UNIVERSITY OF CALIFORNIA, MERCED

Grassroots Networks: Interdisciplinary Modeling of Nomadic Social Organization in Premodern Central Eurasia

A dissertation submitted in partial satisfaction of the
requirements for the degree
Doctor of Philosophy

in

Interdisciplinary Humanities

by

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2022

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University of California, Merced

2022

DEDICATION

To my wife, Shadi.

EPIGRAPH

The error of story tellers is that they like to talk about monuments
but not the exceptional social organization that was necessary to construct them.
—Ibn Khaldun, *The Muqaddimah*

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ACKNOWLEDGEMENTS

I want to thank my advisor and dissertation committee chair, Dr. Karl Ryavec, for making the time for many meetings and conversations about history, geography, and the many stages of the dissertation process. I began my graduate student career learning geographic information systems in his classes to eventually teaching those same labs and collaborating on research. Dr. Ryavec provided me with many valuable research opportunities that were vital for my development as a scholar. I would also like to thank Dr. Sholeh Quinn, Dr. Mark Aldenderfer, and Dr. Rowena Gray who served on my committee and provided even more crucial conversations, research opportunities, and stimulating classes all of which, in one way or another, contributed to this dissertation.

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ABSTRACT OF THE DISSERTATION

Grassroots Networks: Interdisciplinary Modeling of Nomadic Social Organization in Premodern Central Eurasia

by

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Doctor of Philosophy in Interdisciplinary Humanities

University of California Merced, 2022

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The history of Central Eurasia and particularly pastoral-nomadic societies has long been defined by models of dependency. For millennia, nomadic societies have been thought to be dependent on sedentary societies for basic needs as well as cultural and political imports, representing "early-stage", "less complex" societies. Scholars in recent decades across the humanities and social sciences have begun to supplant the older dependency theories with new ones that cast nomadic societies as more complex and capable of endogenous social evolution, historical agency, and broad cultural influence. However, change has been uneven between relevant disciplines. Historical narratives and archaeological records have been significantly reinterpreted to reflect social complexity, but nomadic societies are nearly completely ignored in cultural evolution and historical geography. Further, some ideas such as geographic determinism ("the empty steppe") is still employed to explain nomadic migrations, invasions, and military conflicts in lieu of rich, native archives. This research begins by suggesting a novel assemblage of historical, social scientific, and complex systems theories in order to bring together many threads of knowledge about human societies into an interdisciplinary framework of modeling. This framework enables more coherent comparisons between verbal narratives and formal mathematical or computational models as assumption-laden vehicles of logic and communication. Using this framework, a conceptual agent-based model is suggested as a way to think about how wealth inequality might develop in a pastoral economy, how inequality leads to patron-client relationships, and how those socio-economic networks are maintained and strained under variable climatic conditions. Results of the modeling exercise indicate that notions of nomadic dependency are increasingly outdated and that high mobility, diffuse social and resource networks, climatic shocks, and common behaviors like social signaling are enough to produce complex internal social orders. Moreover, cross-cultural contact such as the trade in prestige goods or agricultural products can be more accurately understood as interdependency within a connected social world. Historical and anthropological evidence upending linear understandings of human societies continue to mount, closing the gap between how we think about our past and contemporary worlds. Nomadic societies of the past can be considered to have been "fully formed", complex, and adaptive. Interdisciplinary frameworks, methods, and models continue to reveal the limits of disciplinary knowledge but also the possibilities of research that is greater than the sum of its parts.

Chapter 1

Introduction

The critical question of how nomadic pastoral societies could have organized themselves into capable empires still looms large in the historical fields of research. History often focuses on elite nomads who lead conquests, rivaled neighboring kingdoms, and commissioned monuments and chronicles. Many written sources we rely on are highly ideological and say much about what was meaningful for nomadic leaders but little about how they adapted to stochastic climates, how wealth inequality manifested, how hierarchies formed/dissolved, and how various social processes may have interacted and lead to the emergence of confederations and empires. Moreover, how nomadic societies could achieve social complexity, even domination, in seemingly very different conditions—pastoral mode of production, mobile, dispersed—has yet to be comprehensively addressed.

Nomadic-pastoral societies in Eurasia and beyond have long been considered fundamentally different than sedentary-agrarian societies. For thousands of years, scholars and administrators of various backgrounds have represented and modeled nomadic societies as essentially poor, vulnerable, irrational, and violent. Many scholars developed and reinforced the notion that nomadic societies were wholly dependent, parasitic even, on their sedentary neighbors for both sustenance and the means—

prestige goods, rituals, titles—by which to establish political hierarchies. The steppes of Eurasia has long been considered a sterile, empty desert that seemed to produce erratic human behavior, particularly when the climate shifted dramatically.

This enduring picture is, however, at odds with clear signs of socio-economic hierarchy in the historical and archaeological record and the ability of nomadic empires to gather the resources and social organization necessary to conquer apparently "more complex" societies throughout history. Recent research has ameliorated this crude portrayal of nomadic societies. Historical research and theory into cross-cultural trade and interaction has revealed significant pastoral agency in the cultural evolution of Eurasia. The spread of Indo-European and Turkic languages transformed the way people communicated and continue to communicate throughout the world. Nomadic empires connected the Eurasian continent on an unprecedented scale, only surpassed in modern times. Even at the local level of pastoral families and herding groups, anthropologists have uncovered the complex dynamics of mobility and decision-making.

Still, some of the old tropes survive in new forms today. Nomadic societies are still considered "less complex" than agrarian societies in the historical and archaeological literature while no consensus on the definition of "complex" has yet to appear. Nomadic societies are still largely understood as tribal and centrifugal thus stymieing political organization. Nomadic societies are often still considered vectors of trade in goods and ideas rather than full agents that manipulate and transform those goods and ideas. Finally, nomads are considered to be extremely vulnerable to climate change where droughts or winter storms can completely upend even basic subsistence and lead to mass migrations, raids, and invasions. Climate science has intersected with historical explanation to add new credibility to old environmental determinism. How these social, economic, and political processes may have unfolded in the steppes is also unclear. The fall of the U.S.S.R. has opened access to archaeological sites throughout Asia and historians have largely renounced the model of the barbarian as a means to explain cultural others both of which have made large strides in understanding nomadic societies in relation to themselves and others. Ethnocentrism of Western scholarship is receding quickly and gradually we are beginning to see the nature of nomadic societies as fundamentally human and complex.

However, modern developments in academia which saw significant specialization and localization of research has created fault lines within and between history, archaeology, anthropology, and many social sciences. While interdisciplinary research is increasingly encouraged and funded, there still are no clear ways to go about synthesizing a wide array of theories, hypotheses, data, and methods besides *ad hoc* assemblages needed to understand specific questions of nomadic history.

Although this research cannot promise a panacea for disciplinary divisions, an interdisciplinary framework for understanding historical nomadic societies and other societies in comparison will be introduced. Frameworks that introduce broader ways of thinking about problems have transformed fields such as technology and bioethics and allow researchers to escape the troughs of sub-fields and the phenomenon of "learning more and more about less and less."

The framework here combines rarely acknowledged parallel epistemological and heuristic threads between contemporary historical thinking and complex systems science. Historians see human affairs as non-linear and somewhat unpredictable and complexity thinking, out of a need to better understand how real-world systems work, has decidedly eschewed the notion that any system can be closed or studied in isolation. Many intellectual activities can be theorized as some kind of modeling as any scholarly attempt to connect patterns to principles distills reality into digestible explanation. In this way, humanists and scientists conduct, at a high level, investigations that reduce the uncertainty of reality using verbal and external means. No longer do historians and scientists stand at the opposite ends of the law-finding/descriptive spectrum. Historians who previously rejected empirical certainty and one-answer equations by quantifiers now find more in common with scientists interested in the non-linear, often unpredictable behaviors of complex systems such as human societies. A focus on general processes of social evolution, organization, and interaction is already found in World and Universal History but here the addition of complex systems as an equal part in both theory and method is more rare.

Second, complex systems research—systems that have many interacting parts that add up to more than the sum of the parts—often require very precise data, sometimes generated by simulation which is often not available for the distant past. In this case, an agent-based model is created to understand how patron-client relationships may have formed around wealth inequality and how a variable environment can intersect with an intensification of inequality and hierarchy. Agent-based models (ABM) are computational models in which hundreds of independent, heterogeneous, interacting virtual agents are programmed with simple rules but create unfolding, sometimes complex, collective behaviors. The agents are autonomous leading to the bottom-up emergence of group behavior which can be compared against existing theories and historical case studies.

Results of the ABM reveal that given a relatively equal start on a variable resource surface, over time, the artificial society of agents quickly becomes unequal. Although much ethnography of the past argued that nomadic societies were egalitarian by default, this assumption is easily overturned by studying contemporary pastoralists, patron-client relationships, and elite burials of the past. As a result, poor agents approaching destitution attach themselves to a patron agent who is richer and able to share their resources for labor and potentially loyalty. This rule yields hierarchical networks where patrons continually attach clients to themselves in each time step. So long as we assume differential access to resources and an uneven distribution of resources, inequality is very likely.

Further, potential patrons also compete with one another for clients but purchasing prestige goods from historical trade cities such as Greek Black Sea colonies, Silk Road cities in Central Asia, and China. Patrons that could access these prestige goods and set themselves apart from other patrons enjoyed preferential attachment—clients preferred to attach to the most prestigious patron. This reflects the historical reality that nomadic leaders, just the same as agrarian ones, sought to cultivate political legitimacy and power though, of course, this was achieved by many different strategies. Legitimacy, charisma, and cultural beliefs could solidify loyalties while strategies of political repression or discipline could tether clients to elites. Centrifugal forces are, of course, present in all human societies, but the assumption that they always lead to a quick collapse of an internal order are not always supported by the evidence.

Finally, climate change and therefore resource stress was introduced into the model to investigate how it might interact with socio-economic hierarchy. By depressing the simulated world's resources, agents move longer distances, sometimes migrating to one side of the world space where resources were more reliable. However, climate change did not necessarily create chaos but triggered adaptive strategies of higher mobility and increased reliance on patrons' shared resources. Further, after resources returned to normal, the increased hierarchy becomes the new normative structure and the networked sub-society can take advantage of greater resources. This result challenges us to think about how climate change and climate shocks might have diverse outcomes depending on the social organization of the society in question and also the order and types of climatic events occur in succession. Climate productive for biomass growth could be effectively wielded by an organized society in pursuit of empire but abundance might also encourage local organization as a superstructure provides few extra benefits.

Proposing new frameworks for thinking about nomadic history and generating new models, or formalizing and extending old models, holds the potential to better integrate nomadic societies into the fold of the global human story. While narrow research continues to provide invaluable local cases, comparative frameworks of human societies, rather than typologies or particularism, is also needed to understand inter–regional interactions that shaped the course of premodern history but also the past of the current world-system.

This dissertation is arranged into four substantive chapters. Chapter 2 will delve deeper into the "nomad other" model of nomadic societies and how little data and crude assumptions have long convinced authors that the Eurasian steppe and its inhabitants were fundamentally needy and barbaric. The chapter will also review more recent research and how the narrative is changing, though somewhat limited by the available data and frameworks accessible to the historian.

Chapter 3 will define complexity and complex systems in more detail as an approach to understanding societies and how history and complexity have recently and unexpectedly overlapped in philosophy if not in method. A review of computational and mathematical models round out the chapter to illustrate how they can be useful to study human societies of the past and be used as cognitive tools to generate better theory.

Chapter 4 details the data and methods of the study. An ABM will be created step-by-step by modifying Epstein and Axtell's *Sugarscape* model and introducing important modifications to address primary research questions. Results and limitations of the model will be discussed.

Chapter 5 presents an elaboration of the model results in light of historical, archaeological, and ethnographic research as well as interpretations of the results within the discussion of complex systems. Future directions are also discussed regarding interdisciplinary frameworks and modeling nomadic societies.

Chapter 2

The Challenge of Nomadic History

History will never reveal to us what connections there are, and at what times, between science, art, and morality, between good and evil, religion and the civic virtues. What it will tell us (and that incorrectly) is where the Huns came from, where they lived, who laid the foundations of their power, etc.

—Isiah Berlin quoting Leo Tolstoy, *The Fox and the Hedgehog*

2.1 Stating the Problem

The rise of premodern nomadic power in large-scale political structures such as kingdoms and empires is a critical question still heavily debated in historical disciplines. For example, the Scythians, Alans, Xiongnu, and Huns vied with antiquity's Persian, Hellenistic, Chinese, and Roman Empires. In the Medieval Period, the waves of Turkish and Mongol empires and their afterlives shaped history centuries afterward. The Mongols are even blamed for stunting the growth of the modern world. The fall of the USSR and subsequent increased access of international archaeologists as well as theoretical developments in history have reopened the question of nomadic power, social organization, climate-driven events, and interaction with the sedentary world in a powerful way. Many scholars of the 20th century relegated nomadic, pastoral, and hunter-gatherer societies to historical prototypes or obsolete forms of intensive agrarian and industrial societies. However, more recent scholarship has cast nomadic societies in a new light. Nomadic societies are differentiated and increasingly complex rather than dependent, egalitarian, poor, and warlike. However, while new interpretations continue to grow, disciplinary boundaries have moderated attempts to combine multiple lines of new evidence.

While we know that Ghengis Khan's Mongols professed, at some point, the desire to conquer the world and the many ways in which he and his successors legitimated their dominating positions, how hierarchy formed in nomadic societies is still somewhat of a mystery. While we know the military tactics and technologies that helped their armies defeat so many rivals, how social forces wrangled a stratified, ethnically diverse army into an organized campaign is unclear. How did mobile pastoralists who lived in very different ways than settled farmers and palatial lords, who lived in low densities in the steppes of Eurasia, and who were largely illiterate organize themselves into powerful socio-political forces? How nomadic families, clans, and tribes may have networked to form hierarchies is of chief concern here; specifically, how nomadic people may have networked as a response to economic and environmental variability as well as the social structures that formed from these connections in time and space.

A word of caution is necessary when discussing the state of the field as data and knowledge is hardly uniformly distributed across geographic and temporal extents. For example, much of the territorial extent of contemporary Kazakhstan has not been mapped historically or archaeologically. It is not, though, merely a matter of synthesis as the archaeological evidence does exist has not received a comprehensive evaluation as more data-rich cultures and the kinds of artifact distributions necessary to map regional patterns are non-existent for early periods (Brosseder 2015). Inner Asian studies and what we might call "Silk Roads" studies not only has a high bar for access to relevant written sources but historians and archaeologists largely work separately making synthesis difficult (Christian 2000). As for archaeology specifically, only a “bare outline” exists regarding the networks that may have connected archaeological sites and how they fit into polities, states, and empires (Honeychurch 2014). Still, even if the kind of rich data available to us for Outer Eurasia is not available for Inner Eurasia and theories can be lacking, this only means there is plenty of room for modeling, thought experiments, and theorizing in order to shape historical and archaeological research for the future.

As this research is fundamentally concerned about models, a survey of what I call the "nomad other" model is needed to unpack the data and assumptions that have led to narratives of nomadic society and its members as inherently needy, greedy, and belligerent, wandering the empty wastes of the Eurasian Steppe. An extended discussion of models and modeling in the humanities and sciences can be found in Chapter 2. However, we might define a model as a flexible, general-domain tool that allows us to advance explorations and explanations about phenomena, typically by distilling and restructuring information.

Bohr’s model of the atom with its central nucleus and orbiting electrons is a famous model that uses an external representation to communicate the structure of an atom. This model is considered "external" because it presents knowledge of structure or process as a physical manifestation sometimes with the purpose of expanding the limited capacity of working memory (Zhang and Wang 2009). An internal representation is an idea or image in the mind, invoked or communicated through narrative, speech, or image but is difficult to diagram precisely. Because science is typically interested in explaining how biological and physical systems operate, we might define modeling as “the act of providing the best possible description of one’s understanding of the relevant aspects, both statistical and deterministic, of the process of the mechanism (the real-life phenomenon) that generates the data of interest” (Belsley 1991). But creation stories, written histories that go beyond the chronicle, and some works of art seek to combine a fraction of temporal developments or a message into a narrative arc. Historians have often sought to explain why events occurred the way they did. Thus, their narratives also seek to communicate the relevant aspects of the process that generate the events. Beyond a story or a representation either in visual or narrative form, Barbara Tversky argues that “a model generally does more than represent. It is meant to go further, to encourage thought, to allow inferences, discovery and creative leaps. It’s a thinking tool” (Tversky 2018). In short, many things can be considered models, or types of models, that seek to connect patterns to principles as a function of explanation. The review below will treat historical and anthropological narratives as models with implicit or explicit assumptions, data, and logic.

2.1.1 The "Nomadic Other"

A model is considered ineffective when the assumptions underpinning it are found to be weakly grounded in the available data and theory or when another model more adequately explains the process in question. While not all scientific models are effective and not all humanistic ones are ineffective, they can be critiqued more easily as models rather than simply the veracity of the data fed into them. A survey of the “nomad other” model—developed by many writers across several cultures—–which depicts nomadic society and its members as inherently needy, greedy, and belligerent, wandering the empty wastes of the Eurasian Steppe is needed to deconstruct the fundamental modelling assumptions.

Models that are primarily informal—models that include non-precise components—and verbal are not necessarily unpacked and investigated the same way formal models can be deconstructed. Formal models differ from their informal counterparts by precisely stating their components which also makes them well-defined during communication. Component and parameter informality is at once a strength and curse as they become flexible enough to apply to a wide range of situations but weak or culturally-biased assumptions can endure for decades and centuries without a second glance.

The "nomad other" model is one such informal, mostly verbal, model that has been perpetuated in writing for millennia. We might read the caricatures of Scythians, Huns, and Mongols as marauding warriors as literary tropes, but hidden between the lines are assumptions about human-environment relationships, cultural evolution, and the categories of civilization which add a logical legitimacy to them. While scholars in the historical disciplines have moved away from the "nomad other" and crude descriptions of nomadic-pastoralists, the model has evolved to accommodate similar assumptions about the barren steppe and the destitute lives of nomads—this time as needy or victims.

This model has been and continues to be predominately articulated informally and verbally (that is, through narrative) which has allowed it to ossify as natural (Pennebaker and Banasik 1997). Thus, the "nomad other" model is weak on the grounds that the only relevant aspect is the connection between a different (poor) environment and fundamentally different society (barbarian). Most histories of historical nomadic polities, states, and empires usually begin with primary source accounts and here I will review these just the same with an eye towards bridging the similar dynamics discussed by various authors through time.

