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Surf & Turf: The role of intensification and surplus production in the development of social complexity in coastal vs terrestrial habitats

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ABSTRACT

Social complexity in coastal and terrestrial environments both emerge as forms of subsistence intensification on previous foraging patterns but take different trajectories because of differences in the spatial and temporal structure and density of harvestable biomass between the two ecozones. Norms and values surrounding standards of living motivate households to intensify production above what is needed for mere survival (i.e., surplus), which in turn has the effect of providing a buffer against unpredictable shortfalls and longer-term population-resource imbalances caused by population growth. Economies of scale introduced by increasing labor group size and differentiation as well as technology fund the production and consumption of surplus and drive the emergence of social complexity among foragers and cultivators alike.

1. Intensification, productivity and efficiency

V. Gordon Childe (1950; 1951) gave a 20th century voice to Rousseau's (1985 [1782]) old idea that crop domestication entailed a kind of Faustian bargain with nature freeing humanity from a life of wandering and chronic privation, but paradoxically rendering them susceptible to exploitation by allowing farmers to produce large, storable surpluses that could be extracted as tribute or rent by an emergent ruling class. In Childe's view, surplus funded "leisure time," defined specifically as time not spent on necessary food gathering or production, and which allowed for the development of art, architecture, craft specialization, the sciences, as well as secular and religious institutions structuring social complexity. Partly because of Childe's theorizing on the role of surplus production in the origins of domestication and urbanism, crop agriculture came to be the *sine qua non* for the development of world civilizations. Yet, many of the accepted archaeological markers of social complexity—including elaborate mortuary programs, evidence for feasting and the production of prestige goods indicative of embedded craft specialists and even monumental architecture have been present since the Late Pleistocene (Boyd & Richerson, 2022; Singh & Glowacki, 2022; Graeber & Wengrow, 2021), indicating not all foragers followed the "Zen road to affluence" (Sahlins, 1972).

Questions about how, why and when foragers develop social complexity in the absence of crop agriculture have become frequent over the past few decades (Ames, 2003; Arnold, 1993; Fitzhugh, 2001; Grier et al. 2006; Kennett, 2005; Marquet et al., 2012; Petersen & Meiklejohn, 2007; Stutz, 2020). As Arnold et al. (2016) pointed out, part of the problem is the continuing influence of the subsistence stage concept in explaining the emergence of social complexity. We argue here instead it is the labor coordination requirements surrounding subsistence intensification, rather than agricultural production per se, that allows more efficient production of surplus and drives the development of social complexity. We employ an expanded version of Bettinger & Baumhoff's (1982) Traveler-Processor continuum as a starting point and show how this continuum plays out differently in aquatic and terrestrial ecosystems (Fig. 1).

In terrestrial environments, forager intensification converges on areas with high levels of primary harvestable productivity (PHP). Such habitats also support large and diverse populations of animal prey. Human foragers exploit and deplete animal prey first because they are generally ranked higher in the diet. As human population density increases and foragers exploit and deplete higher ranked animals first, lower-ranked fallback PHP allows foragers to maintain high population densities despite prey depletion. This results in heavy intensification on plant resources, which can eventually culminate in crop agriculture. The intensive collecting and cultivation of seed crops eventually becomes productive enough that small household-level labor groups harvest, process and store sufficient amounts to support them until the next

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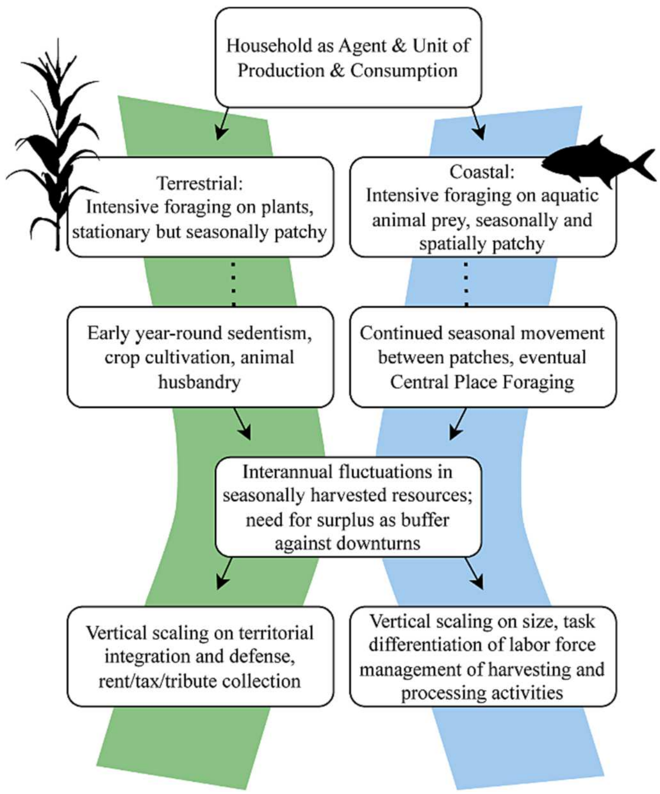

Fig. 1. Flow chart outlining an expanded and generalized version of Bettinger & Baumhoff's Traveler-Processor model of forager intensification to terrestrial and coastal environments.

harvest. Surplus production can be maximized by bundling many like units of land production, incentivizing households to form larger corporate communities capable of defending land and demonstrating a group's ability to produce and consume resources. Thus, agricultural societies scale on social integration of land tenure systems (Adler, 1996), tribute or rent flow (Scott, 1976, and group territorial defense (Crabtree et al., 2017).

In contrast, marine, neritic, estuarine and riverine environments are dominated by dense, often transitory populations of aquatic seasonally migratory animal prey. Prodigious nutrient-dense harvests are frequently possible but must be carried during brief windows of time, often at spatially specific access points that must be shared or defended, and require large, task-differentiated labor groups and labor-intensive technology to harvest, process and store the catch. Prey population booms and busts can cause severe interannual fluctuations and stormy weather that affect availability or access to harvest at any given patch. Hence, coastal forager group size and complexity scales on labor force coordination and diversification within large households and villages (Ames, 2003; Arnold, 1993,1996,2006; Hayden, 1994; Stutz, 2020).

In both contexts, we argue that the underlying adaptive value of subsistence intensification and surplus production is that it raises household production above what is required for mere survival, thus providing a buffer against unpredictable shortfalls as well as longer term population-resource imbalances caused by population growth (Bogaard, 2017; Halstead, 1989; Winterhalder et al., 2015; Wood, 1998,2020). Surplus production funds the conspicuous consumption (Veblen, 1973 [1899]) that serves as an *index*, or honest signal (Mendoza Straffon, 2021), of the household's resource security, and its viability as a unit of production and consumption in the context of the moral, spiritual and material standards of living in the community. This pattern of intra-community emulation of the form and content of surplus consumption and ritual display can scale up to the regional and interregional level, producing what Freeman et al. (2018) call "synchronization of energy consumption" across polities and entire interaction spheres or regions.

