsistence farming (23). Furthermore, the nature of economies appears to relate to different patterns of fortification in the GINI database, such that earlier fortified sites tend to be low in wealth inequality and to focus on the protection of people in labor-limited systems, while later fortification of high-inequality sites reflects a shift to safeguarding of material wealth in land-limited systems (73).

However, the heuristic labor/land model also has clear limitations and can only represent one set of linked factors that caused residential disparities. Significant positive correlations between residential unit or settlement size and Gini coefficients among land-limited sites, for example, explain around 30% of variation (*SI Appendix*, Tables S7–S10), leaving the majority unexplained. Some labor-limited polities developed considerable site hierarchies (Chalcolithic/Trypillia Ukraine and Moldova, Late Neolithic Shandong, medieval Zimbabwe, and the Southeastern United States (*c.* 900 to 1300 AD) including Cahokia), while some land-limited polities exhibit limited housing disparities, even in large urban centers such as Teotihuacan and Mohenjo-daro.

Collective governance is one institutional mechanism that appears to limit levels of economic inequality in these cases.

A complementary focus for future analysis would be to assess the residential patterns of those directly engaged in food acquisition in labor- and land-limited systems, including longitudinal studies at smaller regional scales. This finer-grained assessment would make it possible to explore other dimensions of how economic inequalities develop and persist, including degrees of separation between farmers/producers, the products of their labor and the wider population.

Our results also have broad implications for the relative stability of high economic inequalities fueled by land-limited regimes. A broad hemispherical pattern is that land-limited systems based solely on human labor mobilization, as in the western hemisphere, are less stable and cumulative than those incorporating animal traction, as in the eastern hemisphere. Further work at smaller geographical scales would enable the investigation of differential stability of land-limited regimes within major world regions.

Finally, our results shed light on the possible routes by which land-limited systems can emerge, building on the scenario of farmers with and without oxen (2). Our model (Fig. 1) encompasses worlds without traction, where land becomes more "valuable" to households with access to seasonal human labor for developing landesque investment and increasing the effective supply of land. Initially that access may depend on cooperative arrangements among households and hence on relational or network wealth (3), potentially translating into differential land ownership through unequal production between households and the accumulation of debts (20, 74). Such a scenario is also relevant to expansive systems with traction that depend upon seasonal labor at harvest time (12) and is consistent with the view that land-limited regimes could coevolve with inequality (75). A further scenario for land-limited systems dependent on landesque investment is that such landscapes of congealed labor (76, p. 59) are susceptible to being co-opted and elaborated through force, as inferred for the Chimu and Inka polities in the Andes (41, 42, 44, 45, 47–49).

Materials and Methods

All of the archaeological data on residential unit area, storage capacity, and measures of site area or size derive from the GINI project database (4). All of the Gini coefficient values in this paper were calculated at the site level. For residential area data, we calculated Gini coefficients for all sites (n = 1,176) with at least five penecontemporaneous residential units (SiteGiniLevel.csv). We also calculated a second set of site-level Gini coefficients for sites with at least two penecontemporaneous residential units (n = 181) including storage capacity data (storage area per residential unit or storage proportion per residential unit, depending on availability) (SiteGiniStor.csv). An R script is provided (Bogaard_2024-00694.txt) to reproduce all graphs and tables in the main text and *SI Appendix*.

For all sites with calculated Gini coefficients based on residential unit area and/or storage capacity data (n = 1,267), we provide citations documenting the basis of their classification as labor- versus land-limited [the variable [Twoscale] in the GINI project database, (4)], or on a 3- or 4-point ordinal scale [the variables [Threescale] and [Fourscale], respectively, in the GINI database, (4)] (Dataset S1). We also indicate the type(s) of evidence on which this classification is based (bioarchaeology, landesque (investment)/spatial assessment, administration (texts), and/or ethnography/ethnohistory). In some cases, this evidence derives from the site itself, while in others site-based evidence aligns the site with land-use regimes documented more widely in the relevant region and period.

In *SI Appendix*, we also adjust all Gini coefficients for comparability to account for biases arising from differential sample size and population scale (64). We show that the contrasts between labor- and land-limited sites presented here are robust to these adjustments.

Data, Materials, and Software Availability. All scripts and data for replicating the analyses and reproducing main and supplementary figures are provided in this tDAR Project (https://core.tdar.org/project/496853/the-global-dynamics-of-inequality-gini-project) (77).

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