A long tradition of illustrating nomadic societies as exotic, violent, and poor peoples living in a desolate environment survived in part by little contact between those of the sedentary literati classes and nomadic cultures. In addition, early models of the development of human societies reduced nomadism to a stepping stone to whatever was familiar to the writer's culture—likely intensive agriculture or industrial capitalism. For example, the Roman writer Marcus Terentius Varro formulated a model of human economic evolution in which each society would visit each stage along the way to agriculture. He writes:

> ...the remotest stage must have been the state of nature when man lived on those things which the virgin earth produced spontaneously. Then from this mode, the pastoral, in which, by plucking from wild and woodland trees and shrubs. . . they made a store of fruit for subsequent use, and in the same way and for the same end captured such wild animals as they could and shut them up and tamed them. . . milk and cheese were added to his food, and for his body they furnished clothing in the shape of skins. . . finally, with the third stage, they reached, from the pastoral mode of life, the agriculture... (Kramer 1967)

As they often do, histories about nomads begin with Herodotus (484-425 BCE), the Hellene historian and geographer. His Histories remains the oldest known, extensive work that deals directly with nomadic pastoralists neighboring the Hellenic World of the Aegean littoral. Most of book four of the Histories describes the Scythian and Sarmatian societies——ethnogenesis, geography, gender relations, military——considered very relevant in connection to the Persian Achaemenid Empire and particularly Darius I's Scythian campaign. Herodotus, though he traveled to a town near the Danube to collect information from locals and other travelers, learns about Scythia and the Scythians through intermediaries. Whether it was his frame of reference or his informants', Herodotus describes Scythia as an extreme in relation to temperate and civilized Hellas. Scythia is considered the extreme north while Libya (or Africa), which finishes the chapter, acts as an extreme south. Of Scythia's climate he writes:

> So a winter of this severity [water and soil completely freezing over] lasts for eight months, and for the remaining four months it is still cold there. Winter in this part of the world is also different in kind from winters anywhere else in the world, in that it hardly rains at all, as one would expect in this season, but in summer it never stops raining. At the time when thunderstorms occur elsewhere in the world, they do not happen there. . . (Herodotus 2008, 244)

Herodotus also makes connections between environment and culture: "The Euxine Sea—the region Darius invaded—is home to the most ignorant peoples in the world" but, to be fair, also states "I exclude the Scythians from this judgement" but adds "in other respects [other than their ability to retreat and use mobility to their advantage] I do not find the Scythians particularly admirable"(Herodotus 2008, 250).

Further, Herodotus claims that there is not anything interesting about Scythia. He writes: "The land does not really have remarkable features except for the size and number of its rivers" and is treeless and by the time Darius and his army reaches the Oarus River in modern-day Ukraine, Herodotus reports that they found it "empty" not just of people but natural features as well (263, 276). And of the peoples lurking in this vast region: Cannibals, man-killing Amazons, and possibly (though he doubts this claim) werewolves. Tropes of emptiness, barbarity, and the connection between "extreme" environments and salient cultural difference are already present in the Histories.

Another account of the Eurasian steppes and its human inhabitants comes from Sima Qian (c. 145-86 BCE), the Chinese historian that wrote during the Early Han Dynasty (206 BCE – 220 CE). His Records of the Grand Historian or Shiji contains an account of the nomadic Xiongnu that were suzerains of the Mongolian or Eastern steppes north of China. Although clearly not influenced by Eastern Mediterranean rhetoric, Sima Qian produced an environmentally deterministic model of nomadic society.

He writes of the Xiongnu: "The Barbarians of the west and of the north are ravenous wolves who cannot be satiated. . . [they] are greedy and grasping; they care only about profit" (Sinor 1990, 5). This reflects the general view of non-Han peoples but particularly those to the north and west who vied for political supremacy. Ban Gu remarks on Sima Qian's Xiongnu memorial: The Yi and Di people are greedy an desirous of gain. . . they have human faces but the hearts of wild beasts". He follows this description by arguing that because "they are separated from us by mountains and valleys and cut off by the desert" and "their land cannot be cultivated so as to produce food. . . for these reasons they are kept outside and not taken as relatives, they are kept distant and not accepted as kin" (Chin 2010, 317).

The Roman writer and soldier Ammianus Marcellinus (c. 330– 391 CE) echoes some of the exact same tropes hundreds of years later. Despite admitting that "Massagetæ, the Alani, and the Sargetæ, and several other tribes of little note, of whom we know neither the names nor the customs" (Marcellinus 2009, 292). Marcellinus goes on to describe various nomadic tribes as groups whom

> a small part of whom live on grain. But the rest wander over vast deserts, knowing neither plough time nor seedtime; but living in cold and frost, and feeding like great beasts. They place their relations, their homes, and their wretched furniture on wagons covered with bark, and, whenever they choose, they migrate without hindrance, driving off these wagons wherever they like. (293)

Marcellinus directly invokes the idea of the steppe as a desert, bestial culture, but also an assumption that nomads freely migrate seemingly randomly.

As to be expected, he also derides the Huns who the Romans dubbed "The Scourge of God": "In truces they are treacherous and inconstant, being liable to change their minds at every breeze of every fresh hope which presents itself, giving themselves up wholly to the impulse and inclination of the moment; and, like brute beasts, they are utterly ignorant of the distinction between right and wrong"(580). Clearly, perhaps like Herodotus, Marcellinus is describing nomadic societies without much first-hand information and filling in the gaps by modeling them as decidedly opposite of Romans who, we are urged to imply, are sedentary, stable, rational, consistent, and trustworthy.

Giovanni da Pian del Carpine (1185 – 1252 CE), or rendered in English as John of Plano Carpini, a prominent member of the Franciscan Order, was the first European to travel to and witness the Mongol political system and war machine. He traveled from Eastern Europe to Mongolia as the Pope's legate to deliver a message to the imminent new Great Khan, Guyuk, after Ogedei's death. Giovanni wrote a narrative of his 3000-mile journey and a more formal history Ystoria Mongolarum after his travels. The travel narrative is typical of the genre and does not, despite some ill-treatment by soldiers and illness, attempt to make sense of the society of the Mongol Empire. He reports while traveling through contemporary Ukraine that:

> We travelled through this country (of the Cangitae) from the eighth day after Easter to nearly the Ascension of our Lord. These people are pagans, and the Comans as well as the Cangitae do not till the soil, but only live on the produce of their animals; nor do they build houses, but live in tents. The Tartars have also annihilated them, and now occupy their country; those of them. who were left they have reduced to slavery.(De Plano Carpini 1903, 13)

The author reports details as matters of fact with little interpretation. Giovanni was likely learning as he went, and quickly it was.

Giovanni's Ystoria Mongolarum written after the travel narrative is much more congruent with writings of antiquity—arrayed in thematic chapters and venturing into an orderly explanation of a nomadic social system. Like many such writings ancient and modern, it begins with a description of the land—"Of the situation and qualitie of the Tartars land". Here he describes Mongolia as "In some part thereof it is full of mountaines, and in other places plaine and smoothe grounde, but euerie where sandie and barren, neither is the hundredth part thereof fruitefull. For it cannot beare fruite vnless it be moistened with riuer waters, which bee verie rare in that country (108). In addition, he also seems to have received hyperbolic reports that lightning kills many people during the summer and that even Chinggis Khan was "slain by a thunderclap" (120).

Weirdness and ferocity of nature finds its way into the descriptions of the Mongols themselves. Although he mentions the "good" qualities such as loyalty to their leaders and chaste women, likely something he wished of his own Europe, he describes their negative qualities at length. Not only do they look different than anyone else, but they are also brutal beyond belief:

> The Mongols or Tartars, in outward shape, are unlike to all other people... Moreover they are angry and of a disdainful nature unto other

> people, and beyond all measure deceitful, and treacherous towards them. They speak fair in the beginning, but in conclusion, they sting like scorpions. For crafty they are, and full of falsehood, circumventing all men whom they are able, by their sleights... The slaughter of other people is [accounted] a matter of nothing with them. (De Plano Carpini 1903, 109–111)

Genre certainly plays a role in the differences between the travel narrative and the explanatory history. Whereas one is more like drive-by journalism, the other needs to make sense of what was seen and heard for an audience. But there are also other factors that lead to the creation of books like the Ystoria. Encountering a new culture can be overwhelming, especially if the environment, climate, and sensual experience are different than one is familiar with. This partial confusion can be ameliorated with a model. For example, Timothy Mitchell illustrates how world exhibitions became a tool of representing the world, particularly the non-Western world, as a series of essential, cultural models. Microcosms of Egypt and the Middle East more broadly were presented as collections of half-real-half-imaginary architecture, fashion, and customs. These models were necessary, perhaps in a crude sense, to make sense of otherness. As Flaubert wrote in a 1850 letter from Cairo:

> What can I say about it all? What can I write you? As yet I am scarcely over the initial bedazzlement... each detail reaches out to grip you; it pinches you; and the more your concentrate on it the less you grasp the whole. Then gradually all this becomes harmonious and the pieces fall into place of themselves, in accordance with the laws of perspective. But the first days, by God, it is such a bewildering chaos of colours... (T. Mitchell 1989)

As a result of this bedazzlement but also given economic and political interests in the region, world exhibitions became a place to model other cultures. For example, along a boulevard a façade of a mosque attracts the eye but becomes a café once one is inside selling “authentic” Egyptian pastries (298–299). This bewildered Middle

Eastern guests who struggled to make sense of what was being communicated. Indeed, these exhibits were bad models as the borders between the fake Egyptian city and Paris were vague. Likewise, models of various kinds are vulnerable to becoming descriptive but lacking a coherent explanation of a process or system.

The modern period continues to depict Central Asia as a place of fundamental difference and emptiness. The geopolitics of The Great Game and World Wars shaped the definition of Central Asia for much of the 19th and 20th centuries but likewise determined the region to be basically empty of both geographic features and human features.

In 1904, Halford John Makinder wrote his influential article "The Geographical Pivot of History" which contended that ultimately the regions of the "World-Island" (Afro-Eurasia), "offshore islands" (Britain, Japan), and "outlying islands" (the Americas and Oceania), were the fundamental super-regions of any political or economic interest. In the middle of the World-island lay the "heartland" or "pivot area" which corresponded to Eastern Europe and the Russian Empire. To Makinder, controlling the heartland meant controlling the world-island and thus the world entire. However, his depiction in both narrative and map essentially value Central Asia as, opposed to European nations, a "pivot" a "vector" by which European power can be projected—an inert place of political dreams and historical terrors. Mackinder acknowledges the important connection between geography and history, contending in On the Scope and Methods of Geography that to deny geography of history or vice versa yield a future where "the scientist and the historian, will lose their common platform. The world will be the poorer" (MacKinder 1887, 173). His understanding of that connection is made clearer in respect to Central Asia:

> For some recurrent reason—it may have been owing to spells of droughty years—these Tartar mobile hordes have from time to time in the course of history gathered their whole strength together and fallen like a devastating avalanche upon the settled agricultural peoples either of China or Europe...A large part of modem history might be written as a com-

> mentary upon the changes directly or indirectly ensuing from these raids. (MacKinder 1887, 70, 180–181)

Where does this geographer and historian think these people come from? Like earlier writers, Mackinder both reproduces but also adds an interesting critique of map and knowledge to the image of the Eurasian steppes.

> It [the Hill Bank of the Volga] is the brink of the inhabited plain, here a little raised above the sea level. Stand on the top of this brink, looking eastward across the broad river below you, and you will realize that you have populous Europe at your back, and, in front, Where the low meadows fade away into the half sterility of the drier steppes eastward, you have the beginning of the vacancies of Central Asia.(Mackinder 1942, 83–84)

Although Mackinder obviously valued history and even considered the historical presence of pastoral-nomadic peoples to be important in the grand narrative, ultimately, he still depicts Central Asia as “vacant”, “sterile”, and “uninhabited” only spewing forth raiding barbarians on unsuspecting agrarian societies. More importantly, he makes an explicit connection between the environmental sterility of the steppes and both the cultural geography and its strategic importance as essentially empty of any content. This connection between a destitute landscape and extreme behavior would not go away anytime soon.

Bringing the narrative to the latter 20th century, historians sought to update the grounds of the model with more robust political histories and a touch of environmental science thanks to the philological work of decades past, but ultimately the fundamental assumption of environmental determinism of barbaric culture remained entrenched even despite emergent, complex histories.

The Cambridge History of Inner Asia, first published in 1990 but containing contributions from decades before is a good example of how the nomad model had endured nearly unchanged even with the benefit of significant change in the knowledge landscape. The editor of this volume, Denis Sinor, who composed the introduction doesn't simply update the model but directly appropriates it from ancient writers. He quickly dispenses the definition of the region, as Jan Nattier informs us who reviewed the volume, as essentially everything outside of the Middle East, Europe, India, Southeast Asia, and East Asia and therefore a product of excluding the well-known regions of the world rather than including a historically unique area (Nattier 1991).

When attempting a positive definition of the region, that is by things that exist, he cannot seem to find any: "Were there any objective criteria specific to Inner Asia taken as a whole? If they once existed, today they are no longer discernible, the links which usually hold together or create a cultural entity—such as script, race, religion, language—play only a very moderate role as factors of cohesion" (Rossabi and Sinor 1991, 14). He settles into a definition of fundamental economic and cultural difference:

> It would seem that the most workable definition... must remain the relative economic and cultural standard of the area, not its absolute content: it is that part of Eurasia which, at any given time, lay beyond the borders of the sedentary world. To be a part of it involved the practice of specific modes of production and permanent opposition to a more prosperous outer world. (16)

The image of the inhabitant retains its crude outlines despite its relatively scientific character. Sinor argues that despite the complexity of the cultural and political borders between the steppe and sown and the emergence of political histories that

> such actions should not be allowed to obscure the basic nature of the opposition between Inner Asia on the one hand and any of the sedentary civilizations on the other. In essence, it was on between haves and have-nots, the latter trying to reach the proverbial flesh-pots defended by those who had been lucky enough to places themselves close to the hearth. (4)

Sinor goes on to contend that "The Barbarian exploits the natural world which the Civilized tries to improve; there is between the two a basic difference in outlook, rooted in distinct evolutions extending over millennia" (Rossabi and Sinor 1991, 12) and which yields cultures without significantly important writing systems, religions, or art (14–16). In sum, he concludes "what peace can there be between hyena and dog? And what peace between rich man and poor?" Inner Asia is the antithesis to "our" civilized world. Its history is that of the Barbarian" (18). Sinor completely appropriates the tone of Sima Qian and the geographic determinism of Mackinder before any evidence is presented, coloring the otherwise productive political histories that follow.

The following chapter "The Geographic Setting" written by Robert N. Taaffe seems quite out of place after Sinor's introduction as it thoroughly describes the geographic and ecological areas of this region they have defined. Taaffe's emphasis on diversity, productive roles of mountains for grazing, and overall non-isomorphic picture of Inner Asia seem to be at odds with Sinor's conclusion and hints at alternative readings of the landscape. Most notably, he is not only concerned with human mobility and the affordances of travel and communication:

> In discussing the physical-geographic differences and similarities of the arid and semi-arid natural zones located on opposite sides of the mountainous divide from the Pamir to the Altai, the feasibility of movement and interaction across these mountains also should be emphasized. Despite their imposing elevations and relief patterns, major corridors of movements through them exist and have been used intensively. (Taaffe 1990, 39–40)

The geographic descriptions in this chapter would likely be little changed in today's literature but the fact that Taaffe says almost nothing about what such a varied landscape means historically or socially in relation to the other arguments in the volume presents it as a solitary island of raw data to be used by other authors as they will.

This is evident not only in Sinor's introduction but in the chapter that follows Taaffe's "Inner Asia at the Dawn of History" in which A.P. Olkadnikov and Julia

Crookenden lean into the nomad model once again. In attempting to find something interesting about the space of Inner Asia he remarks:

> It would seem to go without saying, one might almost say it would be a priori, that these lands on the Asian continent would be of special interest to the historian from the standpoint of the interaction between man and nature. The peculiarities of natural conditions there would of necessity have left their mark on the course of historical development, on the nature of cultural creativity, and on man's struggle for existence (Okladnikov and Julia 1990, 42).

Further, Olkadnikov also finds the most historical interest in the nomadic invasions of Europe: "Suffice it to recall the upheaval that brought about the eruption of the Huns into Europe, or the dramatic events connected with the eruption of Chinggis Khan's forces into that selfsame Europe seven centuries later" (42). However, this is not to say that Olkadnikov's chapter is completely rejecting all possible worlds as he acknowledges, though still clinging to environmental limitation, that "the interaction of local peoples and environment took place" could "be of less importance" or "uninteresting to anyone interested in the course of the world historical process during antiquity" (42). To be sure, all the writers mentioned so far had the same spark of curiosity that I and the reader also share. The point here is, again, the foundation of historical knowledge resting on sometimes weakly warranted models.

Interaction, even if it be military invasion, is a critical point in understanding nomadic societies of the past. Even if scholars acknowledge the emergence of complex nomadic polities in the steppe, it is typically not attributed to endogenous factors but dependence on critical goods of neighboring settled societies (Barfield 1989; Jagchid and Symons 1989, 165). Further, Thomas Barfield argues that nomadic power "rose and fell in tandem with native Chinese dynasties because they were parasitically attached to them" (Barfield 2009, 34). Therefore, according to this line of thinking, it was not the social organization or institutions of the nomads that led to their rise to power but because they could steal what they needed from the affluent Chinese empire.

The rise and fall of nomadic states and empires was not only due to their deprivation, so it goes, but because of their vulnerability to climate. For example, Ellsworth Huntington's *The Pulse of Asia, a Journey in Central Asia Illustrating, the Geographic Basis of History* posits that the primary motivator of historical change and migration of peoples in Asia was the "pulse" of dry and wet periods (Huntington 1907).

However, there is not anything particularly special about these narratives. Ulrich Haarmann argues about Arab anti-Turk prejudice: "Ethnic stereotypes are symbols. They serve as rationalizations of underlying and—to a certain degree—perfectly normal interethnic prejudices" (Harrmann 1988, 176). Especially in the case of early accounts of Herodotus and Sima Qian, Siep Stuurman argues "even when these ethnographies contain negative judgements and stereotypical representations, they present us with the first step toward an appraisal of the rationality of foreign ways" (Stuurman 2008, 3). And this is the point; mental models which often take on a life of their own, in order to reduce uncertainty and rationalize the world, often from one's own privileged perspective, collapse reality and endure so long as little new information permeates the society. Even with new information, foundational assumptions must also be reexamined which is more likely to occur when a realignment becomes beneficial. For example, Thucydides' secular, analytical history sought to explain historical events in a complex way—humano-centric, cause and effect—rather than god-centric or bardic. However, by doing this, he alienated the Greek populace who found the traditional narratives sufficient and more amenable (Stephens and Breisach 2007, 18).