Our approach assumes the relevant individual interacting agents in social groups are households (Freeman et al., 2015:113) rather than individual foragers or farmers. This allows the scaling effects of division of labor and technology to be incorporated into the subsistence and production decisions made by larger social groups. The first economies of scale emerged with the earliest hearth-focused family groups organized around the division of labor, fire technology for warmth, light, cooking, tool manufacture and the controlled burning of habitat that emerged during the Middle to Upper Paleolithic transition (Clark et al., 2022; Kuhn & Stiner, 2019; Stiner & Kuhn, 2016). Shennan (2011) has argued that with increased sedentism and importance of fixed resources, strategies aimed at maintaining and conserving the household's means of production and reproduction as well as transferring it across generations constitute a form of cultural niche construction. Such strategies would include inheritance strategies, descent rules, and mythical charters, among others. This bundle of material and conceptual strategies constitutes an institutional template effectively describing the Levi-Straussian House (Levi-Strauss, 1976; Heitman, 2007; Marshall, 2006).

One could think of the household as the *ur*-institution: the fundamental building block of social complexity. Foragers have had complex societies from their beginnings, scaling horizontally (Slingerland 2023) over tens of thousands of square kilometers in small-world networks (Watts & Strogatz, 1998) in which clustered local interactions are embedded within much larger, but sparsely connected multilevel metapopulations (Boyd & Richerson, 2022; Hamilton, 2022:20; Hitchock & Ebert 2011; Graeber & Wengrow, 2021). With intensification, these wide-ranging networks persist as regional traditions of long-distance trade. At the same time, foragers in local patches with higher density of harvestable biomass increase in population, intensify energy production and scale up consumption– stack and integrate vertically–in self-similar institutional structures (Hamilton et al., 2007). In this way, they become the familiar, hierarchical structures associated with polities and urban settlements.

1.1. *Boserupian intensification as cultural niche construction*

Subsistence intensification (Boserup, 1965; Brookfield, 1972) is defined as the application of additional time and energy (work) into a subsistence activity (e.g., locating, harvesting, cultivating, processing) within a given unit of resource space with the aim of increasing total production within that area. Intensification results in the decline of individual energetic efficiency of per capita production and is repaid by a gain in the spatial efficiency of the total harvest rate (productivity) per unit area. Intensification trades individual work efficiency for *spatial efficiency*—it produces more food on less space through the application of more labor.

Morgan (2014: 198-199) argued that not all intensification entails declining efficiency and that division of labor and technological innovation can work together to create economies of scale. However, the production efficiencies inherent in economies of scale are about cost-per-unit production efficiency, not individual work efficiency. Coordinated collective action and division of labor allows people to achieve levels of production *that would be impossible if they had to do all the work alone* (Alvard & Nolin, 2002). For example, capital investments in technology can result in qualitative increases in return and increased efficiency if there are requisite economies of scale, such as a larger labor force or division of labor, present to offset the costs of the initial investment (Morgan, 2014: 199; Bettinger et al., 2006; Ugan et al., 2003). This is also referred to in population ecology as the "Allee effect" referring to the *synergistic mutualism* that makes the combined effect of individuals' working together greater than the sum of their individual efforts, provided others cooperate too (Alvard & Nolin, 2002; Kennett et al., 2006).

Subsistence intensification *is* more work and yet it is the central fact that imbues human history with its direction toward increasing complexity. Why do people do it? Below we argue the desire to conform to moral, spiritual and material standards of living in the community (i.e., prestige) motivates households and their members to intensify production above what is needed for mere survival. Surplus production in turn provides a buffer against unforeseen interannual shortfalls; households perennially *overproduce* in the present to ensure they can meet minimum needs in the event of temporary, unpredictable interannual shortfalls in future production (Bogaard, 2017; Ellen 1982: 34-35; Halstead, 1989; Netting, 1993: 84; Scott, 1976; Winterhalder et al., 2015; Wolf 1966: 4-6).

Declining individual work efficiency has been central to discussions of subsistence intensification because it contradicts the old idea that agriculture and surplus production freed humanity from what had once been considered the harsh, deprived nomadic life of the hunter-gatherer. It is what made the question of agricultural origins the key problematic of archaeology in the second half of the 20th century: if agriculture requires more work than foraging, why did people ever bother to do it? The most common answer to the question in processual terms has been: *because they had to*.

According to the classic Malthusian model, natural and technological limits on food production constitute a kind of ceiling against which population growth constantly pushes, maintains a fragile equilibrium with, and occasionally overshoots in the face of environmental fluctuations. Under the NeoMalthusian view, population pressure happens right at the Malthusian limit or ceiling—where the supply of available food exceeds the number of hungry mouths to feed. Hence, agriculture was adopted as a way of resolving the resulting food crisis (Cohen, 1977). This view has always left the population pressure argument open to charges of environmental determinism—in which people are denied agency or free will—and has led to a spate of recent arguments denying population pressure has anything to do with intensification decisions or the origins of crop domestication (Bowles, 2011; Smith, 2011).

Boserupian intensification has frequently been categorized with Neo-Malthusian population pressure arguments as environmental determinism, but as James Wood (1998; 2020) has argued, there was always a place for agency or free will in her approach. Boserup (1965:14, 22) explicitly distanced herself from the Neo-Malthusians, arguing that cultivators are more interested in avoiding declines in current acceptable levels of productivity than they are in accommodating additional population growth. In her view, these declines are due to soil depletion caused by increased cropping frequency, although it is implicit in her argument that increased cropping frequency results from the need to maintain production on less land. Hence, population pressure, in the form of packing (discussed below), is still a significant factor in Boserupian intensification.

As Wood (2020:183) puts it, Boserup's view of population pressure "begins not at the margin of subsistence, but whenever the average per capita food availability falls below the level needed to support the population at its minimum *acceptable* standard of living, which will be higher than the subsistence level." Hence, Boserupian intensification trades the Malthusian ceiling for a floor; a baseline above mere subsistence level below which households are no longer socially and economically viable units of production and consumption according to standards of living set by the community. This standard of living constitutes both a cushion against environmental fluctuations and a culturally defined standard to which people in a community aspire and are loathe to fall below: "fear of falling" as Ehrenreich (1989) called it.

This cushion is the surplus that funds "leisure time," defined as *time and energy not devoted specifically to immediate subsistence-related needs*, and which underwrites the production of the material, cultural and institutional trappings of social complexity and cultural elaboration. These include symbolic and social capital such as social, ritual, and ceremonial obligations defining a household's standing in a community or a community's standing in a polity (Bourdieu, 1977). In traditional societies such trappings include upholding accepted standards of hospitality (like feasting), houses that are larger and more elaborate than necessary for mere shelter against weather, elaborate clothing and items of personal adornment, and exotic prestige goods for household members. They may produce art such as music, dance, decorated pottery, elaborate textiles and participate in domestic and community rituals and ceremonials such as feasting events. This view of a socially constructed "cushion" is inherent in Wolf's (1966) "ceremonial fund" and in Spielmann's (2002) "ritual mode of production".

