

Modeling Patterns of Wealth Disparity in Predynastic Upper Egypt

Jessica Nitschke¹, Geoff Nitschke², Alexander Furman², Matthew Cherry²

¹Department of Ancient Studies, Stellenbosch University, South Africa
jessnitschke@gmail.com

²Department of Computer Science, University of Cape Town, South Africa
gnitschke@cs.uct.ac.za, FRMALE003@myuct.ac.za, CHRMAT011@myuct.ac.za

Extended Abstract

The archaeological record shows that from ca. 4000 BC onwards, Neolithic farming communities in Upper Egypt underwent a process of increasing social complexity. This included a rise in wealth inequality and hierarchy, settlement agglomeration, and the development of complex cultural ideology, all leading eventually to the emergence of a unified territorial state encompassing the whole Nile Valley by ca. 3200-3100 (Wenke, 2009). Most recent work on state formation in predynastic Egypt acknowledges that this transformation occurred as a result of overlapping complex social, economic, geographic factors (Stevenson, 2016). However, scholars still struggle to adequately narrate and understand this process due to limitations of the archaeological record. Many of the traditional explanations by anthropologists to explain the emergence of political structures and rise of social complexity, such as outside invasion, population pressure, or competition over scarce resources, have been rejected by Egyptologists as inapplicable to the circumstances of predynastic Egypt (Savage, 2001).

This study reports work in progress on an *Agent-Based Model* (ABM) that critically explores theories that have recently gained prominence in the study of Egyptian state formation. This study's ABM focuses on wealth accumulation and loss in a simple agrarian society within an environment that simulates the Upper Egyptian landscape in ca. 4000 BC, when clear evidence of economic inequality amongst Upper Egyptian households can be observed in the archaeological record (Wenke, 2009). The question this ABM explores is how entrenched inequality emerged in the Nile Valley given abundant natural resources were available to sustain the population. Understanding the establishment of permanent, entrenched inequality is crucial for exploring the development of social complexity and hierarchy (Stevenson, 2016).

Kemp (2006) compares the emergence of hierarchy and inequality in Neolithic Egypt to a *Monopoly*-like game. In his analogy, the "players" start with more or less equal standing, operating in an environment of unlimited agricultural potential. They compete by obtaining agricultural surpluses with the "advantage swinging first to one player and then

to another" thanks to chance and personal decisions. This process continues until eventually one player gains an unsurmountable self-reinforcing advantage.

This study's ABM replicates Kemp's conceptual model in computational form. The key research goal is not to prove or disprove Kemp's theory but rather to clarify the assumptions and characteristics required in order for it to work in the simulated historical environment of Upper Egypt from ca. 4000 BC onwards. The model illustrates the conditions under which wealth disparity may or may not shift from household to household over time, dependent on a number of variables, especially agent personality.

Methods: Agent Based Model (ABM)

The ABM was created in *NetLogo v6.0*¹. The design is partially influenced by Symons and Raine's model, which explored household movement and the emergence of a labor market in early Egypt (Symons and Raine, 2008). The ABM simulates an abstract version of the Nile floodplain in upper Egypt, with a default setting of 6km x 6km divided into 900 fields (the size of the landscape can be easily scaled up or down). Baseline values for population density are taken from Butzer (1976); average values for settlement density, agricultural production, and grain consumption are taken from Hassan's geoarchaeological studies on the Egyptian predynastic landscape (Hassan, 1984). These values control emergent agricultural and demographic behavior in the model.

As in Kemp's conceptual model (Kemp, 2006), agents represent households that start out with equal resources. Each *tick* in a run represents a year, in which each household makes decisions as to (a) if/where to claim available land and if/where to harvest. Household decisions are based on the following agent variables: field-knowledge, distance of fields, ambition, competence, current grain-storage, and the number of workers.

Ambition and *competence* are variables incorporated to reflect idiosyncrasies of human character in order to encourage emergent agent behavior that more closely mimics human

¹<https://ccl.northwestern.edu/netlogo/>

decision-making (Trescak et al., 2016). The values are assigned randomly to each household at the beginning of a run from a user-determined range and are updated at a random interval ([10, 15] years) for each household to reflect a cycle of changeover in management. The extent of change is determined by the *generational-variance* factor, a global variable set prior to each experiment.

Harvest yield is determined by the following variables: average-yield-per-field (user-determined prior to each experiment), field fertility, competence level of the household, and distance between field and household. Field fertility is variable year to year. We adapted an equation developed by Symons and Raine that simulates the annual Nile flood variability and calculates a fertility value for each field based on its distance from the Nile (Symons and Raine, 2008).

Following the harvest, grain is consumed and set aside for seeding of fields; any surplus is added to the grain storage. Households with insufficient grain at a year's end must shed a member. If a household loses all its members, it is removed from the simulation. Households that maintain a surplus have a chance to increase their membership at the end of every year; determined randomly based on the household's ambition and competency values and surplus grain storage. This approach allows for the potential of a demographic shift from many small households with a handful of workers to larger estates with numerous workers. The total number of household members in the simulation is restricted by the *pop-growth-rate* (variable set by the user) in order to keep the model in line with current consensus about actual population numbers and growth rates in predynastic Egypt.

Results and Discussion

We executed 27 experiments to test the impact of *min-ambition*, *min-competency* and *generational-variance* on wealth distribution across the world. Each experiment comprised 30 runs and each run represented 500 years. The goal was to determine the potential effect of personality and resultant decision-making on emergent inequality in an effort to replicate the initial stages of Kemp's "monopoly" game.

For all experiments, the initial number of settlements, households, and household members was the same, set to agree with the consensus opinion about population density ca. 4000 BC. The *average-yield-per-patch* and individual annual consumption were calculated and set at typical values following Hassan (1984).

Settlements were distributed randomly at the start of each run, with some closer to the Nile and others farther; however, the *knowledge-radius* was set large enough so that each household would have the same information about the fertility of the patches. Individual household wealth was tracked as a percentage of the wealthiest household and categorized as follows: (a) those possessing at least 2/3 the grain of the household with the most grain; (b) those possessing 1/3 to 2/3; and (c) those possessing less than 1/3.

As expected, when the *min-competency* and *min-ambition* are set very low, inequality is high early on in the run, with large volatility in individual household wealth, which shifts between households relative to the level of the *generational-variance*. However, interestingly, even when the *min-competency* and *min-ambition* are set very high, making all households close (but not entirely equal) in personality, a clear entrenched inequality still emerges gradually over the course of 500 years. Under such parameters, the tipping point whereby the number of households possessing less than a third of the wealth (group c) permanently surpasses that of the other two groups combined comes ca. 170-230 years into the simulation. Thus the model is able to simulate a scenario that seems to confirm Kemp's reconstruction, namely that a combination of chance and slight variance in individual personality can, in a resource-rich environment, result in entrenched inequality. That said, the results are preliminary and further experiments are needed with more variation in a greater number of parameters.

Future work will introduce additional environmental factors and agent capabilities, such as: the ability to move; emotional connection to land; intra-settlement cooperation; local catastrophic events; and patronage networks. This will allow agents to create strategies for moving and developing relationships, allowing one to observe the development of complex social networks, fission and fusion of settlements and wealth distribution across communities.

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