Moreover, we should understand that there has always been variance in the ways in which writers, even from the same culture, write about nomads or foreigners in general and that descriptions are not always negative. For example, Arab writers were inconsistent about their descriptions of Europeans to the north, such as the

Volga Bulgars and Vikings; some described people from "the land of darknesss" as liable to kill travelers on sight while others were described as brave and friendly(Attar 2005). Although Sima Qian seemed to have little good to say about the Xiongnu, he was arguably challenging the status quo of ethnography in Han China by following up old stereotypes with new information. For example, after describing the Xiongnu as having no writing, Sima Qian then discusses how the Xiongnu write formal diplomatic correspondence with the Han, undermining the initial statement (Chin 2010, 332–333).

2.1.2 Mapping Central Eurasia

This litany of perspectives is necessary in order to understand many modern conceptions of Central Asia and of nomadic society. However, narrative models are not the only way in which scholars have relegated nomads to the discursive periphery. Maps also also contribute to the "nomad other" model though rather than saying too much, say too little. Maps are imminently useful not because they include everything but because, like all models, they leave out unnecessary details and allow the reader to focus on perhaps one or two particular themes, questions, or sets of information (Miller and Page 2009, 36). If a map of a region's history does not include an entire group of societies then the modeler has implicitly argued that this group is not a "relevant aspect" to that history. Maps are models and images but can take on a unique form of objectivity and validity that is more subtle than traditional rhetoric (Harley 1989). Thus, a void in the map is a void in academic discourse, historical consciousness, and thus how we believe the world was/is interconnected. Only specialists might understand that there really was something quite dynamic in the empty spot on the map.

Perhaps the most visible and influential set of historical maps related to Central Asia is Yuri Bregel's An Historical Atlas of Central Asia (Bregel 2003). The Atlas illustrates a geographic history of the region of, decidedly, former Soviet Central Asia from prehistory to the 20th century. Bregel's atlas is not just "An Atlas" but "The Atlas" as it has become the definitive historical geographic reference for the region. This work is the compilation of every known settlement, cultural area, political boundary, and military campaign that could fit into a series of maps and has been an invaluable resource for scholars for decades.

However, the maps have a very uneven distribution of features and an unequal emphasis on sedentary, agrarian civilization. While the northern half of the map, largely representing the Eurasian steppes and deserts, is nearly completely empty of social features such as settlements or political boundaries, the southern half of each map is brimming with points, lines, and polygons to represent societies of Transoxiana and Northern Iran. The steppe region only receives large banner text to act as a placeholder for the "Oghuz" or "Qipchaqs" but nowhere to be found are any analogue to the settled towns, cities, areas of influence, trade routes, etc. Not until the Tsardom of Muscovy and the Russian Empire enter the geopolitical arena, does the steppes receive anywhere near the amount of detail as the southern half.

An Historical Atlas was a valiant effort and one that should be applauded for its thoroughness to be sure, but as a kind of model, the maps contained within depict what the modeler, Bregel, knew and thought to be most relevant with the former being mostly out of his control.

Although not explicitly a study of Central Asia, the Atlas of Islamic History follows much the same pattern, only fleshing out the steppe region when the Russian Empire emerges (Sluglett and Currie 2014). Even when the steppe receives features, they appear, again, as banner text, arrows denoting the general path of invasions, and political boundaries. In this narrower case which is a history of Islam and generally of the Middle East, North Africa, and Iberia, has a more significant blind spot for nomadic societies as the Arab culture that founded Islam was semi-nomadic and successive waves of Turks and Mongols as well as many successor dynasties such as the Timurids, Mughals, Safavids, Ottomans, and many more founded Islamic states and empires or came to convert after initial conquest.

Both atlases depict cities that carry some meaning beyond their location. Cities reveal where people live (and not living) and the arena in which politics and history occur, circumscribed by political boundaries. In a later map , lines circumscribe areas of the steppe marking Kazak, Oyrat, and other nomadic groups but now with dotted lines but still no features, and many fewer features overall, within these borders. Thus, because they lacked first-hand experience with nomadic societies and needed to justify their place within existing political or ethno-centric worldviews, writers from vastly different cultural and temporal contexts conceive of nomadic societies as, largely, brutish, morally uncouth, and greedy/needy. Direct links between the destitution of the “vast”, “empty” steppes and savagery are common. At best, nomadic groups are left out entirely given a paucity of geographic data. The picture is not complete, however, and much is to be said and praised about recent research as well. Though, as we see, some of the old ideas have been difficult to easily replace.

2.1.3 Complex Nomads

After reviewing centuries of narratives about nomadic societies, one could move in any number of directions and focus on any subtopic whether it be the geography, written history, or archaeology of Central Eurasia to confirm or challenge perceived blind spots of the past. Any subfield or process could potentially benefit from a verbal or formal model. This section will review more recent developments by theme—interactive networks, hierarchy, and climate—to elucidate how different disciplines approach studying nomadic societies and how they both overturn but sometimes extend old models. This approach seeks to clarify and refine some critical aspects of nomadic societies in preparation for modeling.

Interactivity and Interdependency

The long-held assumption that nomadic societies, particularly politically organized ones, were nearly or wholly dependent on sedentary neighbors has received much challenge in recent years. The dependency theory arose no doubt due to many intersecting ideas but two primary ones are most relevant to this research. First, anthropological thought was heavily skewed by the study of modern nomadic groups who had already been marginalized by industrial nation-states and their hegemonic borders. This will be discussed further under the topic of economic inequality.

Second, World-Systems Theory initially posited that the world economic system beginning sometime in the 16th century became increasingly connected with European then Euro-American nations becoming cores while other countries, particularly in the global south, became peripheral and dependent (Wallerstein 1987; Lawson and Wallerstein 1978). This scheme grew directly out of the Cold War terminology of the first, second, and third "worlds." These ideas of interconnection and hegemony was taken back as far as the first urban centers in Mesopotamia and Egypt to reflect on how Eurasia has been interconnected for millennia (Frank 1990; Abu–Lughod 1989). Thinking of the world as interconnected economically is relevant and useful for thinking about nomadic societies though nomadic societies usually get little attention as the rich documentary and archaeological economic records found in sedentary societies does not exist. At most, the Mongols are considered to be important due to their continent-spanning empire that connected China and Europe with unprecedented closeness.

Tom Allsen was perhaps the forefront of this attempt to elucidate nomadic societies as complex and took upon an investigation, notably in his monograph *Culture and Conquest in Mongol Eurasia*, to untangle cross-cultural exchanges between nomads and sedentary societies in Persia and China. Few other attempts are as wide-ranging and illuminating. He covers topics such as the transmission of knowledge concerning various traditions in historiography, geography, agriculture, cuisine, medicine, astronomy, and printing. He reveals how nomadic societies were agents of these transmissions in addition to various stages of screening, withholding, and transforming (Allsen 2002, 191).

Allsen also argues, at least implicitly, that the broader nomadic society is important. If “such possibilities of cultural transmission were embedded in the very structure of Mongolian rule and in the basic ecological requirements of nomadism” (5) then it stands to reason that not only was political economy important and whims of the Khans, but at some level the network structure of the commoners at the group level not only gave rise to information networks, geopolitical hierarchies, and administration but also facilitated cultural exchange to some extent. Leaning on Elman Service’s work, Allsen argues that “expansive societies, leaving their own physical and cultural environment and entering into a substantially different milieu, are of necessity more open to innovation and thus more adaptive” (197). If society broadly speaking are not the agents, then the history of cultural exchange is limited to a considerably small cast of characters, self-absorbed with their own small, elite societies.

If societies are innovative, adaptive, and complex, then the historical record generated by the elites gives us a good foundation but is hardly the limit of what we can understand about the cross-continental agency of nomadic societies or the extensive world-systems of the past. While Allsen did much to illuminate the history of nomadic peoples in Eurasia using the tools available he also opened the possibility of social scientific modelling by, even briefly, turning to in order to connect the patterns of exchange to some kind of principles of filtering and screening developed by anthropologists studying other cultures.

It seems clear that, to some extent, nomadic societies were not always dominated by their sedentary neighbors even when they did not possess a trans-continental empire. For example, the introduction of the chariot into Shang culture by the Karasuk culture of the Eastern steppe, along with knowledge of maintaining them and horse husbandry, was accomplished through nomadic social networks. Gideon Shelach-Levi argues:

Spatial patterns charting the distribution of materials, artifacts, cultural traits, and styles bolsters the hypothesis that the latter of the second millennium and first half of the first millennium BCE was a period of intensive mid- and long-range interactions. . . contact with the Eurasian steppe's pastoral and semi-pastoral societies was but one dimension of these robust networks that linked up an assortment of cultures and ecological zones (Shelach-Lavi 2014, 26).

Moreover, while it has been argued that nomads were dependent on Chinese prestige goods like metalware and textiles to bolster their political legitimacy and therefore lacking native strategies to do so, evidence suggests that Shang and Zhou kings used Central Asian chariots not for war but for legitimacy (Shaughnessy 1988, 209). Viewing this issue anthropologically, it becomes clear that the use of prestige goods is common across many cultures and was a widely used tactic to organize societies hierarchically (Johnson and Earle 2000). Moreover, nomadic empires on the Mongolian steppe did not rise and fall with Chinese dynasties in temporal lock-step nor did they always invade China for economic gain but also other nomadic groups (Drompp 2005).

This begs the question of not so much of dependency but interdependency of neighboring societies and how goods and information could travel along networks including what David Christian terms the "steppe roads" (Christian 2000). During the beginning of the first millennium BCE, the Eurasian steppes experienced increased aridity, pushing inhabitants to adapt to more specialized nomadic-pastoralism and away from agriculture. In turn, we start to also see the emergence of the Scythian state and a Scythian culture that came to dominate nearly the entire Western steppe region which was "a quite polyethnic political culture. . . represented by different synchronic and diachronic variants, which reflect temporal, spatial, and ethnic differences, inter alia, as well as foreign influences" and which was "shared across the entire region" regardless of polity or state (Khazanov 1994, 32–37). A robust and wide-ranging political culture emerging after a transition to serious nomadism implies that exchange is occurring on a broader scale and on real-world connections beyond just the elite. Prestige goods and wide connections suggest that the common people were engaged in symbolically consuming prestige goods and that information networks sustained common ways of symbolic valuation.

Premodern nomadic societies were clearly more stratified and less marginalized than many modern groups tend to be. Despite the influence of Barfield and Khazanov's arguments of nomadic dependency, a closer look suggests a mixture of *interdependency* and independence. The fundamental assumption that nomadic states rise and fall with Chinese empires due to parasitism is not completely true.

Economic Inequality

As already mentioned, anthropologists and historians used modern nomadic groups who typically have worse economic and health outcomes than their sedentary neighbors as a proxy for premodern nomadic groups. From the 1940s to the 1970s, scholars attempted to define a "traditional" and closed rather than a dynamic and open ways of life (Dyson-Hydson 1980, 16, 35). Moreover, due to the lack of well-organized nomadic states in the modern period, especially after the 18th century, many scholars assumed that pastoral societies were inherently egalitarian and without significant hierarchy (Salzman 1999; Borgerhoff Mulder et al. 2010). Dahl argued that pastoralism as a mode of subsistence was unable to accumulate wealth, like in a sedentary one, to delineate social strata. Burnham though that mobility allowed unhappy nomadic subjects to simply vote with their feet and leave a coercive leader. However, as Sneath makes clear, "the counterarguments do not appear to have been seriously considered—that rulers might also be mobile and have political relations with neighboring power holders" and that "the 'substrata of power' that underpinned each polity involved the construction of legal personhood in the form of rulers and subjects of various ranks, including slaves" (Sneath 2007, 186).

Besides socio-political positions, wealth in the form of animals and access to grazeland is always subject to quality of information and political economy. For example, Murphy shows how differential capacity for mobility, when, and where was correlated with herd loss due to extreme winter weather events such as one of the various types of *dzud* where an extreme amount of snowfall and/or ground freezing prevents livestock from grazing. thus, even without strictly political or legal force, inequality can manifest (Murphy 2011). *Dzud*-based losses are also, partly political as access to the best graze and especially areas protected the most from extreme weather are always defended by those who are able (3). However, the emergence of economic inequality in a pastoral setting is usually overshadowed by the emergence of political structures such as states and empires and more research is necessary.

Climate

Climate and environment is clearly a cornerstone of studies of Central Eurasia and nomadic peoples but the picture has become more complex. Often, the argument is that the Eurasian steppes do not provide the needed resources for survival or the development of complex societies. Further, nomadic societies are believed highly vulnerable to stochastic climate events such as droughts or severe winter storms. To some extent this is true. A combination of stressed carrying capacity and severe winter weather that causes the freezing of the ground or deep snow-have been known to result in high herd mortality (Begzsuren et al. 2004). However, climate events such as droughts have also been attributed to mass migrations, deprivation, and raids towards the south where the climate is more temperate and richer societies can be plundered.

Aridity increased the value of nomadic pastoralism as a strategy and the mobility that accompanied horse-riding allows herds and herders to exploit spatially distant resource patches. This flexibility throws the notion of exceptional climate dependency into question. The stochastic climate patterns of the interior steppes produces local, not necessarily global, patterns which in turn prompts local decision-making (Rogers 2012). This decision-making and the flexibility of mobile groups has produced a dynamic tradition of pastoralism despite major climatic fluctuations through time implied by thousands of years of nomadic history (Weber and Horst 2011). In parallel, there does not seem to be anything exceptional about nomadic vulnerability at least qualitatively because climate change—often expanding desertification of arable land—is often linked with the demise of Chinese dynasties as well (Wang et al. 2010; Elvin 1996). And as Bret Hinsch argues “an economy primarily dependent on agriculture, such as that of China, faced particular vulnerability to climate change” (Hinsch 1988). Similar arguments are made about the Roman Empire and Meso-America as well. Again, the question is really about which variables are important enough to include and in what magnitude. If we think that nomadic societies are especially vulnerable to climate fluctuations, then we need to specify to what extent rather than simply correlation.

Initial research has shown that nomadic invasions are correlated with climatic downturns but the picture is not entirely clear which causes lead to which effects and their probabilities. Nicola DiCosmo is a leading scholar on the effects of climate change on nomadic societies. He and colleagues studied long-term precipitation trends in Mongolia and argue that an increase in precipitation and biomass just prior to the Mongol expansion explains the rise of Chinggis Khan’s organized empire.

> Our tree–ring evidence now shows that rapid expansion of the Mongols after their unification is correlated with favorable climate conditions, which were conducive not just to increased pastoral production but to the political centralization and military mobilization that would make conquest possible (Pederson et al. 2014).

Bai and Kung echo these conclusions using more statistical, as opposed to case study, methodology. They find that nomadic invasions are "positively correlated with less rainfall and negatively correlated with more rainfall" both for Asia as well as modern sub-Saharan Africa (Bai and Kung 2011).

Another line of evidence suggests that a direct correlation using years of events might not reveal all the mechanisms or outcomes. Employing more sophisticated nonlinear statistical models common to econometrics, Damette, Goutte, and Pei show that "during a dry period, the push of climate change is strong enough to make nomads migrate mainly southward into the agrarian region of China" but this is evident only in a centuries-long dry period but not common in wet periods (Damette, Guotte, and Pei 2020). In addition, migration is not always southward towards the "rich" neighbor and if the precipitation events are not severe enough, other adaptation could result. Deeper dives into the data are beginning to reveal that over time and space, stochastic or continental weather trends do not always produce negative outcomes and reactions to weather by nomads does not always neatly fit the "raid or trade" narrative.

2.1.4 World and Universal History

One framework, though perhaps underdeveloped and unpopular, that could bring together disparate historical interests is Universal History which more or less overlaps with the concerns with World History but is even more focused on large-scale trends over long periods of time. Universal Historians do not seek to expunge differences between cultures, but often begin with assumptions of high-level similarities as a counterweight to the proliferation of very local studies.

This greater unit of the universe can, and usually is, sifted down to smaller more manageable units by professional historians yielding the “Mediterranean World” (Braudel 1949), “Islamicate World” (M. G. S. Hodgson 1977), the “Atlantic World” (Bailyn 2005), and so on. These worlds are conceptualized as spatial and temporal webs of salient interconnections that transgress nation-state centered histories.

Therefore, if these worlds are assumed to be coherent with identifiable characteristics–littoral communication, cultural unity, transnational identity–then it stands to reason that there are also yet more commonalities between these regions and, more importantly, to human societies at scale. Universal history takes this as an assumption of the approach.

The definition of universal and world histories is always debated but share an obvious convergence in geographic and temporal scope. World History, writ large, is the study of historical people, events, and societies at relatively large geographic and temporal scale, typically spanning several or many societies at once or in comparison. In general we can distinguish the approach from more recent historiography (approximately 1975 to present) in that temporal scope is necessarily greater than a human lifespan and embraces what Fernand Braudel calls the longue-durée or long-term in the analysis (Lockard 2016, 23; Guldi and Armitage 2014, 7).

Geographically, both approaches seek a broad scope to highlight the connections between coherent but different societies. Scope is perhaps better conceptualized as scale, like in geography, where one scale is one among a continuous gradient and new patterns may emerge depending on the scale at which a researcher observes phenomena. Therefore, interregional connections are only obvious at larger spatial scales.

Recently, a focus on cross-cultural connections has been popular in our globalized world where the container of the nation-state has been transgressed. Patrick Manning defines the unique quality of world history as "a story of past connections in the human community"(Manning 2003, 15). Jerry Bentley prefers "an ecumenical history of increasing complexity over time as a result of cross-cultural interactions among groups" (Bentley 2016, 95). Marshall Hodgson implored that no civilization's development in Afro-Eurasia could be understood except through its relationship to the interregional context (Hodgson 2016, 98). For example, the history of the Middle East cannot be subdivided by national borders and, further, is empirically very limiting because historical records and artifacts do not neatly obey such border. Andrew Gunder Frank sees World History as a genuinely “humanocentric” history made manifest; it is a history that seeks “unity in the diversity” of human experience and development between disparate times and places (Frank 2016, 130). Clearly, there is a social commentary underlying each of these recent statements but also an operational scale from which connections emerge and unique particularities are softened.