Boserup's and Wood's perspective on intensification changes the answer to the question "why do they do it?" from "because they had to" to *because they want to*. Cultivators work harder because they want to maintain their standard of living, not because they are constantly on the edge of starvation. Economic activity is embedded in and constrained by the norms, values, and institutions of the community and what constitutes surplus production and consumption is defined by these institutions (Pearson, 1957; Polanyi, 1957). This process can be understood as a form of cultural niche construction (Smith, 2011). Boserupian intensification regulates the Malthusian population-resource balance from within the household and the community rather than simply through response to imminent challenges and external constraints set by the environment. The internalization of norms and values associated with successfully maintaining the standard of living or quality of life within a given social or spiritual context, works as a *commitment strategy* (Frank, 1988; Nesse, 2001) to encourage people to work harder to maintain production above the mere subsistence level. As David Graeber (2001: 12) put it, these norms and values are "the false coin of our own dreams" encouraging people to "want to reproduce society". Thus, the production of a Boserupian cushion based on the comparison with their social peers is what puts the pressure in population pressure: it motivates people to overproduce in the face of infrequent, unpredictable shortfalls and long-term decline in productivity due to population growth.

1.2. Coordination takes teamwork

Coordination of collective action is an effective way for communities to intensify production, but it can be difficult to get started. Typically, coordination coalesces around leadership and an associated set of beliefs and values—an ideology—that structures the group's material and spiritual goals, for example, as a form of "managerial mutualism" (cf. Smith & Choi, 2007; Hooper et al., 2010). In a behavioral ecological analysis of coordinated collective action, Noë, et al. (1991) argued collaboration involves three distinct phases of activity: an associative phase, a cooperative phase, an allocative phase. In the associative, or what we might call the "team building" phase, actors signal or advertise their own suitability and commitment to achieving group production or defense goals and choose with whom to collaborate and/or to follow. During the cooperative phase, time and energy are invested in cooperative activity, structured by leadership and/or systems of values and norms that shape expectations about actors' contribution to group goals. These values and norms give meaning and motivation to action. One implication of this view is that coordination is aspirational rather than transactional in nature: "Alone we each bring home a hare, together we will bring down a stag!".

In the allocative phase, goods and services produced by collective activity are distributed among the participants. At the very least, actors must perceive their shares are marginally better than returns would be for alternative opportunities, if they exist (Alvard & Nolin, 2002). In small mobile hunter-gatherer groups, equal division of game may be enforced by daily face-to-face interaction and by the somewhat random nature of individual hunting success fosters a sense of shared fate, which in turn creates a durable egalitarian ethic. Inequality really begins when some collaborators, through increased bargaining power, through prestige or by coercion, skew the allocation of goods and services produced collectively for their own gain. For example, Ames (2003) has shown that in communities where collaboration is structured around leader–follower or patron-client relationships, patrons compete to optimize the number of clients–that is, to appear to be the most benevolent or effective leader–and clients compete to get the best return from a patron–to be the best or most effective worker or follower.

The result of this competition is a prestige hierarchy rather than a dominance hierarchy (Henrich & Gil-White, 2001). Prestige competition is a form of market competition for an audience of followers, believers, clients, cooperators (Barclay, 2013). You cannot have prestige by yourself; others must give it to you. Desire for prestige is really desire for recognition, which gives one agency, defined as the power or capability to use social relations to achieve one's individual or group's goals—what Bourdieu (1986) called social capital.

The key strategy of conspicuous consumption in the context of prestige competition is the conversion of abundance produced by a collective into scarcity controlled by a relative few. Rituals, ceremonials, sumptuary crafts, and production of the arts exist in part to highlight individual variation in commitment or adherence to values, norms, beliefs, ideologies that structure a community's common material, defensive and spiritual goals. They converge on common standards to facilitate invidious comparison in the struggle for recognition. Thus, somewhat ironically, social conformity and emulation are the result of individual agents attempting to distinguish themselves from each other (Smith & Bliege Bird, 2005:231; Bourdieu, 1984). Below, we will show how the prestige of wealth and its conspicuous consumption become powerful signals of resource security among households, and how this prestige replaces coercion as a means of exercising agency. In this way, Veblenian signaling (Mendoza Straffon, 2021) acts as a kind of territorial marker in social space.

1.3. Boserupian foragers: Logistical mobility and distributed risk

Boserup (1965) was interested specifically in the agricultural intensification of small holders; she said relatively little about forager intensification or the origins of agriculture. However, her approach is generalizable to any pattern of subsistence change in which humans are organized into corporate groups acting as units of production and consumption. The logical structure of the Diet Breadth Model (DBM) in optimal foraging theory is analogous to Boserupian intensification: both employ the logic of the marginal returns on increased effort to improve production. Under the assumptions of the prey choice model, intensification correlates with increasing diet breadth because handling costs mount up as lower ranked prey items are taken, and the costs of handling/processing start to surpass those of searching in total foraging costs. Broadening diet breadth is potentiated by declining availability or encounter rate of higher ranked resources, increasing search time to the point where it becomes worthwhile to expend extra effort in collecting and processing lower ranked foods, resulting in a marginal increase in the forager's average return rate. Foragers do not have to be starving to death when they add a lower ranking prey item to their diet. They can be doing fine but do even better by working harder and increasing their average return rate over what they had before. Hence, maintaining or improving average return rate in the DBM corresponds directly to the idea of maintaining a socially aspired-to standard of living in the Boserupian intensification model. This means that individual households will not necessarily experience resource stress as members of a population approaching carrying capacity; another reason why environmental determinism is incomplete as an explanation for subsistence change.

The diet breadth model assumes random dispersion of prey species on the landscape, but just as importantly, it implicitly assumes unbounded or limitless search space as well. Search time is a function of encounter rate, and declining encounter rate is what drives broadening diet breadth. Higher-ranked prey like large mammals require a lot of space, and they tend to have large ranges as a result. Depletion of these prey can cause declining encounter rates, certainly, but reduction of search space can also force foragers or cultivators to intensify by resorting to lower ranked plant and animal resources available locally, because encounter rates for larger prey decline in proportion with available search space. Given variation in patch quality across the landscape, the opportunity costs associated with searching larger territories and leaving a good patch open for others to move in and claim make it worthwhile to stay put and invest more effort locally (Freeman et al., 2019). Therefore, a reduction in search space can be as effective as depletion in motivating foragers or cultivators to intensify (Binford 2001:366-367).

Bettinger and Baumhoff (1982) characterized the spatial dimension of intensification in terms of a "traveler-processor" continuum. When forager population densities are low, the optimal strategy for maximizing energy return rates is for foragers to minimize the time they spend acquiring resources within a patch and move frequently between resource patches. As the population density increases, all foraging habitats become occupied, the landscape is "packed" (Binford 2001:238–239), and patch holders must compete or cooperate to use resources beyond their own compressed territories (Freeman & Anderies, 2012).

Packing refers to the observed or perceived increased density of human occupation and use of the landscape. It corresponds to Boserupian population pressure in the sense it is subjectively experienced as the density of use in an area increases locally, long before the food runs out. The subjective feeling of crowding serves to signal that shortage may be on the horizon. It obviates environmental determinism by putting the emphasis on how people relate to each other on the landscape rather than how the environment manipulates or puts limitations on human agency. Packing is potentiated by increased population density and intensified use of the landscape and results in the compression of resource space used to support local populations. Resource space compression results in intensification, initially involving the inclusion of lower ranked food sources, then longer residence time on resource patches, and to increasing investment of time and energy in managing territorial boundaries and sharing arrangements, eventually with exclusive use rights, land tenure, or territoriality (Freeman & Baggio, 2019), or what Stone and Downum (1999) called "non-Boserupian intensification".

Boserup's and Wood's views on overproduction, discussed above, focused on sedentary subsistence farmers during an annual crop production cycle. Mobile foragers "overproduce" to mitigate local resource depletion and/or environmental downturns by maintaining information and patch-sharing networks over long distances (Hamilton, 2022), integrating resource streams from distant sources by patch-sharing and by moving to where the food is (Bird et al., 2019; Hitchcock & Ebert, 2011; Stewart et al., 2020; Wiessner, 1977,2002). Such summing-up of resource streams may be on an annual seasonal schedule, in the case of interannual downturns, or over a period of years or even decades for longer-term fluctuations in prey or other forage availability. For example, Hamilton (2022) has recently argued the Australian Aboriginal Dreaming tradition is a small-worlds network that regulates and equalizes access to patchy, fluctuating forage distributed over wide expanses of landscape by encoding accumulated information into culturally inherited knowledge systems (cf. also, Traditional Ecological Knowledge; Smith, 2011; Zeder, 2016). Here, "knowledge accumulated over generations essential to survival and cultural identity are encoded into norms of behavior, craft, kinship, mythology, art, and ritual" (Hamilton, 2022: 20).

Thus, foragers maintain these networks by exchanging tokens of connection serving as place markers in a social network or evidence of access to resources or foraging space far beyond the immediate locale. Material manifestations of access to and participation in these far-ranging networks might include traditional ecological knowledge encoded into ritual knowledge and tradition, as well as into the production of sacred knowledge traditions, portable art and personal adornment, made of exotic materials such as shell, ivory, red ochre, or mineral pigments, and the production and use of prestige chipped stone tool forms.

1.4. The plot thickens

Intracommunity emulation of the form and content of ritual displays, prestige goods and practices can scale horizontally to the regional and interregional levels, producing what Freeman et al. (2018) call "synchronization of energy consumption" across polities and entire interaction spheres or regions. Synchronization accompanies a shift in scale from what Winterhalder & Leslie (2002) call micro- to macro-intensification, where production intensification decisions shift from intra-household responses to a local habitat into a situation where household decisions depend on what others are doing in the area (see Ritchie & Lepofsky, 2020 for a Northwest Coast example of this process).

As we will argue below, such decisions might be made to emulate the apparent material and spiritual well-being and "staying power" of neighbors. In this way, the cultural inheritance of institutional values and norms structure niche construction behaviors aimed at maintaining or improving current and future biological and social reproduction. This is the process by which labor-intensive subsistence strategies like cultivation can expand into habitats where they would not normally be "worthwhile." It is the reason, for example, why domestication spread at the expense of foraging in Neolithic Europe (cf. Bowles, 2011), even though it apparently required more work effort. More generally, it is at least in part what drives the ratchet-like nature of population growth and cultural evolution. This shift in the scale of intensification is the "tipping point" which is often recognized archaeologically as a new subsistence "stage" (Freeman & Anderies, 2012; Ullah et al., 2015).

Wood (1998; 2020) attempts to account for this ratchet-like pattern of subsistence change, population growth and social/technological development with what he calls the *MaB model* (i.e., Malthus and Boserup model). In the MaB Model, population density increases (either by intrinsic growth or immigration) until stress on the existing production system begins to compromise the average household's ability to maintain their aspired-to standard of living. A decline in the standard of living signals to the household, however indirectly, they are in danger of falling below the level of mere subsistence. This stress zone, which exists just below what Wood refers to as the Malthusian equilibrium, is where households would be motivated to intensify and increase production to improve their state of well-being. Social and technological innovations promote increased production, which ratchets the population level up with more surplus production and greater levels of well-being, at least temporarily. As population density starts to increase again, surplus production and well-being start to decline once more toward mere subsistence below the Malthusian equilibrium. In the long term, what Wood calls the Malthusian-Boserupian Ratchet effect results in waves of density-dependent population growth following technological innovation, and subsistence intensification continually converging toward a new, higher point of temporary equilibrium (Freeman et al., 2021:2).

The MaB model assumes the population can somehow gather and process information about the current state of the population-resource balance and respond appropriately by producing the surplus necessary for a viable buffer above bare subsistence (Freeman et al., 2021:2). So, increasing production does not just maintain the current standard of living, it allows for more population growth as well, as Malthus originally pointed out; that is how population growth stimulates further intensification. Puleston et al. (2014) subsequently presented an analysis of population growth and subsistence change in an agrarian setting using a version of the MaB model predicting conditions in which population grows so rapidly that it reaches the Malthusian limit before farmers can anticipate the future need to intensify production to accommodate further population growth (note that the model only considers the effects of intrinsic growth, not immigration). At this point, the population arrives at a stable, stationary state, growth stalls, and farmers can only produce enough to maintain their current status quo, leaving it without the wherewithal to intensify further, resulting in a lull in the population ratchet effect posited in the MaB model. It also implies that a sudden environmental downturn could cause a population collapse.

Puleston et al.'s (2014) analysis is demographic rather than economic in focus: it assumes individuals rather than households are the fundamental units of production and consumption. This makes it difficult to introduce the effects of inequality into their predictions, because wealth inequality is defined in terms of differences between units of production and consumption in a society; in traditional societies, those units are households. In effect, the demographic focus of the Invisible Cliff model assumes everyone in the population has equal access to the conditions necessary for adequate food production, accurate knowledge of global conditions, and equal say in what to do about maintaining the conditions which sustain it. More specifically, it assumes an Ideal Free Distribution (IFD) of households on the landscape, wherein population growth creates a scramble competition over means of production and available resources. Thus, each new individual added to the population reduces the total available food supply by $1/n$ unit requirements of resources. Theoretically, a population growing rapidly at the Malthusian limit eventually reaches a level where the addition of just one new individual or household to the system reduces the consumption rate for the entire population below survival level, and the entire population starves, or at least all households fail as viable economic units simultaneously.