Historical thought in previous centuries also reveals that systematic connections and the concept of intertwined histories is nothing new and far from being a Western invention of the 20th century. As world historians know well, that which is proclaimed to be new is usually not (Crossley 2008, 8). Even before modern times, authors argued for a world historical if not universal approach, already witnessing the interrelations of societies at the scope of “the known world.” Liang Qichao–Chinese politician and scholar of the 19th and 20th centuries–wrote "All countries have the same sun and moon, all have mountains and rivers, and all consist of people with feet and skulls; but some countries rise while others fall, and some become strong while others are weak. Why?" (Lockard 2016, 23). Comparison of different societies has always been a fascination and a difficult question to answer without searching for common processes.

The Greco-Roman historian Polybius also remarked upon the interconnectedness of the Mediterranean world after the Second Punic War between the Roman Republic and Carthage:

> Now up to this time the world’s history had been, so to speak, a series of disconnected transactions, as widely separated in their origin and results as in their localities. But from this time forth History becomes a connected whole: the affairs of Italy and Libya are involved with those of Asia and Greece, and the tendency of all is to unity. (Polybius 2013, 1:3).

Polybius could, in some way, perhaps through written correspondences or written histories, sense that the Mediterranean was an increasingly connected complex system forming a sum greater than its parts—a new system state. Marshall Hodgson points to another important property of interacting systems. He understands that the quality of interactions of people, institutions, and states can change due to noise and conflict:

> After the Mongol turmoil, the most recent Chinese inventions evidently found a faster diffusion than ever; their historical effects are not however reducible to sheer diffusion, but reflected the complex pattern then attained by the interregional configuration. They had very different effects as developed in different areas" (Hodgson 1963).

In both cases ancient and modern scholars can see interrelations between human societies and groups within societies, but more tools are needed to elucidate the dynamics of these networks and systems.

Universal history has a central focus that differentiates it from traditional historiography and the pursuit of universal history has unique benefits. Jerry Bentley articulates the benefit, especially for university students, of studying history at broad scales as a needed addition to postcolonial Western education. He argues that we "must place an intellectual and moral wager that ecumenical history and education of that history will lead to a sophisticated understanding of the world and its development through time and possibly also to the formation of wisdom and the cultivation of values conducive to responsible global citizenship" and therefore a more peaceful future of globalization (Bentley 2016, 146). The value of global citizenship often appears on the syllabi of World History courses. Bentley also argues that broad history "must be more honest and inclusive than patriotic conservative history and more constructive and pragmatic than critical versions served up from the Marxist and postcolonial left (Bentley 2016, 147) which further illuminates Bentley's optimism that a better, more stable historical narrative is possible despite the recent events of the "culture wars." Nancy Fraser and Linda Nicholson argue that

> Global historical analysis brings fresh insight to the understanding of processes such as large-scale migration, imperial expansion, cross-cultural trade, biological exchanges, environmental change, economic development, and cultural exchanges that are prominent features of contemporary as well as earlier times (Fraser and Nicholson 1988).

These large-scale processes are not just things of the past, but concerns of our present, and thus a universal history approach can allow us to better understand processes in progress that, perhaps, most matter to the general public as well as scholars interested in "grand challenges."

Large challenges or questions like population growth, anthropogenic climate change, or the myth of infinite economic growth, are to David Christian the province of "Big History." Big history, coined by Christian, was a pioneering first-year course and approach to history from the beginning of the universe some 13.5 billion years ago to present with an eye towards the future. Christian argues that Big History allows "us to consider the history of humanity as a whole in its context. . . invites us to ask questions about the relationship between the history of our own species and that of other living things. . . [and] allows us to tackle these large questions with new approaches and new models because it encourages the drawing of new links between different academic disciplines (Christian 1991, 227). A distinction is made between this big history and contemporary world history due to the vastly different time scales and methods used; as Christian argues elsewhere, the "chronometic revolution" only saw its beginnings with the 1890s discovery of radioactivity by Marie and Peirre Curie. Radiocarbon dating, further enhanced in the 1950s, provided subsequent and increasingly precise Carbon-14 dating up to 50,000 years into the past (Christian 2016, 315). This development brings prehistory into clearer focus and is now more precise for long-term historical thinking.

Universal history encourages the use of previously untapped methods of investigating historical questions, visualizing the results, and sharing across disciplines. Machine learning to parse large corpora of texts (Guldi and Armitage 2014, 95), geographic information systems to study the spatial logic of religious institutions in China (Wu, Tong, and Ryavec 2013), agronomy and remote sensing to test hypotheses about nomadic carrying capacity of strategic pastures (Smith 1999; Bowman 2018), complex adaptive system modeling to understand Eurasian nomadic social change (Rogers 2017), and more have already been used. So-called "natural experiments" can also be used, when the data is available, to test, for example, why Haiti is a much poorer country than the Dominican Republic despite sharing the same island based on environmental factors or whether it is true that French invasions of Germany increased growth in some provinces and not others (Diamond and Robinson 2011). Universal historians, if they are to do anything new, must appreciate the work done by archaeologists, anthropologists, economists, sociologies, linguists, and more (Crossley 2008, 108).

2.1.5 Conclusion

A survey of multiple disciplines, the lacunae of Central Eurasian studies become clear. The thin, meandering coastline of the field rarely connects back to itself and the historians, archaeologists, and anthropologists share information through weak ties. Many narratives and models have been created but have not necessarily come into harmony. The necessity of research on particular topics, archives, or sites can create a partially connected constellation of facts and ideas as in many intellectual fields. While data collection and publication access has increased significantly in recent decades, nomadic societies have not fully left their historical waiting room to join the other complex civilizations of the world. How might nomadic societies have developed highly unequal access to wealth and power that allowed them to conquer many settled societies? How did spatial interactions with other nomadic societies and settled societies lead to positive feedback loops? How do many mobile herding groups that do not live in urban areas still form powerful social structures like states and empires? Large questions still loom.

Scholars may need to look broader beyond their local domains in order to bring together all the productive strands into a synthesis of the humanities and social sciences. First, an interdisciplinary framework is needed to provide a big tent for the creative ideas that have emerged in the past fifty years or so. The framework would need to be quite nuanced as well to provide coherence without being too general. It would also need to be one in which historians and scientists both find their experiences and intuitions validated. The next chapter will expand upon how particular definitions of "complexity" and complex systems could be a useful framework for thinking about human societies, not just nomadic societies, as non-linear, interacting, networked, and oftentimes unpredictable systems. As this chapter has touched on, thinking of how we construct models of nomadic societies is vital to this framework.

Returning to the epigraph of this dissertation provides the significance of developing new interdisciplinary frameworks for thinking about human societies. Ibn Khaldun contends that storytellers of his time had exaggerated the influence that distant times had on the bodies of humans and the forms of their societies but ignored the cloudy traces of networks, adaptations, and social institutions.

> The error of (storytellers) results from the fact that they admired the vast proportions of the monuments left by nations (of the past), but did not understand the different situation in which dynasties may find themselves with respect to social organization and cooperation. (Ibn Khaldun 2005, 144)

Chapter 3

Complexity and Modeling Past Societies

I believe that research must ceaselessly move from social reality to the model, then back again, and so on, by a series of alterations, of patiently renewed voyages.
— Fernand Braudel, *The Longue Durée and World-Systems Analysis*

So far, I have claimed that humanists and the intellectual ancestors of the modern humanities have been modeling for a very long time, although they may not have labeled it as such. Models of how nomadic societies operated in relation to the settled, agrarian world were not merely representational. They ossified into predictive—or retrodictive—models that helped generate knowledge about the past with little change for hundreds of years.

Here we turn from largely verbal, descriptive models to formal models that employ more bounded mathematical and computational logic and rarely exist without external representation. Historians and scholars of the historical sciences have developed more explicit models that have tested assumptions and revealed new questions about traditional and nomadic societies.

Explicit, formal models using the language of logic, mathematics, or computer programming have the advantage of making the modeler's assumptions and decisions far more transparent if done carefully. In turn, the internal dynamics of the model become more evident and subject to criticism, revision, and refinement. Moreover, explicit models offload representational capacity and cognitive processing power, allowing us to make new connections upon common ground.

The use of external representations in problem-solving from constructing flat-pack furniture from instruction manuals to solving mathematical equations is a well-studied topic. A major conclusion of this research is that working with external tools makes problem-solving more efficient and more effective (David Kirsh 2010; A. Clark 2008; D. Kirsh, n.d., n.d.; Kirsh and Mahglio, n.d.). David Kirsh argues that "interactive cognition enhances effectiveness because it regularly helps subjects to compute more deeply, more precisely, and often more broadly" because action is incremental and continually unfolding, requiring constraints and visual hints to maintain a coherent understanding of an idea beyond the capacity of working memory (David Kirsh 2010). Further, the visuality and constrained construction of external and formal models, though potentially still inaccessible to non-experts, provides observers with an external representation that can be manipulated either externally or internally within their own minds.

In particular, the social sciences have developed formal models regarding nomadic and other non-industrial societies that have been of great importance due to their transparency and explicit explanatory approach. Ideas, such as those mentioned in Chapter 1, such as environmental determinism, can be tested using simulation where adequate data is not forthcoming. They might also be used to explore internal dynamics such as wealth distribution, conflict, or a combination of processes. Important here is not that computer simulations can generate new data of the past; they cannot create archaeological sites or historical documents from whole cloth and can never replace hard evidence. What computer simulations and models more broadly *can* do, is provide a rigorous testing of conceptual models by quantifying the relationships of variables. The "process of building a simulation model points out flaws in logic, identifies weak areas or gaps in knowledge, and forces the modeler to think more rigorously about the problem" (Aldenderfer 1991) which ideally produces conceptual utility if not predictive power.

This chapter will begin with an operational definition of a model. Then, a review of complexity and complex systems will follow in addition to how a particular definition of complexity overlaps productively with historical thought. Then a brief history of agent-based and spatial models will illustrate the usefulness of formality when attempting to understand social systems, including nomadic ones, as collections of interacting agents. Finally, some motivation is provided to understand nomadic societies as complex systems and push forward a modeling approach.

3.0.1 What is a model?

Models and the activity of modeling are strongly connected to the empirical and statistical investigations of scientists and social scientists. If we think about models, we might think about external means of communicating a description or a dynamic of a phenomenon such as a grade-school diorama of the solar system or erupting volcano presented at a smaller scale. Models use external, usually visual but also logical verbal, means to describe and explain processes or systems and are useful in communicating ideas across domains of knowledge. Although we may not call them "models" *per se*, there are countless examples of how scholars use informal and formal, verbal and mathematical vehicles to explain phenomena of interest.

So long as we conceive of models as a general and flexible cognitive tool for thinking and explaining, models are ubiquitous across the humanities and sciences. This, of course, will require a sort of "model of modeling"——connecting perceived patterns to principle——which only reinforces the need, especially in interdisciplinary work, to work within common frameworks of intellectual activity. A brief survey of the different ways in which scholars of different disciplines use models will help to illustrate this point and allow us to generate an interdisciplinary framework for thinking between disciplinary divisions.

Because science is typically interested in explaining how biological and physical systems operate, we might define modeling as "the act of providing the best possible description of one's understanding of the relevant aspects, both statistical and deterministic, of the process of mechanism (the real-life phenomenon) that generates the data of interest" (Belsley 1991). In other words, if the solar system model illustrates how gravitational waves create disturbances in space-time which lead to the planetary orbits we can examine today, it would be closer to explaining how the phenomenon came to be or how a certain structure is maintained.

The search for relevant factors is a common, if not foundational, demand of statistical models. Researchers use statistical models such as the various types of linear models, multivariate models, principal component analysis (PCA) models to either identify the unequal influence among many different variables or to test the relationship of one or more variables against a dependent variable. For example, if we are interested in how we ended up with a distribution of student scores on an exam, we might compare scores to hours of study that the students self-report. Although the model is mathematical, we can visualize the results in a simple scatter plot chart and determine if a rise in the number of hours student studied is correlated with their respective test scores. These kinds of charts are everywhere in scientific publications because they are useful in helping us to think about relationships. However, we have only chosen two variables because we thought them to be the most relevant but there are many other variables that could exist and have an even larger impact individually or as an interdependent group.

Relevance and parsimony are important to the sciences. Modelers tend to limit the number of "relevant aspects" to those most influential in a system to make explaining the system easier and to parse which variables are most important. Further, models are not just useful as an end product and do not do all of the explanation themselves. Models are ultimately cognitive extensions.

> Necessary for thinking; by omitting, adding, and distorting the information they represent they can recraft the information into a multitude of forms that the mind can work with to understand extant ideas and create new ones... These mappings can be put into the world and made visible or visceral in graphics and gesture. Putting thought into the world promotes thought in self and other (Tversky 2018, 64).

All models necessarily boil down complex reality—a dizzying array of interacting parts—to a set of the "most important" variables, parts, and connections. In this sense, as George Box has famously put it, "all models are wrong but some are useful" (Box 1979, 1976). No model can encompass all aspects of a process or exactly represent a real-world system, but even simple models can interrogate our assumptions about a system which sounds a lot like Picasso's famous assertion that "art is a lie that helps us see the truth." Both "lie" and "wrong" are rather strong words to use here as there really is no other alternative and no better way to discuss and explain complex reality. Just as a statistical model can reveal a relationship but leave much to be interpreted so do creation stories and historical narratives.

But how we measure the value of a model? To many in the sciences, prediction is paramount and many times a model is considered useful if it can predict future outcomes with precision such as the weather trends, financial fluctuations, or elections. But models do not necessarily need to predict. This narrow way of evaluating them belies their flexible nature. Joshua Epstein argues that there are at least sixteen reasons to model other than prediction including to "explain (very distinct from predict), guide data collection, illuminate core dynamics, suggest dynamical analogies, discover new questions, illuminate core uncertainties, challenge the robustness of prevailing theory through perturbations, expose prevailing wisdom as incompatible with available data" and/or "reveal the apparently simple (complex) to be complex (simple)" among several others (Epstein 2008). Moreover, Epstein argues that rather than scientific theories merely summarizing data inductively, they also precede and guide data collection. Theory creates data of interest by providing a relevant context.

In brief, modelling in the sciences is much more flexible than rigid mathematical equations that produce a single numerical answer; they are intellectual tools, rooted in general-domain cognition that allow us to make sense of complex realities. Models allow scientists to sieve, extract, relate, even to fundamentally change the way we think about a topic or system which then fundamentally changes how we see the available data. While modeling is clear in the sciences, using our working definition of "model" we can also find models working in the humanities.

3.0.2 Modeling in the Humanities?

Models are ubiquitous across all disciplines wherever scholars attempt to "make sense" of traces, clues, patterns, or some other data. This is obviously clear in the sciences and social sciences but not so obvious in the humanities though modelling masquerades under other names here. Much more is needed to define, legitimate, and bundle a vast assortment of intellectual tools that perhaps rarely carry the same name into a coherent framework in order to transmute intellectual cherry-picking into interdisciplinary synthesis.

Looking for models in the humanities is not necessarily difficult historically, though they tend to be lacking in explicit ways in most recent scholarship. Models are rarely the focus of modern humanistic investigations and thus, as Bod argues, "they have rarely been analyzed from an epistemological perspective. This is partly due to the fact that humanities scholars tend to leave their modelling decisions implicit – and sometimes even deny that they are 'modeling'" at all (Bod 2018).

Tension between description and law-finding is clearly illustrated in the trajectory of geography. Since the late 18th century, the discipline had continually debated whether geography is an Ideographic (descriptive) or nomothetic (law-finding) discipline. For example, Alexander von Humboldt (1769 – 1859) introduced his *erdbeschreibung* or "earth description" which sought the interrelation of natural systems located in the same areas. Humboldt was one of the first to combine observation and theory to test deforestation on erosion and runoff, a problem identified by Plato much earlier but one that the classical Greek could not explain (Martin 2005, 113). Humboldt also described the relations of altitude, air temperature, and vegetation in tropical mountains. These relations were considered across the globe as isotherms which began to overturn the linear latitude delineations of Aristotle's times (122–123).

Humboldt sought to create more descriptive models. On the other hand, his contemporary Carl Ritter (1779 – 1859) directly opposed Humboldt with his erdkunde or "earth science" which sought causal interrelations through empirical methods rather than creating lists of facts, countries, and cities. Ritter's emphasis was on strictly nomothetic knowledge production; he believed that research should move from observation to general laws inductively rather than beginning from personal opinion or intuition. He also saw the interconnections between geography, ethnology, and history which made his "earth science" a more lateral synthesis than Humboldt's. Although Humboldt sought description, isotherms and erosion are inherently models since they are external understandings. Ritter's "earth science" of which he was only able to publish about Africa and Asia during his lifetime was, as he said, evidence of God's plan.

Later, Richard Hartshorne debated Fred Shaefer on the topic of whether geography was Ideographic or nomothetic. Hartshorne argued for the paramount position of uniqueness to phenomena in geography and rejected social science. He argued, "while this margin is present in every field of science, to greater or less extent, the degree to which phenomena are unique is not only greater in geography than in many other sciences, but the unique is of the very first practical importance" (Hartshorne 1939).Geography is thus Ideographic, a specialization in clear descriptions of unique regions of the Earth's surface. Hartshorne also took up Kant's argument that geography, like history, is exceptional and unlike other areas of study because it was especially concerned with the description of things in space like history was concerned, narrowly, with things in time while everything else was concerned with concepts.

Fred Shaefer argued that, unlike other healthy fields at the time like economics, geography lacked a clear focus. He disapproved of studies that focused on spatial social relations——"the geographer turns into a jack of all trades"——and instead argued that "like all others [scientists] had better cultivate his specialty, the laws concerning spatial arrangements" (Shaefer 1953). Although he primarily discusses laws, not models, he argues "no single such law or even body of laws will fit any concrete situation completely...as in all other fields the joint application of the laws available is the only way to exhibit and to explain what is the [specific] case" (Shaefer 1953). Given that even laws in the natural sciences are less and less enshrined given that nearly all of them have been overturned or modified at some point, we return back to the idea of the model—abstract but useful to explain.

Shaefer also sheds light on how geography applies models by comparing how historians use models. Assume, for instance, that he [an historian] is interested in the market prices that prevailed in ancient Rome during a certain period. Naturally, he will first have to find out what they were. But then he will wish to go beyond that limited goal and try to find out how demand and supply interacted with each other and the other relevant social factors to produce those prices. The causal relations on which he dreams for such "explanation" are not special historical laws but obviously, such as they are, the laws of economic theory. . . In trying to understand or, better, to explain them he does exactly what the regional geographer does in applying systematic geography to his region (Shaefer 1953).