Although serious famines among foragers and farmers certainly do occur and have significant consequences for human population history (Gurven & Davidson 2019), the extreme situation of 100 % mortality rarely occurs, because there is always household variation in resource patch quality, differences in energy requirements, efficiency in acquiring resources and other factors causing variation in instantaneous resource access (cf. Boone, 2002: 14; Rogers, 1992), and because households tend to maintain a socially adjustable cushion against temporary shortfalls. In this context, some form of private property or use rights rule (institutionalized or social territoriality) can be seen as a way for households and communities to preserve access to and reduce conflict over the resources they need to maintain their cushion or standard of living in the face of increasing population and competition over critical resources (Freeman & Baggio, 2019).

This results in an Ideal Despotic Distribution (IDD), wherein the already-established households can maintain exclusive access to resources critical to their survival and maintenance (Prufer et al., 2017). Under the IDD, the addition of new households through intrinsic growth or immigration does not necessarily reduce the harvest rates of households with exclusive use rights to resources. When a shortfall does occur, households at the bottom of the distribution fail as viable economic units of production and consumption and are forced to emigrate, form dependency relations with remaining successful households (see below), or starve, leaving the surviving population with a more favorable population to resource balance. In this case, crashes, when they occur, will be less severe than in the case where access to critical resources is equal in the population (Boone & Kessler, 1999; Boone, 2002). Thus, unequal partitioning of resources within a population has, sadly and perhaps counter-intuitively, the effect of increasing population stability in the long run (Rogers 1992: 379-92). Further, as we show below, the differential failure and success of households in such a population creates opportunities for labor organizational innovations that can improve productivity and fund further innovation and intensification through managerial mutualism (Ames, 2003; Prentiss et al., 2018; Prentiss et al., 2023), generating in turn further wealth inequality.

Our interpretation of Boserupian intensification is that households are not necessarily concerned with the population-resource balance of the entire system, but rather how they are doing in relation to their neighbors or social peers: that is, people they normally interact with and depend on socially. Comparison with their social peers is what puts the pressure in population pressure: it motivates people to perennially overproduce, which in turn provides, perhaps unintentionally, protection from infrequent, unpredictable shortfalls and long-term decline in

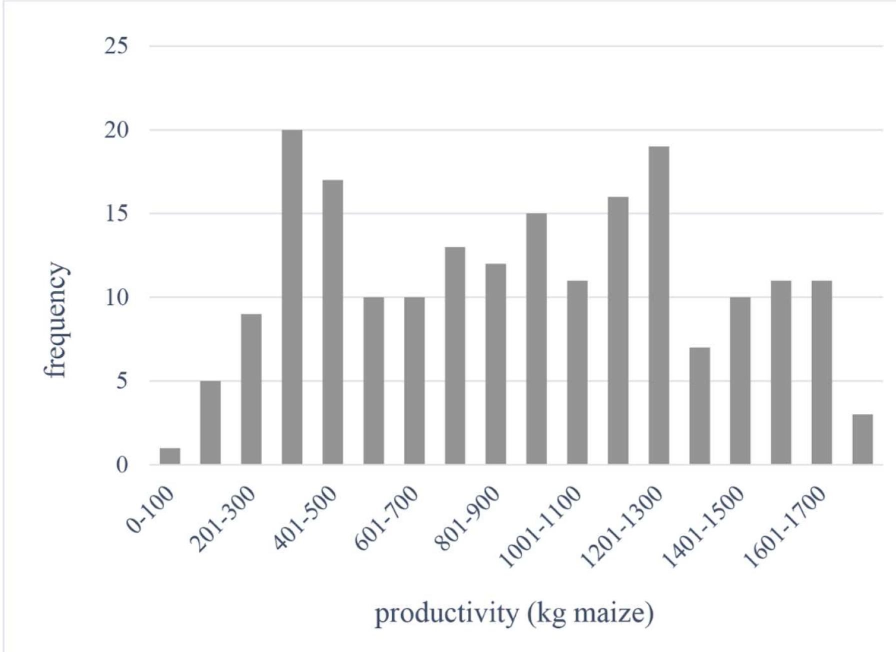

Fig. 2. Histogram of annual harvest rates from simulated maize production for 10 model Hopi households in the Three Mesas area over a 20-year period from 1932 to 1951 (N = 200 observations; data is from Hegmon, 1989: Tab. 3). The histogram shows two peaks because model production was divided between two ak-chin patches and one floodwater patch for each household as a risk-reduction strategy.

productivity due to population growth. Below we present a model of how this works.

1.5. *Staying ahead of the curve*

Sedentary foragers and cultivators overproduce and sum up harvest rates locally on an annual schedule, tracking seasonal primary productivity and mitigating unforeseen interannual shortfalls by marching in place across the seasons to produce an annual harvest. Perennially overproducing in the present ensures they can meet minimum needs in the event of an unpredictable interannual shortfall in the future (Ellen 1982: 34-35; Netting, 1993: 84; Scott, 1976; Wolf 1966: 4-6). This view of surplus was developed by Paul Halstead in *Bad Year Economics* (1989; see also Pauketat, 1996; Bogaard, 2017; and Winterhalder et al., 2015) as a way of explaining the rise of wealth inequality in subsistence agricultural economies in Bronze Age Greece.

How much should a household overproduce in the present to stay safe over the long term? Here we present a simple formalization of the *bad year economics strategy* using the z-score model developed by Winterhalder & Goland (1997) and the results of a simulation of Hopi agricultural production published by Michelle Hegmon (1989). First, rather than matching maximum production to average household needs, subsistence farmers and sedentary foragers must adjust mean production so the probability of falling below the minimum annual harvest rate required for household survival is as low as possible. Since average annual harvest rates typically distribute around a normal curve due to interannual variation in environmental conditions like precipitation and temperature, maintaining a low probability of falling below the household's minimum requirement invariably involves continuous, yearly overproduction, in addition to routine storage for seasonal gaps. Food security, expressed as the probability of staying above a defined minimum requirement, is maximized by keeping the minimum harvest rate for survival *as far to the left of the curve* as possible (Fig. 3). The payoff is long-term survival of the household as a viable economic unit and social reproductive estate against infrequent but severe shortfalls in production.

Hegmon modeled the annual production of 10 Hopi households, each with equal access to a mix of floodwater and ak-chin fields using actual maize production and rainfall figures for the Hopi Three Mesas area for a twenty-year period from 1932 to 1951 (data presented in Hegmon, 1989: Tab. 3; see histogram of results below in Fig. 2). Over the resulting 200 model production years, Hegmon found the average annual production was 1174 kg of maize, with a standard deviation of 448 kg. She estimated an average household needed 1017 kg per year to maintain itself as a viable social unit. This included an amount put aside in long-term storage each year to maintain a running three-year buffer against production failure, as well as a ceremonial fund.

Using the z-score model to calculate the probability of falling below a households yearly minimum requirement in any particular year, Fig. 3 shows the risk of failure is quite high: p =.352, or a little over 1 year out of 3, which would be unsustainable. However, since each household maintains a three-year store, the actual probability of failure could be estimated at $p^3 = 0.043$, or about 4 years out 100, assuming, as Hegmon does, drought years occur independently of each other. And yet, for the remaining ninety-six years out of a hundred, Hopi households are producing more than they need to maintain themselves in the long term, including a three-year buffer in storage and a ceremonial fund. In fact, half of the time, they will be producing 125 % *or more* than their minimum requirement to survive as a viable economic unit. Perennial overproduction is an integral part of a household's long-term survival and social reproduction.

Does this mean that the Hopi farmers somehow calculate the risk of shortfall and adjust their optimal level of overproduction accordingly? It seems unlikely. Notice that a household overproducing at this rate could pass through a generation or more without experiencing a three-year downturn that would result in its failure as a viable unit of production and consumption. Meanwhile year after year they produce a harvest far beyond what they need or can store. What could possibly motivate them to put in all this extra effort?

Our argument has been that decisions regarding how much to produce are *satisficing* decisions based on maintaining their social standing in the community and meeting social and ritual or ceremonial obligations. Selection then acts on variability in these decisions among households to optimize surplus production with respect to the long-term benefit of improving the chances of survival through unpredictable interannual downturns. In other words, they can estimate how much overproduction has worked in the past by observing and emulating levels of conspicuous consumption of surplus maintained by their social peers in the community who have survived for generations. This is why houses and lineages with long genealogies or histories ("old money") have greater prestige.

Where does all this extra production go? In traditional communities with year-round sedentism it seems clear perennial overproduction funds the construction of larger, more elaborate housing, household wares and personal ornamentation of household members, and sumptuous feasting and ceremonial events, and elaborate mortuary programs. Households base their production levels on their social peers in the community: this motivates households to maintain production level above mere subsistence. Conspicuous consumption of this surplus serves as a visible signal of the amount of sustained overproduction the household is capable of in its social context. The medium is the message: the medium is energy consumption; the message is resource security. Conspicuous consumption of surplus is an *index*, or honest signal, of the household's resource security, and its viability as a unit of production and consumption. In this way, the norms of wealth and prestige in a community motivate the conspicuous consumption of resources, and the desire to meet these norms is what puts the pressure in "population pressure.".

Jerrold Levy (1992), in his 1992 monograph *Orayvi Revisited* presented an extended case study of the 19th century Hopi community on Black Mesa in northeastern Arizona vividly illustrating these processes. Levy (see also Eggan, 1966:124) held that Hopi clan ranking constituted an abstract charter system establishing priority of use rights to agricultural fields of variable extent and quality around washes at the base of the mesa upon which their community was located. Following mainly Voth's (1905) and Waters' (1963) accounts of Hopi origin narratives, Levy argued the position or rank of clans within villages was established, at least theoretically, by the order of arrival of the clan into the community and maintained by the clan's possessions and ability to finance a ceremonial granted to them by a higher power. These ceremonials appear to have been critical in signaling a clan's ability to support itself and to reinforce its perennial claims to the cultivable lands they were granted. Clans unable to produce enough to fund ceremonials at the appropriate level of elaboration, perhaps through attrition of their household labor force or the vicissitudes of patchy summer rainfall, were subject to losing their charter on the fields, whereupon the fields (and the rights to stage the ceremonial) could be taken over by a lower ranking clan, often a related one in the same phratry. This may be the reason about half the clans listed in the Hopi origin narratives appear to be unoccupied or "vacated." Thus, a clan's capacity to underwrite periodic ceremonials was critical to signaling continuing entitlement to the fields they cultivated and ultimately determined who would survive severe droughts and crop failures. Hopi ceremonials justify a clan's claims to productive fields by demonstrating a clan's ability to "make it rain," and hence, to support itself as well as contribute to the well-being and prosperity of the community at large.

1.6. The rich get richer

As the discussion above indicates, increasing the mean annual production decreases the probability of falling below the minimum level of production necessary for survival of the household. In this way, houses rank themselves by resource security, and signal security by the level of surplus they can visibly dispose of. As some households fail as independent units of production and consumption, they may be forced to emigrate to find more favorable conditions for life elsewhere, *or* their holdings and labor can be absorbed by more successful landowners through sale, forfeiture or force, and their former occupants become tribute payers, renters or sharecroppers. Such labor organizational innovations improve productivity and fund further innovation and intensification, thus turning the initial chance success of some households into a path-dependent process that generates increasing wealth inequality (cf. Pauketat, 1996; Arthur, 1990) and can drive the MaB population ratchet upward by supporting higher population densities through increased productivity.

In this way, the differential success and failure of households plays a formative role in creating social stratification based on an owner-renter or patron-client relationship. The normal surplus formerly independent smallholders produced as a buffer becomes the rent, tribute and tribute labor allowing the landowner patron to accumulate wealth and facilitate their removal from production, resulting in what Scott called "the moral economy of the peasant" (1976:26–34). In this moral economy, property holders typically have a reciprocal obligation (often euphemized as benevolent despotism or *noblesse oblige,* or more currently, managerial mutualism (Prentiss et al., 2023; Smith & Choi, 2007) to ensure dependent households of their clients can maintain themselves just above mere subsistence level, and to provide relief during serious downturns, although the power asymmetry inherent in ownership of property and the means of production confers a decided advantage on the patron in these negotiations (Scott 1976:180-192). Scott argued that the temptation for patrons to renege on their obligations is high, and failure to do so can lead to rebellion.

This kind of asymmetric reciprocal relationship probably underlies the redistributive Polynesian chiefdom idea introduced by Sahlins (1958), the development of temple communities in early Sumer (Postgate, 1992), and other redistributive arrangements seen in the historical and archaeological record. In an ideal free distribution of patrons and clients, a two-way market competition among landholding patron households for client/laborers and among poorer households for the most beneficent landholding patrons could develop, based on the moral economy concept developed by Scott. Clients could adjust and shift their loyalty to landholders who can offer them the most protection and hospitality. Patrons protect themselves and their (and their clients') holdings by maintaining the largest following they can by redistributing surplus extracted from their tenants. (Ames, 2003; Boone 1992: 326-327). Ames (2003, 2006) argued the labor-based economy of NW coastal forager communities conferred an advantage on large households through their enhanced ability to field labor, underwrite harvesting, processing and transport technology and to benefit from the resulting economies of scale. The differential success and failure of houses generated social stratification between patrons and clients in which some successful noble households persisted for many generations while others failed, and new ones formed. At the core, the proliferation of these patron-client relations becomes a fundamental generator of division of labor, economic specialization and the evolution of social stratification and hierarchical social complexity in general (Henrich & Boyd, 2008; Hooper et al., 2010).