While Shaefer makes productive comparisons between history and geography on an intellectual level by dissolving the boundaries created by language and Kantian tradition, he also advocates for a progression from simple classification to Newtonian process laws. However, as has been mentioned, Newtonian laws are much more like models and limited to their simplifying parameters, particularly the assumption that any process could occur in a closed system. The problems with this approach is discussed in the next chapter.

While the descriptive or law-finding factions had their times of greater influence, much of the geography students that emerged from the "culture wars" of the 1980s and 90s immersed in social theory, the linguistic turn, and phenomenology almost completely abandoned the debate in favor of local studies, often urban, of culture.

However, it is not the case that humanists completely stopped looking for or being interested in patterns but were mostly disillusioned by attempts to fit messy reality into what they perceived as reductive, rigid models. As Bod argues, a closer look reveals that the pattern-rejecting historians criticized not so much patterns per se but 'universal' patterns that were claimed to be culture independent. Their criticism made way for a quest for different patterns that were culture-specific or ideological" (Bod 2018). This has not held the quest for the universal in check as World, Global, Big, and Universal histories are more popular than ever (Graeber 2011; Christian 2010; Whitehouse et al. 2019).

In any case, physical and human geographers, including historical geographers, tend to all use maps in one form or another to represent spatial phenomena. Maps are perhaps the most widely-known models and far more wide-spread and naturalized than graphs. External or visual representations of models such as in the form of maps, graphs, charts, network diagrams, and the like are not the only manifestations of a model. Tversky argues that "Models need not be tangible.

Models can be mental, a set of beliefs of how something, a machine or a government or a person, operates" (Tversky 2018). For example, Roland Barthes in his various works advances a model of semiotics to deconstruct texts from the reader's perspective using a metalanguage. Natural language does not easily yield to structured models, but Barthes not only assumes that language is structured enough to constitute a construct but that texts can be deconstructed based on fundamental principles.

We can also look to the distant past to find historians and polymaths developing, extending, and formalizing models to explain historical change. The impetus to better understand historical change was likely brought about by thinkers like Thucydides who inspired subsequent Greco-Roman and Mediterranean thinkers in turn. Thucydides attempted to turn historical narrative and explanation away from deity-centric dependence to humano-centric dynamics. Through works such as The History of the Peloponesian War, he focuses on the primarily political forces that drive collective human action but also the unpredictability of future events (Stephens and Breisach 2007; Earley 2020).

The Greco-Roman historian Polybius (200 BCE – 118 BCE) refined an already existing Greek model of anacyclosis—a circular model of political evolution—of great concern since at least the time of Aristotle. The general model stated that human governments begin with a strong-man and thus a monarchy—the rule of one—which then dialectically advanced to aristocracy then democracy then mob rule and back to tyranny as political power became more and more diffused only to coalesce in the hands of an order-bringing strong-man once again.

Polybius' iteration of the model was used to compare the ascendant Roman Empire (though still professing to just be a republic) to the declining Greek states. He argued that the mixed constitution of the Roman society (legislative senate and executive consuls) in important ways broke the cyclical pattern of genesis and decay. More importantly, Polybius did not create any external visualization nor formalized the model into well-defined categories as far as we know but clearly even a verbal model can be transformed into an explicit one. As for predictability, Polybius provides a somewhat moderate perspective:

> If a man have a clear grasp of these principles he may perhaps make a mistake as to the dates at which this or that will happen to a particular

> constitution; but he will rarely be entirely mistaken as to the stage of growth or decay at which it has arrived, or as to the point at which it will undergo some revolutionary change. (Polybius 2013, 466)

Models were not confined to the Greek World either. Arab polymath Ibn Khaldun al-Hadrami (1332-1406) created another anacyclosis model, this time for the Maghreb or Western Arab World of North Africa. Unlike many of his contemporaries, he worked with and at one time took refuge with nomadic societies in the Maghreb which fundamentally shaped the way he thought about political and social change as a cycle which bears a resemblance to Polybius' model:

> 1. Nomadic dynasty, formed in the crucible of nomadic life and kinship, overthrows all opposition of sedentary dynasty usually based in a capital city.
> 2. New dynasty gains sufficient legitimate authority through the appropriation of previous dynasty's legitimating symbols, rituals, etc. and usually lowers burdens.
> 3. The dynasty becomes entrenched and enjoys leisure from active conquest and a tranquility of affairs. The dynasty is admired by allies and feared by opponents.
> 4. The successes of the first generations are imitated which causes a stagnation of policies and the beginning of maladaptation to changing circumstances.
> 5. The dynasty squanders wealth on pleasures and amusements which have become the entitlements of princes and important government appointments are awarded based on nepotism. Degradation is irreversible.

To Ibn Khaldun, history and socio-political change did not occur as a result of big events or individually great people but the *gestalt*, or the organized whole that is more than the sum of its parts. Based on the enumerated summary above, Ibn Khaldun's model requires an interaction of environmental conditions, social and cultural customs, conflict, accumulation of wealth, and transecological political contexts to produce cyclical social change which could not be understood by using any one of these variables alone. The study of social organization inevitably requires models to clearly convey some dynamic of a complex social system.

Ibn Khaldun produced perhaps the most specific model to explain historical change and the most relevant social forces that continually motivate the ebb and flow of social transformation. Although Ibn Khaldun, like Polybius, does not visualize or "map" the dynamics of his model in a way that translates it out of a long narrative form, the model is at the very cusp of becoming the kind of social-scientific models that are created and studied today about social dynamics. In fact, an entire field of Ibn Khaldun studies has been spawned along with many scholarly fans and he is credited by some as the "father of modern sociology." While Robert Irwin makes a compelling case that we tend to see in the *Muqqaddimah* what we desire to see—particularly a European-style rational thinker in a devout Islamicate thinker (Irwin 2018)—approaching the question of interest in Ibn Khaldun's work from a perspective of human cognition and the potential attractiveness of formal modeling is worth a look.

Because scientists, social scientists, and humanists all (though not each individual perhaps) construct ways of illustrating a phenomenon or system (physical, mathematical, or cultural) that explains the relevant aspects of it, we can conclude under this definition that this is what models do and why the tool is so ubiquitous.

This is true much of the time but not all the time. There is work that humanists do that is not modeling. Artistic endeavors are expressive and potentially without any pre-determined meaning or shape. Iteration and overlapping brushstrokes largely hide the serial nature of artistic works. Auto-ethnographies and anyone decidedly immersed in experiential descriptions may be purposely avoiding generalization. While uncommon, interviews and storytelling might be directly reporting someone else's experiences though they may use mental models in order to arrange memory or narrative arcs. In the same way, ethnographers might be more interested in what people of a particular culture might have to say about their experiences, but inevitably the ethnographer has to make sense of the multiplicity of voices and connect them to an issue at hand. Literary scholars might desire to merely describe the language used in a novel but more likely connecting the plot, characters, language, or motifs in a story to some social context which must inevitably be simplified to a model of relevant factors (neoliberalism, postcolonialism). In a great many instances scholars are fitting data to pattern and pattern to principle which we might generously term modeling.

The biggest caveat in this definition is that it reduces uncertainty by fitting a variety of intellectual manifestations to the mold of "model" even though many practitioners in question may be ambivalent or even hostile to the suggestion. Perhaps Snow was correct that there really are two cultures (humanities and sciences) that have grown so far apart that they can no longer communicate and thus use completely different epistemological tools and vocabularies (Snow 1959). One of the largest divisions sowed in historical study, for example, is by those who believe that narrative is fundamentally different than modelling and narrative is the only "real" way of accounting for the past. Narrativist and postmodernist thinkers believe that there is no universal context, only local culture and contingent causes. In addition, and perhaps most importantly, they believe that history is merely our reckoning the past with the present and in no sense a means of recovering what actually existed. Both scientism—the notion that a historian can study history scientifically and dispassionately—and centeredness—the notion that one and all should choose a perspective—are rejected under postmodernism (Southgate 2003, 44–45). In addition, Zygmunt Bauman argues that in the postmodern condition, "synchrony replaces diachrony, co-presence takes the place of the succession, and the perpetual present replaces history" (Bauman 1997).

However, perhaps the division is oversold and relies too much on intuition rather than reality. After all, Snow had to later include "social sciences" as a midpoint or bridge in a sort of continuum between complete ideograph knowledge and nomothetic knowledge. But recent years have shown that there is actually considerable variation in the ways self-described humanists and scientists generate knowledge and not even physics is firmly planted in the "law-seeking" category.

In fact, the humanities often spawn new quantitative sub-fields such as economic history, environmental history, computational literary criticism, and historical spatial analysis to name a few. Although many of these subfields must inevitably move into social science departments, we might also understand that humanists continue to connect patterns to principles. One of the newest comers, Critical Race and Ethnic Studies, makes it its goal to connect patterns of racial disparities to principles of historical, legal, and cultural segregation and the ways in which these enduring forces have shaped social systems. Social theorists like Kimberle Crenshaw have developed a way of thinking about intersectionality or "the interconnected nature of social categorizations such as race, class, and gender as they apply to a given individual or group, regarded as creating overlapping and interdependent systems of discrimination or disadvantage" (Crenshaw 1989). This idea is often modeled as overlapping Venn diagrams or a multi-spoked diagram where each spoke is a social positionality or even a spectrum of possible positionalities interacting simultaneously. More than a simple representation, this model diagrams the multivariate nature of social identity though it does not venture to explain how different identities interact or which are more or less influential. These questions are explored in individual investigations as a means to fit individual patterns to the model though it, like in Critical Race Theory, is not called a "model" but more often a "lens."

To those who contend that something is "Just a model!" Oliver Nakoinz reinforces the notion of a model as a general tool of explanation and communication:

> Models provide a structure for using and communicating comprehensive knowledge, inside and between disciplines. They provide a certain degree of abstraction, which makes it easier to establish connections between different theories, methods, and applications. In particular, models make it much easier to bridge the gap between science and the humanities, because they strip off the knowledge which is important for the different communities but which is not necessary for dealing with a certain topic (Nakoinz 2018, 108)

The critique "It's just a model!" implies that models do not capture reality in its messiness which is to assume that models are designed to do this. Epstein's retort is inevitably "You are a modeler" too as "anyone who ventures a projection, or imagines how a social dynamic—an epidemic, war, or migration—would unfold is running some model." Moreover, the critique also implies that other forms of knowing such as narratives/story-telling or highly-situated explanations are somehow better at explaining complex phenomena. Perhaps we can suggest that models are either implicit or explicit to different degrees and are either isolated or in communication with other models.

Implicit modelling allows for slippages in meaning and fuzzy boundaries which makes them more difficult to validate and communicate clearly; explicit modelling ties up loose ends and become easier to validate and communicate but sacrifices that fuzziness in the real world. The critique of modeling as fundamentally simplistic invokes the realm of exceptions. An exception to a model in the sciences is inevitable and the burden is on the researcher to explain them; in the humanities, often the exception explains the rule that there is no model that explains all variance. However, not only do many humanists model the world in order to make their arguments they also, like scientists, need to clearly deal with exceptions when they do. Models are good precisely because they are simple enough to communicate a nugget of understanding or the beginning of a thread of exploration. In a 1933 lecture, Albert Einstein said "It can scarcely be denied that the supreme goal of all theory is to make the irreducible basic elements as simple and as few as possible without having to surrender the adequate representation of a single datum of experience." This quote is sometimes, fittingly, simplified to "Everything should be simple but no simpler" which is to say that theory and models as its external representation should strive for uncomplicated explanation of the inner workings so as to illustrate a much more complex phenomenon.

While computational models such as recommendation engines, cluster algorithms, or statistical models produced by machine learning can be internally validated using quantitative and probabilistic measures, the same is not true to informal models common to the humanities. This is understandable given the kinds of information available. However, any model can be, at least, partially validated by comparison to other models fitted to the same data. In the cases of Polybius and Ibn Khaldun, their models both describe a cyclical process of socio-political change but we can hardly discuss the solidarity of Bedouin nomads having much to do with Greek democracies or democracies having much to do with the dynastic traditions of Maghrebi governments. By comparing them, we can refine and improve these models before naively finding where our own society falls in the cycle. Even quantitative models should ideally compete against each other to cover all possible blind spots created by simplifications (Page 2018). Likewise, any models purporting to explain some aspect of human society should ideally be compared to models describing other human societies to ascertain what could be common or specific between them. Perhaps we exaggerate the influence of a variable in one but not the other.

3.0.3 Scientism and the Humanities

At first glance, one might be convinced that the "lenses" and "theories" of the humanities and the "models" of the sciences are fundamentally incompatible, particularly with the introduction of postmodernism in the humanities and social sciences which rejects general explanations. Afterall, many intellectual tools carry different names and developed within different scholarly networks and are applied to or represent different sources of data. But perceived differences are often reified in rhetoric when disciplinary borders and claims to legitimacy are threatened. Recent years have seen many denunciations of scientism by humanists who resent the encroachment of science into big questions of existence. Steven Pinker summarizes an identifiable trend in the humanities where "they accuse these interlopers "of determinism, reductionism, essentialism, and worst of all, something called 'scientism'" (Pinker 2013).

This term, "scientism", is often invoked too broadly to assert that scientific epistemology and method is fundamentally different that humanistic epistemology and, further, that it simplifies—even maliciously—issues of human societies and cultures. To those who contend that something is "Just a model!" Oliver Nakoinz reinforces the notion of a model as a general tool of explanation and communication: Models provide a structure for using and communicating comprehensive knowledge, inside and between disciplines. They provide a certain degree of abstraction, which makes it easier to establish connections between different theories, methods, and applications. In particular, models make it much easier to bridge the gap between science and the humanities, because they strip off the knowledge which is important for the different communities but which is not necessary for dealing with a certain topic (Nakoinz 2018, 108).

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A new direction that finds some consensus between qualitative and quantitative approaches without the solipsism of realitivism might be found in the philosophies of post-positivism. Post-positivism contends that while there may be a reality outside of human awareness, our models and understandings are always shaped by our personal experiences and cognitive biases. Perhaps a more specific label for this general perspective is "critical realism" to distinguish it from post-positivist perspectivism which assumes a certain amount of relativism and that all beliefs are potentially valid, so long as someone believes something to be true, therefore grand narratives should be condemned and dismantled (Groff 2004, 135). However, an over-reliance on relativism also forecloses on validation of beliefs through evidence-based investigations and arguments and instead often retreats into moral quandaries or political loyalties. Instead, critical realism still asserts that the "truths" about the world we discuss are never objectively true but provisional. In addition, Roy Bhaskar argues that causal mechanisms exist beyond the cognition of humans, that they exist as entities that cause change, and that reality cannot be fully accessed by empiricism and, therefore, reality has indeterminate depth (Bhaskar 1986).

There will likely never be a broadly shared consensus on how the humanities, social sciences, and sciences can form a concerted effort. For now, local explorations and definitions will have to suffice to make headway into interdisciplinary frameworks. Critical realism holds the potential to lay the foundation for bridges between similarities between disciplinary thinking or "habits of mind" than does more extreme claims of positivism or relativism. Modeling seems to be broad enough to encompass enough of the intellectual landscape to cohere one such framework. While modeling does not simply have one definition even in the sciences, the areas of agreement are a promising epistemological foundation for building frameworks.

3.0.4 Complexity and Historical Thinking

The humanities largely abandoned quantitative work by the beginning of the 21st century, but historical and scientific thought have intersected in profound ways in the past two decades. This intersection can be fruitful ground for interdisciplinary thinking and not just in the "digital" humanities.

Complex Systems is a decidedly interdisciplinary field that, like Universal History, has claimed hundreds of years of thinkers as its genealogy. We might think of complexity science more as a synthesis than a new discipline. One broad objective of the field is to "explain how large numbers of relatively simple entities organize themselves, without the benefit of any central controller, into a collective whole that creates patterns, uses information, and, in some cases, evolves and learns" (M. Mitchell 2009, 4). These systems generally find temporary equilibria between order and chaos that emerge from the interaction of internal components (Beekman and Baden 2016, 3). Because so many potential systems can be studied using this approach, complexity scientists must find applicable systems studied by the established disciplines.

For example, Henri Poincare (1854-1912), a French mathematician, solved the simple "two-body" problem in which one calculates and predicts the motion of two planetary bodies exerting gravitational force on each other. However, as part of a mathematics contest held in honor of the King of Sweden in 1887, he faced the "three-body problem." By adding only one more celestial body to the problem, the motions proved too much for Henri and the other competitors to predict (M. Mitchell 2009, 21). He found that even with only three bodies and perfectly known laws of motion, it is impossible to predict their motions without infinitely precise measurements of gravitational pull, position, and velocity. Complexity theorists take this to argue for the notion of sensitivity to initial conditions, although Poincare did not think of himself as such a theorist but a mathematician.

Historians do not have a specific name but would very likely find the notion helpful to understand the trajectories of different societies in comparison. One example is Jack Goldstone's work on revolutions, which argued that population size is not the cause of social breakdown. Thus a simple diachronic measurement could not predict the collapse of order. Instead, growth and the growth rate indirectly place stress on many individuals and institutions, which then perturbs sociopolitical stability (Goldstone 1991, 26–27). Owen Lattimore, the great Central Asianist, seemed to think that there was room in History for thinking about emergence rather than the event. Lattimore interprets Inner Asian history as something different than conquest and courtly intrigue. He evades a political chronicle of "the steppe and sown" and argues that "political events are only the surface phenomena of history. The forces that create them lie deeper, and these forces derive from the interaction of society and environment" (Lattimore 1962, 340). Therefore, human ecology and the “starting” environmental setting come under historical analysis and the narrative sweep shares space with dynamics more common to anthropology.

In his 1947 article, An Inner Asian Approach to the Historical Geography of China, Lattimore outlines a process by which societies outstrip their resources, change their environment to suit their needs (such as deforestation), in turn experiencing the inadequacy of the new environment, then transforming their environment again and again in an iterative process with no specific trajectory (Lattimore 1947). Again, he focuses more on recursive processes that hinge on largely unseen interactions between people and their environment, shaping how they interact with other societies.

Part of what makes human societies complex systems is that they are open systems (trans-ecological, trans-cultural). They contain many interacting people with different personalities, goals, and positionalities and increasingly diversified occupations through time. In addition, humans are interconnected and interdependent. However, any one human usually does not know what most of the other humans are doing at any one time and cannot control everyone all of the time. As historians know well, human societies are unpredictable. Many historians study unpredictable crisis events that arise from the interaction of human groups (Maldonado 2007). This is not to say that human systems, even the global societies of today, are entirely connected. To be completely connected would be for a system to be rigid, flickering between two states or static. Not enough connection would mean a dissolution of the system. Instead, complex systems like social systems are moderately connected into "small worlds" of clusters and weak connections.

Complex systems thinking has been recently popularized primarily from the Santa Fe Institute since the 1980s though it has become somewhat of a phenomenon in institutes and universities across the globe. Complex Systems theory has seen unprecedented popularity since the innovative work at the Santa Fe Institute in the last two or three decades. The approach emerged from a coincident combination of people and tools from biology, economics, physics, and computer science. Drawing on centuries of mathematical and economic theory and using new computational tools, a new path of science was born. At the root of the approach is the modeling of everything from earthquakes to ant colonies to cultural evolution as systems and analyses of their adaptability, resilience, and sustainability among other traits. However, unlike explanations that seek to understand how systems work by understanding how each individual agent or part behaves, a "complexity" approach seeks to understand how the interactions of agents leads to unpredictable, "bottom up" or "emergent" behaviors (Page 2018).

Complex systems are co-evolving multilayer networks that exhibit high nonlinearity and emergent, unpredictable structures (Thurner, Klimek, and Hanel 2018, 23). We might turn to Fernand Braudel's definition of "structure" as "an organization, a degree of coherence, rather fixed relations between realities and social masses" (Braudel and Wallerstein 2009). Braudel elaborates that "certain structures in their life, become the stable elements of an infinity of generations. They encumber history and restrict it, and hence control its flow" such as "geographical frameworks, certain biological realities, certain limits to productivity, even one or another spiritual constraint. Mental frameworks are also prisons of the longue duree" (Braudel and Wallerstein 2009). Structures are difficult to pin down and are often located within ephemeral social interactions and their networks or those things that operate at the unconscious or barely conscious level. Understanding one's place or their small group is not enough to study the long term.

For example, we can learn everything there is to know about an individual ant—its biology, geographic habitat—but it would never tell us how the ant colony efficiently organizes to collect food, reproduce, and construct the colony equipped with extremely simple brains. This is what we might call "emergence." Speaking of brains, cognitive scientists and neuroscientists no longer think of the human brain as a collection of discrete modules but a network of neurons that do not hold information on their own like bytes of computer memory but form knowledge and memory through interactive networks. Therefore, whether ants or the human brain, what makes a system "complex" is the emergence of a gestalt or an organized whole that is more than the sum of its parts.

Although there is no one definition of what complexity is, even at SFI (Baake 2003), several common principles have been identified regarding complex systems across many different fields that engage them. 1) They are composed of relatively simple components (agents) that are likely heterogeneous in their characteristics or behaviors 2) these agents interact in non-linear ways and have no central control beyond their rule sets 3) the behaviors lead to self-organizing behaviors or structures, which is to say they are emergent 4) these emergent behaviors form hierarchies and networks that process information or resources 5) and finally that these structures can evolve in relatively non-linear, unpredictable ways. One rule of thumb to know whether one is studying a complex system is whether the system's dynamics can be explained on a page—physical laws can be summed up in an equation, but the human genome, the brain, or a society cannot. More importantly, these five or so characteristics fit within the understanding that humanists have assumed for years.

Cognitive neuroscientists, economists, and other researchers have already begun applying and honing complexity science for their modeling endeavors. For example, cognitive neuroscientists theorize the brain as a complex system with thoughts emerging as the result of interactions of neurons rather than originating from a specific module that serves a specific function. I am not arguing historians should do brain science, but if anything is a multi–layer, non–linear network with unpredictable outcomes but emergent, metastable structures (stable except for large disturbances) it is a human society—-exactly the things that historians of the past and present have thought deeply about and sometimes have described in great detail.

Therefore, the accepted wisdom about complex systems in many ways overlaps with what we know about social systems. Social processes are challenging to understand in standard mathematical terms because they evolve, are context-dependent, and are not always returning to equilibrium (Bonnett 2013; Scheffer et al. 2009). Like the fate of human societies, the outcomes of complex system processes are unpredictable but are not entirely random. In other words, history matters. But also, unlike a postmodern understanding of historical change, complex systems are self-organizing at multiple scales rather than contingent on chance events. As Mark Twain put it best, "history does not repeat itself, but it rhymes." The classic visualization of a complex system, the Lorenz attractor, illustrates this point best as each developmental path of the actor or institution can come close but never overlap with another in the same corner of the graph (Figure 3.2). We might say the quality of models to look familiar to us is because of this "rhyming", but at the same time—as a new value on the attractor landscape can quickly jump from one side to the other—lacks predictive precision.

Few historians have directly engaged with complexity science, but these few have led the way towards a productive relationship. Typically, historians might use the term "complexity" to refer to the complicated, overlapping nature of plural understandings of the past and meanings ascribed to them in narrative form. The plurality of voices in the historical record makes it extremely difficult to establish a definitive history as different configurations of a socio-economic or political position can change the way an author writes about a person, event, or time period. Moreover, the "parts" of the system are heterogeneous on many levels of thought, expression, and relation. This is not, surprisingly, antithetical to new scientific studies.

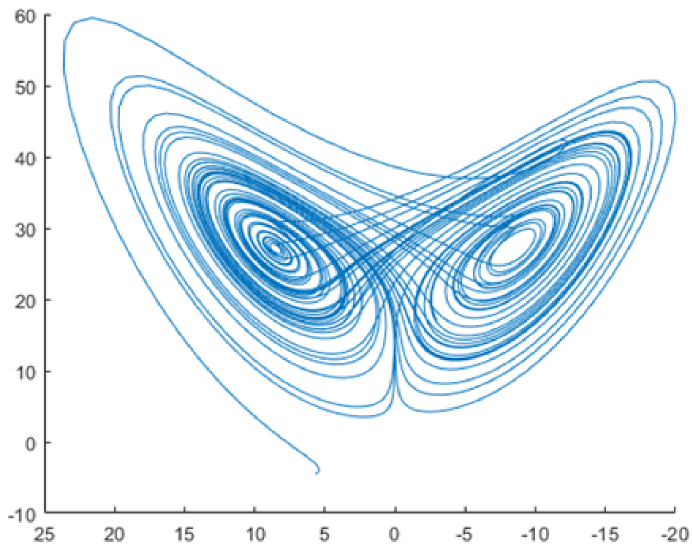

Figure 3.1: An example of a Lorenz Attractor. Each point on a line is a different state of the hypothetical system. Although no line ever perfectly overlaps another, they might come very close, though predicting the next value can still be difficult. A state change can happen suddenly in which a value crosses from one lobe to the other.

Unsurprisingly, Immanuel Wallerstein, who advanced World-Systems Theory argued that historical systems, or societies, are "the most complex systems of all" (Wallerstein 1987) in direct relation to the emergence of complex systems thinking. In the article Historical Systems and Complex Systems, he too likened the trajectories of historical systems to the Lorenz Attractor landscape remarking that "everything always changes, the cycle, the repetition is at best approximate, never exact. But the changes are not random" but also goes on to contend that "they are in principle predictable within the rules of functioning of the system–else it would not be a system" (Wallerstein 1987). As yet there are no models or calculations to comfortably predict significant changes in a human society. Wallerstein also finds some congruence between the ideograph and nomothetic strands of historical thinking. He posits that thinking of human societies and their interrelations as systems does not foreclose on them being understood as both having generic and particular properties.

> All complex phenomena have their rules, their constraints, their trends or vectors, that is, their structures. Any real structure (as opposed to imagined structures) has its particularities, due to its genesis, its life history, and its environment, hence has a history which is central to its mode of functioning. The more complex the structure, the more crucial its history. (Wallerstein 1987)

Unfortunately, this short article did not elaborate on a specific methodology of studying historical systems but did mention the target of "secular cycles", in essence, the cycles mentioned by Polybius and Ibn Khaldun many centuries before.

The connection between complexity and history was rarely picked up, especially by historians for years until recently. Carlos Eduardo Maldonado makes a compelling argument to not only revive interest in the connection between systems-thinking and history but to make the past a larger part of the ongoing trend. The top institutes concerned with studying complex systems—The Sante Fe Institute, New England Complex Systems Institute, Technical Institute in Vienna, Free University in Brussels, and the Max Planck Institute—do not focus on historical systems in real space but abstract systems in phase space—such as the lattice of a computational model (Maldonado 2007). He argues that as history is an open-system, it should be understood, at least by some, as constituting a complex system.

The very claim of history as an open system means that the construction, study, and interpretation of the sources must not be regarded only as a matter of narrative and metaphor, but also of explanation and theory. Thus, the old discussion about 'Clio, muse or science?' can be reframed as a complementary result of the dynamic balance between narrative and theory and...logic (Maldonado 2007).

Maldonado also argues that the nonlinearity of history and the way historians now study it makes it, along with time density, seemingly like an increasingly complex system though how to reconcile the possibility of phase space for historical space is still a question.

Perhaps the most vociferous call for scientific and historical confluence was made by William H. McNeill around the turn of the century. He perceived the fact that physics and biology became historical in the 20th century and birthed an evolutionary world view that challenged the old Newtonian paradigm and led to a convergence of cosmic, biological and human history into one entity. Rather than imperializing the knowledge space previously enjoyed by historians, this convergence opened an opportunity for historians to

become truly imperial—sharing perplexities and limitations with all the other branches of learning, even the most resolutely and successfully mathematical. . . we can justly claim to address the most subtle and complex dimensions of the known and knowable universe. (McNeill 2001)

He finds it necessary for historians to "take note of what happened behind our backs and begin to connect their own professional thinking and writing with the revised scientific version of the nature of things." He follows this with great cynicism for modern historical method, decrying his teachers' "fixation on written sources, assuming that the whole available truth about the past resided in words written down by contemporary observers" and how meaning came…from the mind of the historian; and since historians' minds differed endlessly, agreement about the historical past never emerged. Instead, revisionism prevailed, generation after generation, and will surely persist as long as historians ask new questions and try to answer them" (McNeill 2001).

This might be a harsh critique of what historians actually do, though there are certainly schools of thought that see history as "non-contemporary literature" as opposed to a product of human evolution or significantly crossing into the realms of the social sciences and vice-versa. Although McNeill invokes evolution rather than complex systems *per se* he perceives human history and societies as entire units. To him, we are:

> "one with our predecessors, immersed in a process we do not control and can only dimly understand—a process nonetheless that has made us and our agreed-upon systems of meaning the most disturbing, changeable, and quite extraordinarily powerful factor in upsetting the multiple levels of physical, chemical, biological, and social equilibria within which we exist." (McNeill 2001)

This is perhaps one primary take away from the exercise of crossing the streams of history and complex systems: we are undeniably and perpetually influenced by and influence processes that we cannot see but are inevitably operating at multiple scales. While I do not necessarily agree with McNeill that such history will "improve human chances of survival"—as there is always a chance that human societies are destined to cyclically rise and fall and authors will forget and revise provisionally as their ideological walls permit—but if human societies are really increasing in complexity then we may need new ways of understanding a shared human past that does not rely on previous forms of meaning or perhaps a new scale of thinking and synthesis. Well-organized groups thrive and fractious ones disintegrate.

3.0.5 Formal Models of Human Societies

If social systems are indeed complex systems and can be characterized as collections of identifiable components, subsystems, networks, and are dynamical in nature, then we need useful models to describe and explain them as such. John Horton Conway, a British Mathematician, created one of the first models of a "society"—what was later known as Conway's Game of Life. It is a zero-player game and the only input consists of setting an initial condition of the board. The board is a simple square lattice where each cell or counter within the lattice is either "on"—black– or "off"—white. Simple rules determine, in each time step, how cells either "live" and remain "on" or "die" and turn "off".

> 1. Survivals. Every counter with two or three neighboring counters survives for the next generation. 2. Deaths. Each counter with four or more neighbors dies (is removed) from overpopulation. Every counter with one neighbor or none dies from isolation. 3. Births. Each empty cell adjacent to exactly three neighbors–no more, no fewer–is a birth cell. A counter is placed on it at the next move. (Gardner 1970)

Depending on the initial configuration of living cells and their neighbors, patterns appear and disappear or become locked in a perpetual static block or a perpetually moving "glider" that travels across the lattice. In a sense, this was one of the first agent-based models where simple agents are given rules which shape bottom-up, emergent behaviors without central control.

While Conway's Game of Life is difficult to directly apply to real-world systems, especially its specific rules, it became an extremely influential idea that has sparked thousands of publications. Simple machines can create complex outcomes. Stephen Wolfram's A New Kind of Science expands upon the possibilities of using simple machines to study complexity. He contends that "from the intuition of traditional science we might think that if the behavior of a system is complex, then any model for the system must also somehow be correspondingly complex" but "this is not in fact the case, and that at least if one thinks in terms of programs rather than traditional mathematical equations, then even models that are based on extremely simple underlying rules can yield behavior of great complexity" (Wolfram 2016, 364).

This lattice-world approach was used by British economist Thomas Schelling to investigate racial segregation in cities. Rather than an "on" and "off" attribute, each cell is an agent that is assigned one of two groups. Then, each agent is given a motivation: to live near other agents of the same group. Each agent seeks a fraction of their eight neighbors to be of the same group. If they find too many of their neighbors to be of the other group, they will relocate until they are satisfied. After agents make decisions over the course of dozens of time steps, agents segregate into homophilic clusters. What is surprising about the model results is that agents only need to desire a third of their neighbors to be similar for a completely segregated landscape to result. Although the model does not include political pressure like segregation laws or financial barriers, it reveals that even mild affinity can lead to self-organized segregation.

Conway led to way for the next generations of computational modelers who began to more directly apply simple games to understand aspects of complex social systems. Joshua Epstein and Robert Axtell's work, particularly Growing Artificial Societies, is a landmark in the field and has encouraged the creation of agent-based modelling in the 21st century.

Epstein and Axtell created the Sugarscape model to simulate how agents would react, compete, collaborate, and reproduce given an unequal resource landscape. Simple, deterministic rules about each agent's behaviors given a few variable attributes created emergent—bottom up—macrobahaviors of the entire system. In the same vein as the current research, the authors aimed "to begin the development of a computational approach that permits the study of these diverse spheres of human activity from an evolutionary perspective as a single social science, a transdiscipline subsuming such fields as economics and demography" (Epstein 2008, 2).

A brief description of the model is in order. The Sugarscape model is built in abstract, digital space and upon a lattice or 2D coordinate grid. At every point in the lattice, there exists an amount of "sugar" stored as a value. Sugar is distributed in a gradient from two "mountains" of high sugar content to low sugar areas on the peripheries and a moderate-sugar valley between the mountains (Epstein 2008, 21). While the lattice is 50 cells by 50 cells, the world is a torus which allows agents to move from one edge to the opposite edge as if it were traversing the curve of a doughnut. Agents are randomly placed within the world and their primary goal is to move to high-sugar areas, metabolize sugar, and survive in each time step. Each agents is given a random endowment of initial sugar as well as a random vision range which gives them an imperfect understanding of their surroundings. Other changes can be made as well such as agent age and death, inheritance, and the rate at which sugar regrows.

Even in this rather simple model, and under various configurations, heterogeneous agents extracting limited resources from an opportunity landscape creates notable wealth inequality. Over time, the distribution of wealth becomes highly skewed where few agents hold much of the wealth while many hold little of it (33). This is significant. Out of this relatively simple exercise one can obtain a recognizable outcome and one can, perhaps, find themselves placed within it (think about Polybius' anacyclosis model). However, perhaps many different schema could produce a skewed distribution, especially purely mathematically and is quite easy with software these days. However, rather than a top-down formula producing the distribution, a collection of simple rules as sufficient to generate the same from the bottom up (52). This attempt to "grow" societies has led to important recent tests of hypotheses regarding various societies.

Axtell, Epstein, and colleagues more directly applied the fundamental logic of Sugarscape to the Kayenta Anasazi society in Long House Valley in the Black Mesa area of the American Southwest. This society existed here from 700 C.E. to 1300

C.E. Archaeological surveys have retrieved an estimate on the dates that the Anasazi culture inhabited the valley but also the quick abandonment of the valley after 1300. To explain this spatiotemporal history, the investigators sought to "grow" it.

The landscape was reconstructed using paleoenvironmental variables regarding precipitation and arable land. Agents were defined using ethnographic data such as nutritional needs and agricultural activity. At every time step, agents cultivate and harvest maize then consume and store what is left. If an environmental zone is particularly productive, agents will fission. If agents cannot find productive land or consume more than they produce, they die out/leave the valley. The primary question here is whether environmental change was the largest factor in mass migration out of the valley or endogenous, social factors.

Based on these parameters, the modeled population trajectory closely follows the estimated population. Moreover, the investigators found that even in the period of exodus (1270-1450), the degraded environment could have reasonably sustained a relatively large population. Abandonment of the valley may very well have been more socially determined than environmentally necessary or a mixture of both (Axtell et al. 2002). However, questions remain about such models that attempt to fit a simulated trajectory to real-world data. By adjusting, for example the carrying capacity, one can seemingly fit the population dynamic to a desired one. Also, by not including more complex agent-to-agent dynamics such as trade, the simulation assumes that each household is independent (Janssen 2009).

The authors also extended the model to include sexual reproduction, trade, combat, pollution, disease, cultural affinity, and more to study how different dynamics produce various new patterns. While "generative" social science is an approach and wields a powerful tool, combining so many different or variable aspects to a model can quickly become intractable or overparamaterized making any formal analysis impossible with current methods.

We can also formalize previously black-boxed models, making them more transparent through mathematics and computer programming. For example, the late William Skinner developed a highly influential theory in Chinese history and demography in which he argues that late imperial China contained a hierarchical marketing network that was necessarily nested within physiographic macroregions. In The City in Late Imperial China, he argues that cities during this time "formed not a single integrated urban system but several regional systems, each only tenuously connected with its neighbors. . . that each system of cities developed within a physiographic region" (Skinner 1995, 211). Geography, especially river watersheds and the mountainous borders that circumscribe social and economic systems, thus largely shaped the limits and affordances available to regions of China. With a soft network approach on economic and demographic dynamics, it also led him to the kinds of secular cycles already mentioned—what he calls macrocycles rather than purely political forces. Questions remain about the empirical validity of Skinner's model as much of his calculations and correlations in the data he worked with is not entirely clear. For example, Sands and Meyers sought to formalize Skinner's hierarchical regional model and found it to be productive in the idea that "spatially defined political units are not always the same as economic units" but the "time-irrespective system of eight (nine, including Manchuria) macroregions and core-periphery subregions offered" was an oversimplification (Sands and Myers 1990). Moreover, they argue that "an economy. . . is an interactive system and one that is forever changing in character and extent. To make sense of such complexity (and in particular to determine the individual economies' boundaries over time), we need a general, identifiable framework capable of incorporating structural change" (Sands and Myers 1990). If an economy is an interactive system, then individual cities interacting with each other could be agents in the analysis.