Intensification, labor, production and consumption in coastal vs terrestrial contexts.

Binford (1999:7–8; 2001:365–370) proposed forager intensification trajectories ending with sedentism, private use rights or property, surplus production, and significant wealth differentiation tend to converge on two general kinds of resource bases: plants in terrestrial environments and fish, aquatic mammals, and shellfish in aquatic environments (i.e., coastal marine, lacustrine and riverine settings). Social complexity in coastal and terrestrial environments both emerge as forms of coordinated subsistence intensification on previous foraging patterns but take different trajectories because of differences in the spatial and temporal structure and density of harvestable biomass between the two kinds of ecozones and by the labor organizational requirements of harvesting and processing them.

Intensive foraging and crop cultivation develop on landscapes characterized by high levels of primary harvestable productivity (PHP), defined by Belovsky (1988) as plant biomass available for harvesting and consumption by humans, in contrast to habitats where primary productivity is mostly inaccessible to humans in the form of cellulose (grass, tree trunks), or plankton in marine and lacustrine environments. Belovsky's point was that high levels of PHP also tend to support dense and diverse populations of animal prey which are ranked higher in the human forager diet, and which support high human populations as well. As higher-ranked animal prey are depleted, lower-ranked fallback PHP allows foragers to maintain high population densities, resulting in heavy intensification on plant resources as diet breadth broadens, which can eventually culminate in crop agriculture.

Crop cultivation can sustain high population densities of small, relatively self-sufficient household level labor groups with simple hoe and digging stick technology. Grain and seed crops can be harvested, threshed, and stored for use for the rest of the year at the household level. Grinding maize or other grains for daily household consumption can take two to four hours a day, every day, and is a major labor sink for girls and women in traditional contexts (Kramer & McMillan, 1999), but this processing labor is distributed throughout the year according to daily household requirements for meals. Jack Harlan (1967) famously showed that by using only hand sickles with flint blades, four people could gather enough wild wheat from its natural habitat on a hillside in southern Turkey in three weeks to feed a family of four for a year. Under these circumstances, we can expect to see sedentism precede crop cultivation and domestication (Byrd, 2002). Similarly, in Mesoamerica, Flannery (1976, 1986) showed maize remained an ancillary domesticate until cob size evolved to the point where individual households could produce enough maize to maintain themselves until the next annual harvest. At that point, around 2000 BCE, sedentary villages of household units of maize production and consumption popped up almost simultaneously all over Mesoamerica.

Households beget more households through social reproduction. All household production starts out limited by labor availability, but in cultivation systems, they can quickly become limited by the availability of land (Bogaard et al., 2019). New households need new land. As territory becomes packed, hierarchical organization develops around integrating many contiguous household-level units of production and consumptions to form more larger, more competitive corporate groups capable of controlling and expanding land and demonstrating a group's ability to produce and consume resources. Thus, in territorial systems vertical scaling develops around integration of land tenure systems, tribute or rent flow, and group territorial defense (Adler, 1996; Crabtree et al., 2017; Gilman, 1981 to cite a few selected examples). As Earle (1978:39-41) showed, even extensive irrigation systems can be built and maintained on a relatively egalitarian basis by a cooperative of essentially self-interested cultivators if the payoff to individual cultivators is high and the whole system cannot be maintained alone. Earle further showed that centralized leadership and vertical scaling of such systems typically arise either in mobilizing defense against raiding or plunder of stored grain (Scott, 2017) and the allocation of and settlement of disputes over access to water in cases where it can be controlled from one point.

In contrast, marine, neritic, estuarine and riverine environments tend to be dominated by animal prey, which can often support high human population densities. The primary productivity that ultimately supports the migratory animal prey populations, such as plankton, is out in the ocean, and is inaccessible to human foragers in any case. Consequently, there is little PHP on which humans can intensify when animal sources fail. Mass prey harvests in aquatic environments can result in gains are highly concentrated in time and space, but these gains are labor and technology intensive to realize (Arnold, 2006) and prey populations are subject to natural interannual fluctuations (Schalk, 1977). Water transport is more efficient than land, but moving large labor groups requires heavy investments in boats, nets, lines, and other harvesting and processing equipment. Large quantities of fish or other aquatic fauna often must be harvested during a brief seasonal window, then quickly and laboriously stabilized for storage in a short period of time and transported back to a central base camp for use for the rest of the year. Flooding and stormy weather during harvesting seasons can block access to harvest sites and preclude timely drying or smoking and storing the harvest. Consequently, coastal foragers typically produce a reliable annual surplus by diversifying the number of resource patches and moving between them on a seasonal basis (Ames, 2003) and by increasing capital investment in labor organization and technology (Arnold, 1993,1996; Stutz, 2020).

As a result, coastal foraging groups must continue a "traveler" strategy to maintain seasonal rounds on a temporally and spatially diverse set of harvesting sites for some time. Ames speaks of entire moving villages making seasonal rounds to scattered patches along coasts, coves, rivers, and tidal flats. Households beget households here too, but coastal environments are typically more environmentally circumscribed than terrestrial ones until they settle into a kind of permanent central place foraging arrangement involving the establishment of large Houses. Ames (2003, 2006) especially argued that economies at ritual and subsistence levels were organized around the central problem of maintaining House membership to avoid crises in basic food production where mobility was constrained by packed landscapes and patchy resources (Prentiss et al., 2022). Hence, coastal forager group size and complexity scales on labor force coordination and diversification within large households and villages (Ames, 2003; Arnold, 1993,1996,2006; Hayden, 1994; Stutz, 2020).

2. Conclusions: Will this Scale?

One implication of our approach is that the distinction between foraging and food production as an evolutionary dividing line in human history has been highly overrated (Arnold et al., 2016; Moss, 2011). Crop domestication is not an invention or a discovery, it is the continuation of intensification by other means. We further conclude that the term *food production* (i.e., in contrast to food gathering) is something of a misnomer. All the food humans consume is in all cases produced by plants and animals in the environment. The real distinction is in how and how much humans modify the conditions under which plants and animals produce it. The difference in how societies develop in coastal aquatic contexts and under terrestrial cultivation and crop agriculture comes down to the way primary productivity is distributed across the land and seascape, how animal populations, including humans, map onto to it.