Given a rich data set, we can attempt to test Skinner's macroregional model. Using a data set of 107 years of grain price data, a primary indicator of economic activity, one can find the correlations between these price "signals"—the ups and downs of the market—to trace which local markets are reacting together. By connecting markets that move up and down together, we can reconstruct a spatial network of economic activity (Figure 3.2). Whereas Skinner diligently slaved over hand-calculating hundreds of correlations to draw strict spatial boundaries, we could extend our abilities through computation and fuzzier boundaries modulated by model parameters. We can also use machine learning algorithms to detect communities in the data.

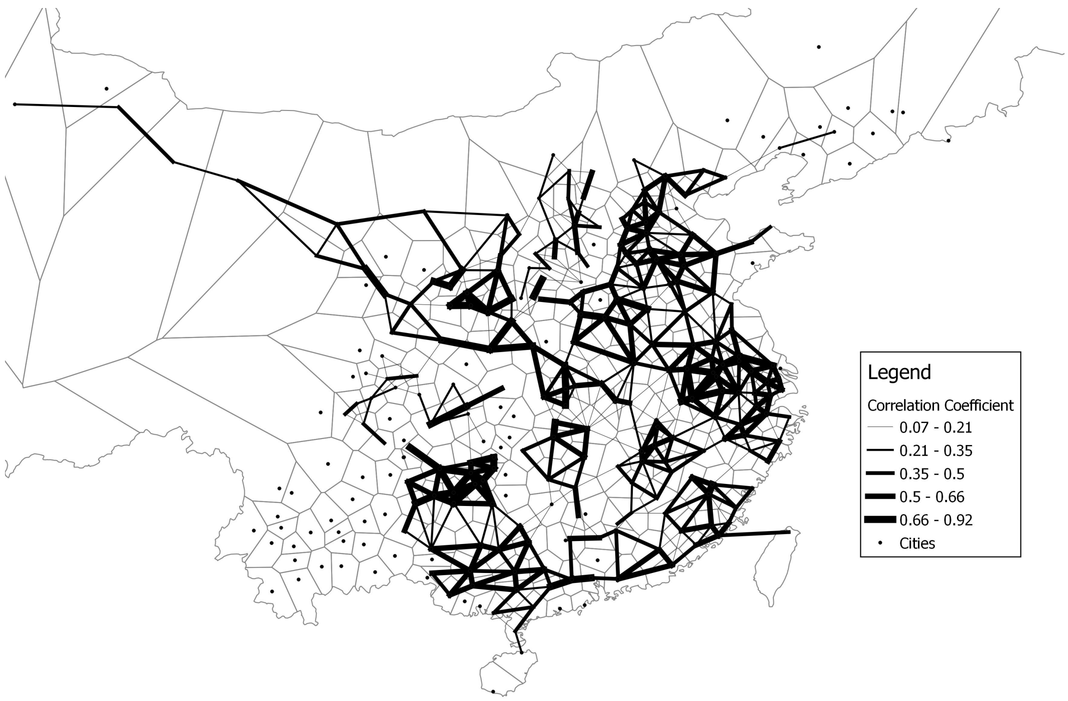

Figure 3.2: Flow map showing strength of cross-correlation coefficients for each neighboring pair of grain price time series.

We found that Skinner's original spatial divisions are largely valid even when geographic impedance to travel and trade are not included. Instead, the effects on connection—thus similarity—of price trajectories are found within the grain data from the bottom up. However, a more complex picture emerges (Figure 3.3). Macroregions do not appear to be completely isolated but, as macro-markets, are highly connected within their clusters and have weak connections to other clusters (Bowman, Hendersen, and Ryavec, under review). As a network, some nodes exhibit high betweenness centrality or the measure of their influence as a "bridging node" between other nodes and clusters. Further, we can divide the data into years or decades, and watch as the network changes and evolves. Rather than a static, geographic model, we can view, study, and visualize the Qing Dynasty's socio-economic landscape as a system of dynamic, interacting market "nodes" synchronically and diachronically. Perhaps best of all, our model is shareable and reproducible and more open to critique, modification, and refinement.

Few other thinkers have received as much attention at the intersection of history and mathematical modeling as Peter Turchin. Trained as a theoretical biologist, Turchin turned his mathematical skills to trying to answer the kinds of questions that kept Ibn Khaldun up at night: what makes empires rise and fall? In fact, much of Turchin's meta ethnic frontier theory in which he posits that culture clashes produce group solidarity and political hierarchy, is largely a formalization of the dynastic cycle model of the Tunisian historian. When historians criticized his attempt to make history a "predictive science", he founded a journal and a subfield called "cliodynamics" that attempts to build databases and study society-level dynamics of the past through mathematical models. Much in line with the research here, Turchin describes the aim of modeling as a way to compare different understandings of cause and effect relationships.

> A general approach to studying dynamical systems is to advance rival hypotheses based on specific mechanisms, translate the hypotheses into mathematical models, and contrast model predictions with empirical patterns. Mathematical modeling is a key ingredient in this research program because quantitative dynamical phenomena, often affected by complex feedbacks, cannot be fully understood at a purely verbal level. (Turchin 2003, xi)

The verbal level is great at describing dynamics informally and getting the ball

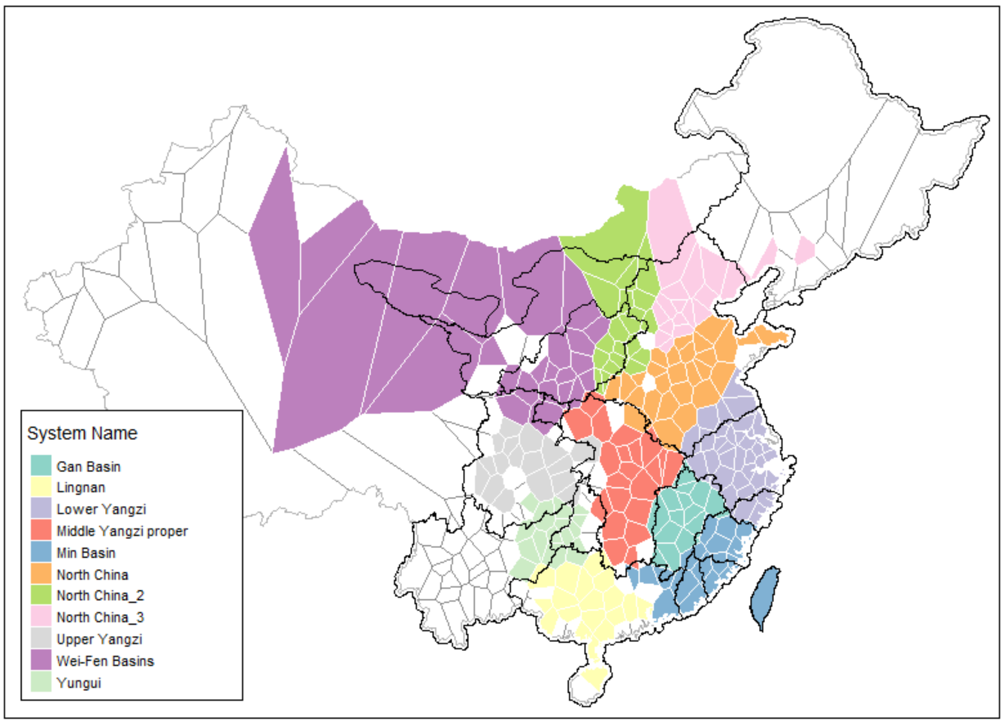

Figure 3.3: Map of empirically derived macro-market regions of China based on the Louvain community detection algorithm.

rolling. Fernand Braudel's exploration of *la longue durée*—the long term—in the history of the early-modern Mediterranean is a classic example of a verbal model of long-term historical cycles and dynamics. The longue duree approach of the Annales school has been very influential, particularly in world history, but understanding the dynamics of the Mediterranean system—perhaps geopolitically or economically—would require a more formal model to "postulate mechanisms (including their rates of change) and predict the ensuing model dynamics (for example, the temporal durations of the rise and decline phases)" (Turchin 2003, 37).

Turchin develops and applies his "metaethnic frontier" model in his book Historical Dynamics to explore how the system of group solidarity—what Ibn Khaldun calls' asabiyya—is a key but relatively forgotten ingredient in the rise and fall of states. He even argues that the medieval Tunisian scholar should receive credit for the idea of group solidarity and that it should be measured in "khalduns."

Turchin also believes that modeling can lead to history becoming a "predictive" science. This is questionable though maybe this could be modulated to "retrodictive" in the attempt to find cyclical patterns. Predicting the future with the past is always extremely difficult. If we return to the three-body problem or any attempt at time-series forecasting, it becomes obvious that the further in time we want to predict, the less accurate our predictions become.

Turchin also decidedly ignores nomadic societies for Western Europe due to knowledge about geopolitical boundaries and historical knowledge. Though he acknowledges "addressing these societies should be the first order of business, particularly because nomadic polities were so important in the history of Eurasian empires" (Turchin 2003, 203). However, it is also interesting that Turchin actually makes a mini-model regarding the rise and fall of states along the Chinese-Inner Asian frontier: what he calls "one of the most prominent and long-standing metaethnic fault lines in Eurasia" (60). Here he illustrates how nomadic empires preferred not to conquer China but extort tribute from it—what he calls "the parasitic nomad" and that confederations would collapse into warring tribes. However, if states extracting tribute after military victory and later fragmenting into rival factions is somehow qualitatively unique to nomadic states, why can the same be said about the Chinese and Roman Empires? Was Rome parasitic when it demanded mountains of silver talents from Carthage after the First and Second Punic Wars without outright conquering it until the Third Punic War? If we are to make a general model of state formation and collapse, why are nomadic states singled out when nomadism is not even explicitly included in the model? Perhaps what is needed are frameworks that break down strict barriers between traditional definitions of civilization and between "simple" and "complex."

Examples abound in which the divisions between culture, complexity theory, and computational modeling are blurred. Stephen Lansing's work on Balinese culture is a good example of how complexity and modeling can meld organically with cultural anthropology. Complexity, spatial analysis, and culture also come together in Stephen Lansing's book Perfect Order: Recognizing Complexity in Bali. Lansing's work is one of the best examples of a sophisticated way of studying social processes with a solid anthropological background but with the power of computing. Lansing is an external professor at the Santa Fe Institute and the Vienna Complexity Hub, as well as an emeritus professor of anthropology at the University of Arizona, making him well-positioned as a multi-interdisciplinary thinker. Perfect Order is a study primarily of Balinese water temples located in villages along the length of principal rivers and how the institutions self-organize, without omniscient or centralized state apparatus, irrigation schedules to maximize food production. Theoretically, many villages subsisting from a shared resource, such as a river, might be classified as a "tragedy of the commons." However, Lansing illustrates how in this particular system-—-a complex system——actors act for the benefit of most while also acting in their own interests. Not only is the study one of how the present system and decision-making works, but how the system or a simulated version of the system can develop as an emergent structure from chaos.

Again, focus on interaction rather than the description of one village or water temple alone here is key to greater insight. Lansing draws our attention to the fact that not only are decisions made among a group of people at the water temple, but the decisions made by a village "inevitably affect its neighbors, altering both the availability of water and potential levels of pest infestations" (Lansing 2006). Water temples were originally created by farmers and dedicated to a group of deities representing the rice they grew as well as the mountains, lakes, and rivers that formed the natural setting. Moreover, the temples established a framework for cooperative management but also justified by religious practice and belief. The emergent structure of the irrigation management among the villages as an interacting network delegitimated kings and village councils who could only provide a less effective (and perhaps taxed) system (16).

While the present Balinese system is possible to study ethnographically and even spatially, simulation is necessary to elucidate the past (or "rewind the tape of history") as a diachronic process. Lansing develops a simulation using geographically referenced spatial information, including village locations, river courses, etc., and each village is an actor in the spatial network. The villages co-develop that reacts to information from their immediate neighborhood, especially in an attempt to emulate successful harvests by other villages (41). However, in the simulation, if the villages communicate with all other villages (omniscience), the system cannot adapt, and if there is no connection, the system becomes frozen. In complex system simulations, the researcher is ideally looking not for perfect stability or complete randomness but "the edge of chaos"—that amount of stability and input that allows a system to be stable enough while also evolving to meet new challenges. In this instance, a village having three neighbors was optimal and allowed for villages, commanded at the water temples with limited information of the whole system, to adapt in a complex, non-linear ways.

The simulations are but one part of Lansing's study; however, and as an anthropologist and not just a computational computer scientist, he explores how the complex system is perhaps already understood or rationalized, but the cultural worldview. He finds:

> At the core of Balinese religion is the belief that the universe is coherent and that it has been built up from a finite set of elements, including colors, letters, numbers, sounds, and forces (which can also take the form of emotions). From the combination of these elements emerge both the physical universe and the inner world of the self. The underlying premise is that simple forms give rise to more complex ones in orderly patterns.(Lansing 2006, 71)

Much in the way so-called "universal" historians think about creation stories and world histories as two items in the same set with different times and places, Lansing challenges the notion that a primarily agrarian society without a strong central government cannot be complex. Further, his study is a compelling case to argue that religion and myth are not separate from real-world constraints and the many, often invisible, interactions of actors in a system, whether they know it or not, are vital to social systems of relations and meaning.

This turns us now to the more specific topic of this research—nomadic societies. Before exploring the few agent-based models currently available, we should turn to the work of archaeologists who have made a variety of models first. J. Daniel Rogers puts forth a compelling argument for studying complexity of nomadic empires. He acknowledges that complexity, much as it is in history, is used casually and that "in archaeology the term 'complexity' is used in high-level descriptive and comparative analysis of the components of a society. Usage is seldom based on a specific formal analysis of attributes that provide the rationale behind what is considered complex or not complex" (Rogers 2019). Instead, he argues that researchers should develop ways of more precisely describing complexity within nomadic polities and link them in dynamic trajectories that can be studied simultaneously through tools such as agent-based models. He identifies three structural elements to a trajectory: dimension or the macrostructure of the polity including initial conditions of political hierarchy and population; probability space or the traditions and social structures that create the context for dynamic processes to occur; and "bundles" which are individual characteristics such as technologies, political rituals, religion, etc. that can change over time separately (Rogers 2019). The past is typically understood linearly or within the limits of pen and paper but "unless fine-grained behaviors can be accounted for, the use of standard inferences and analogies only adds more layers of unknown bias to interpretations" (Rogers and Cegielski 2017).

This is not only important for particular groups but the interaction among nomadic groups that established common institutions across Eurasia that then became the opportunity spaces for the cultivation of legitimacy and power. Michael Frachetti proposed the concept of "nonuniform" complexity to "explain how economically and culturally diverse communities came to shape wider-scale institutional movements across Eurasia" (Frachetti 2012). Institutions are "nonuniform" in that local traditions are particular to local social contexts but "as steppe communities increasingly widened their spheres of interaction, some institutions appear to translate over a wider, more general scale. . . but these institutional alignments did not necessarily draw regional communities into a shared sense of society" (Frachetti 2012). A focus on general and specific institutions—religious, linguistic, economic, political—among many groups softens the importance of studying only the rise and fall of particular imperial governments and shifts focus to the processes of social interaction, cohesion, and dissolution.

We can now shift our attention to particular modeling attempts that have begun to unravel the old accepted wisdom of needy or "less complex" nomadic societies. Building off of Growing Artificial Societies, Claudio Cioffi-Revilla and colleagues directly apply the basic framework of a Sugarscape simulation to mobile, pastoralist societies. Rather than looking to reconstruct history, "social simulations of nomadic and pastoralist societies provide unique computation models and virtual laboratories for testing generative theories of social complexity among interactive and mobile agents, as well as for exploring and discovering new patterns of socio-environmental interactions" (Cioffi-Revilla, Rogers, and Latek 2010). Using the MASON (Multi-Agent Simulator Of Neighborhoods or Networks) system, the authors created the HouseholdsWorld model of nomadic households and clans. Following a set of deterministic rules—like seek grazeland, avoid other grazers, maintain camp cohesion—household agents metabolize biomass resources on the landscape to survive. Three of the five main rules consider the interactions of agents among themselves, consistent with complex adaptive system dynamics.

The model succeeds in a few respects. First, given a simple resource landscape and up to five behavioral rules, the model eventually reproduces a log-normal (highly skewed) distribution of resources much like that of Sugarscape and, most importantly, the real-world system in question in Kazakhstan or Mongolia. Second, the movement times and distances roughly equate to those nomadic households that typically move between summer and winter quarters. Lastly, adaptive grazing strategies (aided by memory) allows households to increase their number of animals over time.

The authors acknowledge the difficulties of *in silico* experiments as well. For example, the population and herd animal density equilibrium obtained by the model is significantly different than real-world observations. In addition, the authors did not show how their primary or secondary historical sources could be used to further verify model results or specific dynamics. Overall though, the HouseholdWorlds model is one of the few ABM available for studying nomadic societies and contributed useful parameters and experience for future attempts.

ABM can text theories of dependence on nomadic societies and for specific issues. For example, Daniel Shultz and Andre Costopoulos created an ABM to test the effect of environmental conditions on patron-client networks of herders. Given that herders whose flocks are decimated by natural disasters must seek stability as a client of a richer patron, the conditions under which stable, hierarchies can arise (such as that of the Xiongnu or Mongol empires, is an important question. This model uses "as little real-world input data as necessary, avoiding making too many unjustifiable or inaccurate assumptions about the past" (Shultz and Costopoulos 2019), possibly very prudent given the lack of hard data currently available for the distant past. More importantly, this exercise seeks general processes and to test logic.

The rules of this simulation are quite simple. Each agent is given an endowment of animals and if that number is below a certain amount, more animals will be created via reproduction. A flip of a coin determines if an agent's herd will die by 50% due to a natural disaster. If they suffer a disaster, then they must find a patron or, if they already have a patron, will receive animals from the patron. All the while, links are being made and a network quickly unfolds. Finally, if a patron's herd size drops below 500, then they lose patron status and the hierarchical network is dissolved.