A second implication of our model of Boserupian intensification is that wealth inequality is a scalar rather than an evolutionary phenomenon. Paleolithic research over the past couple of decades has converged on the idea that of the cognitive and behavioral capabilities necessary for social complexity and its material markers evolved during the mid-upper Paleolithic transition and become ubiquitous by the later Pleistocene (Clark et al., 2022; Graeber & Wengrow, 2021; Kuhn & Stiner, 2019; Singh & Glowacki, 2022; Graeber & Wengrow, 2021). With the emergence of the first hearth-centered family group as the unit of production and consumption, the hearth and its products become the first private property (Wrangham, 2009); what develops later with the expansion of the household's resource space is an extension of the concept.

The marked increase in material markers of wealth inequality we see in the Holocene results in part from improved environmental conditions which in turn fostered increased population density and the need to produce more food on less space. As Richerson et al. (2001) hypothesized, agriculture may have been impossible in the Pleistocene, but necessary in the Holocene. Using Wood's MaB model (2020), we have argued that Boserupian intensification results in the expansion of the scale of production of surplus, which is in turn afforded by large, coordinated labor forces that form to create it. This surplus production protected the households, communities, and polities from the effects of unpredictable interannual downturns, which seem to have kept population growth to near zero during the Pleistocene (Boone, 2002; Gurven & Davison, 2019).

But why can't people, after working together to produce this

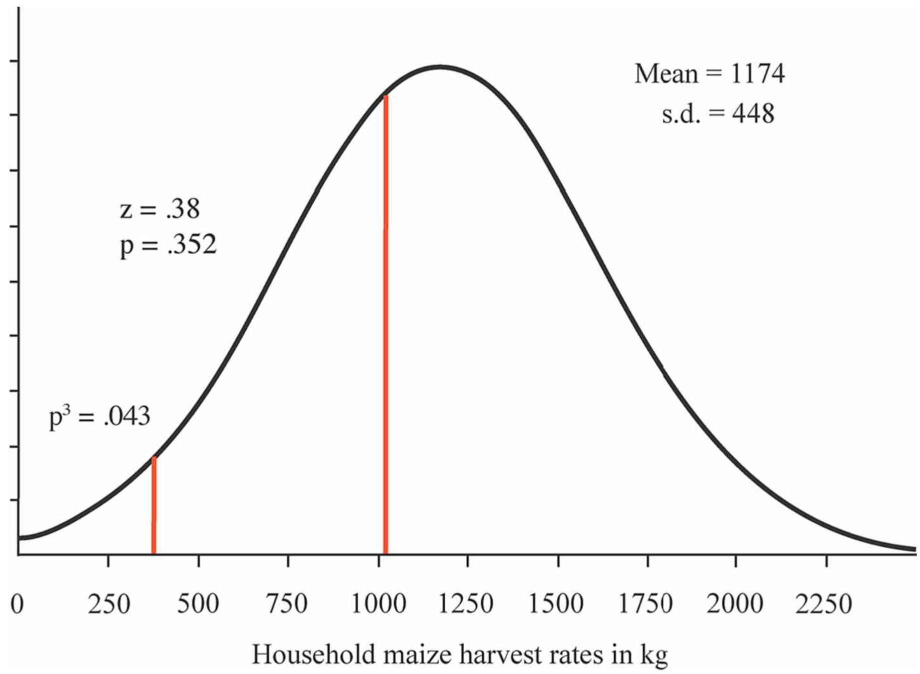

Fig. 3. Z-score model calculated from the simulated maize production data summarized in the histogram in Fig. 2. Each household needs a minimum annual harvest of at least 1017 kg of maize to survive as a viable social unit. The probability p of falling below that minimum requirement in any particular year is 0.352. The probability of falling below that minimum in three consecutive years is $p^3 = 0.043$.

protective cushion, then divide the proceeds among themselves equally, and live in a world like John Lennon Imagined? We have developed two interconnected arguments about why this might be. The first is that a population of households with equal access to food production would move inexorably toward the Malthusian limit, or Invisible Cliff (Puleston et al. 2016; see also Winterhalder 2015:347 on this point). Here, the Boserupian ratchet of population growth and innovation would stall, and more seriously such a population would be subject to crashes brought on by unpredictable interannual downturns in production. So wealth inequality between households maintains and regulates population stability and continuity.

The second argument stems from the idea that coordination as a collective action strategy is difficult to get started and to maintain without some level of leadership and/or ideology to consolidate group support. The increased efficiency of production introduced by economies of scale generates an increasing gap between the value of what is produced and the cost of producing it. This is related to Marx's concept of *surplus value.* Surplus value is created when market forces drive the price per unit of production of a commodity above the labor, materials, and technology it costs to make it. This allows the factory owners to draw a profit on each unit produced. This is the reason why Marx took such a dim view of the division of labor. Now, in a market competition for cooperation such as we described above, market forces increase the value of social signaling or advertising above what it costs the primary producers to produce the surplus, which leaders or managers extract as a kind of profit. So, we can state this as a hypothesis: it costs more to be rich, but the marginal value of each additional unit of surplus increases with the scale of production at a potentially exponential rate. This would be a subject for further research and formalization.

In the above discussion concerning "Staying ahead of the curve," we argued households estimate how much surplus production and consumption is optimal by comparing themselves to their social peers. In a new or unfamiliar socioeconomic environment, reliable standards may not be available, or demographic, economic or climate conditions may be fluctuating so rapidly that such standards are constantly in flux. This could lead to a kind of runaway effect in prestige competition between houses, particularly near the top. Something like this may have occurred, for example, in the mid-19th century Northwest Coast with the introduction of European trade and wage labor economy along with the decimation of the indigenous population by epidemic diseases, when Kwakwak'wak^{W} potlatches reached alarming proportions, at least in the eyes of European observers (Suttles, 1991).

What might act as a brake or regulator on such a runaway effect? In this light, conspicuous consumption can, in some contexts, be seen as a levelling mechanism (Flannery, 1972). Although leveling mechanisms are usually a way for communities to maintain an ethos of equality (they certainly can have this effect), they can also benefit individual agents by putting a cap on runaway competition that could push them to produce more surplus than they require for a cushion. This happens when the marginal value associated with acquiring more social/cultural capital through the consumption and display of surplus production reaches a plateau or begins to decline. It is possible, for example, that the ceremonialism practiced by middle range societies such as the 19th century Hopi and other Puebloan communities, as well as those of the Northwest Coast communities function as levelling mechanisms in this way, and which prevent more centralized, despotic polities from forming. Again, with conspicuous consumption, the medium is the message: the medium is energy consumption; the message is resource security. Hence, the paradox inherent in humanity's control of fire: we waste so much energy because we are trying to protect ourselves from not having enough.

CRediT authorship contribution statement

James L. Boone: Conceptualization, Writing – original draft, Writing – review & editing. **Asia Alsgaard:** Conceptualization, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

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