The authors find that under conditions of increased biomass and decreased environmental risk—that is, richer and more stable—nomadic empires are more likely to emerge. More importantly, socio-economic hierarchy are more likely, and able, to emerge independent of sedentary support. Perhaps a coin flip to determine herd die off and abstract reproduction rates might be refined with real data in the future but, regardless, this simulation presents logic that helps put the dependency model to bed. Dependency theorists must either find better data to support their claims or rethink why exactly nomadic societies were dependent. In this way, explicit formal models and ABM are useful in testing and pushing thinking towards more complex forms and models that are dynamic and do not ossify into shaky common wisdom.

When social scientific models are carefully constructed and explicit, they can reveal powerful dynamics, even when it comes to complex social systems and even those in the past for which we have few human-made sources of information. Although they might be simple or not take absolutely every variable into question, they can still be extremely helpful tools to think with or even test influential theories.

However, as alluded to in the first paragraph, explicit even scientific, chiefly quantitative models are not a silver bullet. Like all models, they all contain limitations and potential blind spots and, for the most part do not "replicate" or "rewind" reality in all its complexity. Furthermore, computational or mathematical models should not replace other kinds of models or eclipse other domains of knowledge but should be read alongside other approaches holistically or, at most, compete with other models when the same question is being approached. For example, creating perfectly rational agents creates numerous potential problems given that human beings often act irrationally and against the interests of the individual and the group.

In addition, the dominance of postmodernism in the humanities and some social sciences has come to equate to hostility with "scientific" epistemology as, in general, the perspective rejects observational objectivity and, therefore, any claims to "real" truth. Much like the critiques of "scientism," the reconstructions of science practice is outdated and no longer accurately describes scientific practice (Henrickson and McKelvey 2002).

As with any epistemological approach, one might easily begin to believe that simulation is the best way to understand everything about a topic. If one is too highly invested into this or that model of a society or some social process, it can be difficult to understand it using any other model which might be equally as valid and even more effective at explanation.

However, as long as we assume that no approach has an absolute monopoly on unraveling reality, then quantitative models are no less productive than verbal ones and can, hopefully, find some correlation between them. For example, Scott Page discusses the need to take a "many-models" approach to as many issues as possible. Drawing on Aristotle's advice of combining the excellence of many, "the logic behind the many-model approach builds on the age-old idea that we achieve wisdom through a multiplicity of lenses" (Page 2018, 5). The evaluation of different parallel or competing models is not completely clear and is beyond the scope of the current research but even juxtaposing and taking time to understand different models could lead to important insights. To be clear, I do not mean to be completely relativistic here; not all epistemic approaches are equally legitimate since contradictory ideas would create a paradox. First, there is a nature that exists and operates outside of human observation and social constriction of communication and meaning. Second, models are a useful, perhaps even inevitable, tool in order to close the gap between interactions of elements in nature and observed outcomes. As humans are parts of the natural world and we are socially interested in outcomes of concern to human societies, models should help to close, asymptotically, the gap between human behavior and society-level outcomes. The "many-models" approach is incommensurate with the notion that scientific knowledge is fundamentally socially constructed and therefore never really explaining.

Rather than focusing on epistemological purity and clean disciplinary divisions, interdisciplinary research can find fellowship in concordant or complementary heuristics, theories, metaphors, and models. For example, Henrikson and McKelvey argue that complexity science and postmodernist views of human agents have begun to overlap.

> Given the connectionist parallels between complexity science and postmodernist views of human agents, we conclude that their ontological views are isomorphic. Complexity science ontology has emerged from the foundational classic and quantum physics and biology. Postmodernist ontology has emerged from an analysis of the human condition. Thus, an epistemology based on complexity science and its agent-based modeling approaches may be applied to social science ontology as reflected in the agent-based ontology of postmodernism. (Henrickson and McKelvey 2002)

Such an approach seeks to generate value across the board by reflecting upon and valuing the productive reminder of postmodernists that human societies cannot be reduced to mathematical equations that reject the very real consequences of context, history, and recursion but also obviously valuing science for its formal approach.

While I have thusfar supported quantitative, computational modeling it is important to further understand that formal modeling in any form cannot and should not necessarily "replace" textual history or archaeological excavation. In fact, agent-based modeling is fundamentally based on physical finds, translations, and interpretations provided by those working with traditional methods. These methods are not likely to become obsolete any time soon. However, since the separation of the disciplines in the modern period, the narrow-and-deep accumulation of knowledge—primarily on the collection, translation, and dissemination of data and information—has led to opportunities to synthesize at a higher level and across disciplines in parallel or in collaboration. Higher levels of synthesis focus on the development of explanatory models of general processes of complex systems emanating but converging (Bar-Yam, McKay, and Christian 1998).

3.0.6 Conclusion

Modeling is ubiquitous as academic disciplines attempt to create information, knowledge, and perhaps wisdom out of whatever data is available to a question. While informal, largely verbal models have dominated much of human history, a steady improvement of tools—writing, mathematics, logic, symbology, computation—has made formal, explicit models quite powerful. Disciplinary siloing and cultural bias has, arguably, narrowed the available assumptions to be used in models of nomadic and other societies, leading to informal models of the needy, greedy nomad or else the needy, victimized nomad becoming reified. Rather, we should consider a many-models approach where we take advantage of the interdisciplinary nature of Central Eurasian studies to array many models beside each other to better understand how nomadic societies may have existed, developed, and behaved. The "term Central Eurasian" is used broadly here; however, the next section will clarify what this exactly means in relation to the modeling exercise. Clearly, most of this history is lost to time but the overlapping wisdom of the historical fields and complexity science can allow us to test and modify our foundational assumptions and more properly compare sedentary and nomadic civilizations. From a perspective of universal history, we can begin at the similarities between societies rather than the highly particular—path dependence, sensitivity to initial conditions, non-linear dynamics, and relative unpredictability.

Chapter 4

Modeling Nomadic Inequality and Hierarchical Networks

For, if the multitude of elements is unlimited, fortune has in the abundance of her material an ample provider of coincidences; and if, on the other hand, there is a limited number of elements from which events are interwoven, the same things must happen many times, being brought to pass by the same agencies.

— Plutarch, *Life of Sertorius*

4.1 Introduction

The fundamental questions of nomadic social organization and the rise of nomadic states and empires require hard data and written records that we do not have in sufficient quantities yet. As discussed in previous chapters, models are needed to bridge the gap between data and assumptions—-the worlds of which are somewhat amorphous. In addition, formal models are also needed to test the assumptions and logic of models going back decades in light of a new turn towards complexity regarding nomadic societies. Unfortunately, few agent-based models are concerned explicitly with nomadic-pastoral societies through many dealing with hunter-gatherer societies, migration, economics, networks, foraging, and cultural evolution. This chapter will describe a new agent-based model of nomadic societies in the Western Steppes, specifically, how spatial socio-economic hierarchies can form endogenously and in interaction with other societies under spatially diverse conditions. The model presented here will evolve throughout the chapter, moving from simple and most abstract to complex and employing real-world data. In this way, the dynamics of the model and its application remain clear. Models are helpful and a primary way for scholars of different disciplines to make sense of the world and create knowledge. Models are not new to archaeology or history, and thus the model here adds to this tradition.

The ABM presented here will not attempt to reconstruct historical realities or demonstrate particular regional distributions. Instead, the model is designed to understand the abstract dynamics of a simplified system produced within the simulation. That said, "growing" the society of agents using simple rules can create recognizable patterns which greatly aid interpretation and validation.

Clarifying the goals of the model can help highlight the subsequent decision-making process regarding new rule creation and clarify how introducing real-world data can help extend the model. First, understanding nomadic societies as complex systems, rather than "less complex" cultures, is essential to understanding them as social systems of many interacting parts. These parts—people, culture, institutions—interacted in various ways lost to time. These interactions emerged behaviors and social structures that could contend with powerful sedentary societies across Eurasia. Thus, interaction will be of great concern when creating rules for the agents who will be heterogeneous regarding spatial location and attributes. The creation of networks from simple rules of socio-economic importance will be crucial.

Second, interactions should be limited in time and space and remain present long enough to form emergent structures across the simulation space and a gestalt which can be measured using state variables such as some measure of inequality of wealth and network connections. The only structures that will form are networks of connected agents rather than the more complex structures of states and empires. Ideally, these networks should form due to the rules rather than pre-determined by static attractors. Having a "trail" of the network hubs—agents with many connections—can help visualize where and when these networks form. One way to do this is to have markers appear when the highly-networked agent "dies" or ages out of the simulation. These markers will form a spatial distribution that will accumulate over time. These can be understood as merely abstract tokens or as kurgans—nomadic burial mounds—to aid analysis.

This chapter will begin by returning to the original Sugarscape model developed by Epstein and Axtell and operationalized in the programming package NetLogo by U. Wilensky (Li and Wilensky 1999; Wilensky 1999). The ABM presented here will also apply some dynamics and lessons from Shultz and Costopoulos' model(Shultz and Costopoulos 2019) and extend them. Applying new rules to a known model will help home in on the particular dynamics of nomadic societies, namely, patron-client relationships, climate change, political elite formation without too many idiosyncrasies, which aids inter-model comparison.

4.2 Reviewing Sugarscape

Before adding new rules and real-world data to a new model, it would be wise to return to Epstein and Axtell's original Sugarscape model and change the rules to illustrate how those rules work in abstract space and which patterns emerge. Presented here is the smaller version without extra rules for trade, conflict, and reproduction.

In the original model, the world of Sugarscape is represented as a landscape of sugar patches organized as two hills of yellow "sugar." First, on the summits of these hills are patches that contain a large amount of sugar, while the slopes and valleys between the hills contain less sugar. Next, the periphery of these hills contains less sugar still. Finally, the two outer corners of the landscape contain no sugar. Thus a gradient of resources is formed where concentrations are spatially exclusive.

Next, agents are created and randomly placed to forage, survive, and interact on this resource surface. Each agent is given a random numeric value within a range representing their metabolism (rate of consuming sugar), vision (how far each agent can "see" around them), and the maximum age they can reach before leaving the simulation. Each agent is also provided with a random amount of starting sugar to get them going.

Algorithm 1 Create Agents on Setup

```
Move to a patch without any other agents
Set sugar to a random number between 5 and 25
Set metabolism to a random number between 1 and 4
Set maximum age to a random number between 60 and 100
Set age 0
Set vision to a random number between 1 and 6
Set prestige between 1 to 5
```

A few simple rules propel the agents to forage and for the world to supply resources. First, agents move to the patch closest to them with the most resources within their range of vision. This represents an agent's need to find resources but with limited rationality about the total environment. Once on a patch, they consume the resources on the patch and burn sugar equal to their metabolism. The patch then regrows by a partial amount. If an agent's sugar level reaches 0, they die, and a new agent is recreated and randomized.

Algorithm 2 To Move Agents

Let X be a set of patches within vision without agents on them

Let Y be patches in the X set with the most sugar

if any patches meet this criteria **then**

  Move to the closest candidate patch

end if

Algorithm 3 To Eat

Set sugar to the agent's current sugar – metabolism + the current patch's sugar

In short, simple rules and heterogeneous agents can recreate unequal wealth distributions without top-down control. This concludes the summary of the Sugarscape Model and its operationalization in NetLogo. The model reveals that an unequal resource landscape, when subjected to variable foraging, creates unequal outcomes and a "rich get richer" effect. These dynamics and patterns reflect many real-world social systems. While we might find ways to apply Sugarscape directly to nomadic societies, it is important to see how such a model fits with current discussions around nomadic society dynamics to specify the model.

4.3 Creating New Rules

The basic version of Sugarscape is suitable for its purpose, but it does not yet have any rules for how agents interact with the environment or each other. As a result, many agents leave the simulation in the first few rounds, and each agent is an island that only seeks survival. A few additional rules can help us imagine what flexible and social nomadic pastoralists would have done given the situations on the agents within the simulation.

First, we can make agents adaptive. Rather than eating more than they can to survive, agents can adapt their metabolism to adjust for a mismatch. Now the average amount of agents surviving increases to around 340 from 240. The only agents that die are those trapped by low vision in the far periphery (Figure 4.1). Pastoralists are not only pastoralists and were/are able to adapt to changing circumstances before catastrophic social collapse occurs. In addition, if a society allows disadvantaged members to exit, it risks losing still-productive individuals that share a cultural identity.

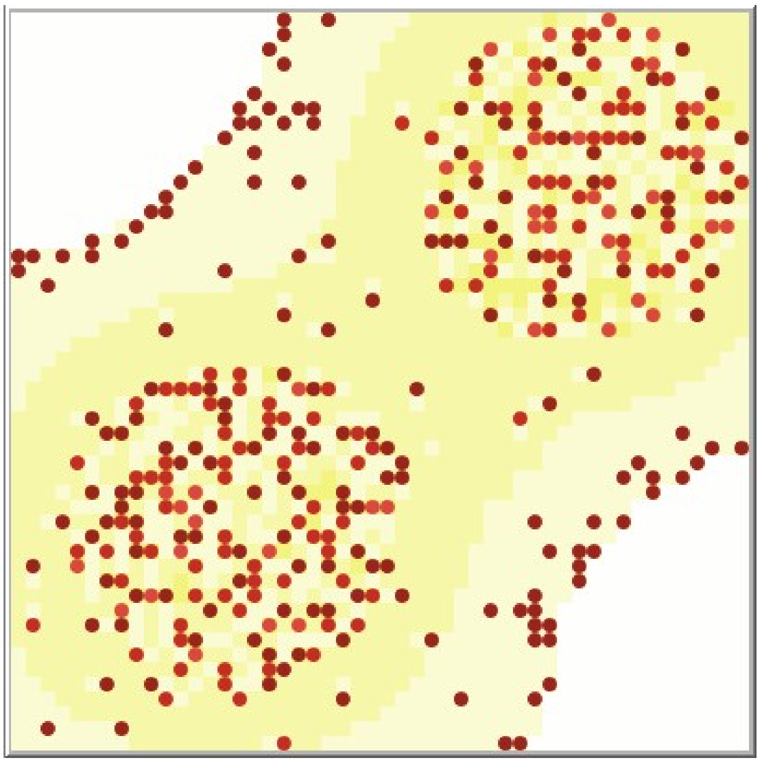

Figure 4.1: Screenshot of the original Sugarscape model with adaptive metabolism rule applied. Agents are colored by metabolism on a low (dark) gradient to high (light). For example, agents within the peripheral light-yellow zone and low resources adapted to survive there. In contrast, in the interior, high-resource zones, agents retain their higher metabolisms and ability to accumulate a large surplus.

Wealth inequality is obvious when looking at one run of the model, but in order to measure and test inequality across different runs, a few key metrics should suffice.

The model provides economic inequality indicators more germane to economic analysis, including a Lorenz Curve and Gini Coefficient. The Lorenz Curve is a graphical representation of the cumulative share of income (on the Y axis) earned by the poorest X percentile of the population (on the X axis) (Figure 4.2). A 45-degree slope marks true equality; for example, the poorest 50% of the population would own 50% of the total wealth, and the poorest 20% of the population would own 20%, and so on. A curve represents the observed wealth distribution of the agent population and moves away from the total equality line. The further the curve moves away, the more unequal the distribution. In short, the curve intensity indicates the wealth share of the higher percentiles (e.g., the poorest 80% own only 50% of the wealth). The Gini Coefficient is closely tied to the Lorenz Curve. The Gini Coefficient is a single number normalized between 0 and 1, representing the area between the Lorenz Curve and the equality line. The higher the Gini Coefficient, the higher the wealth inequality.

Agents can now interact with their environment in order to survive. If agents are preserved, they should also fit into their artificial society somehow. An additional rule states that if an agent finds themselves at risk of hitting zero resources, they find a viable agent near them with the greatest prestige (the sum of clients and prestige goods discussed later) and attaches themselves to that agent as a client. The more prosperous agent becomes a patron. Clients borrow resources from their patrons in the amount needed to survive though they continue collecting resources themselves. Inevitably, this creates a wealth gap between the haves and have-nots (Figure 4.3) In return, patrons gain prestige to continue enhancing their preferential attachment chances. There must also be ways to break these ties. The patron-client relationship ends if a patron drops below a resource threshold or a client above.

These rules create unequal networks in space (Figure 4.4) and quantitatively as evident in the in-degree distribution (Figure 4.5). Some of the richer agents collect most of the client connections while some collect far less connections. While the

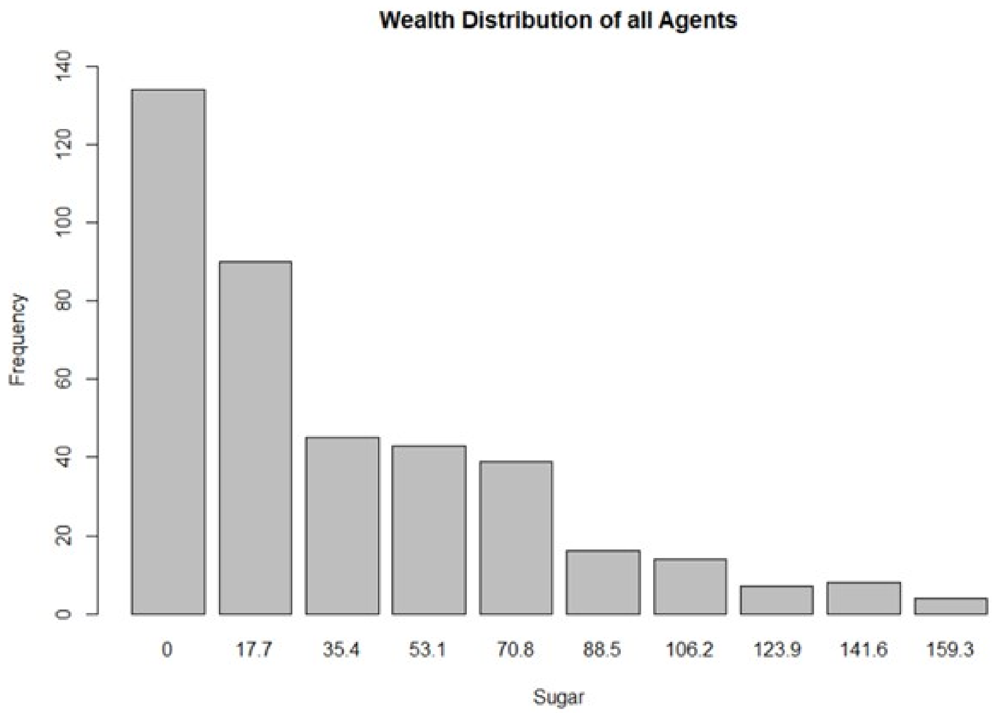

Figure 4.2: Histogram of wealth distribution of the agent population after 200 rounds. Very few agents have a high amount of resources, while many agents have less than 17.

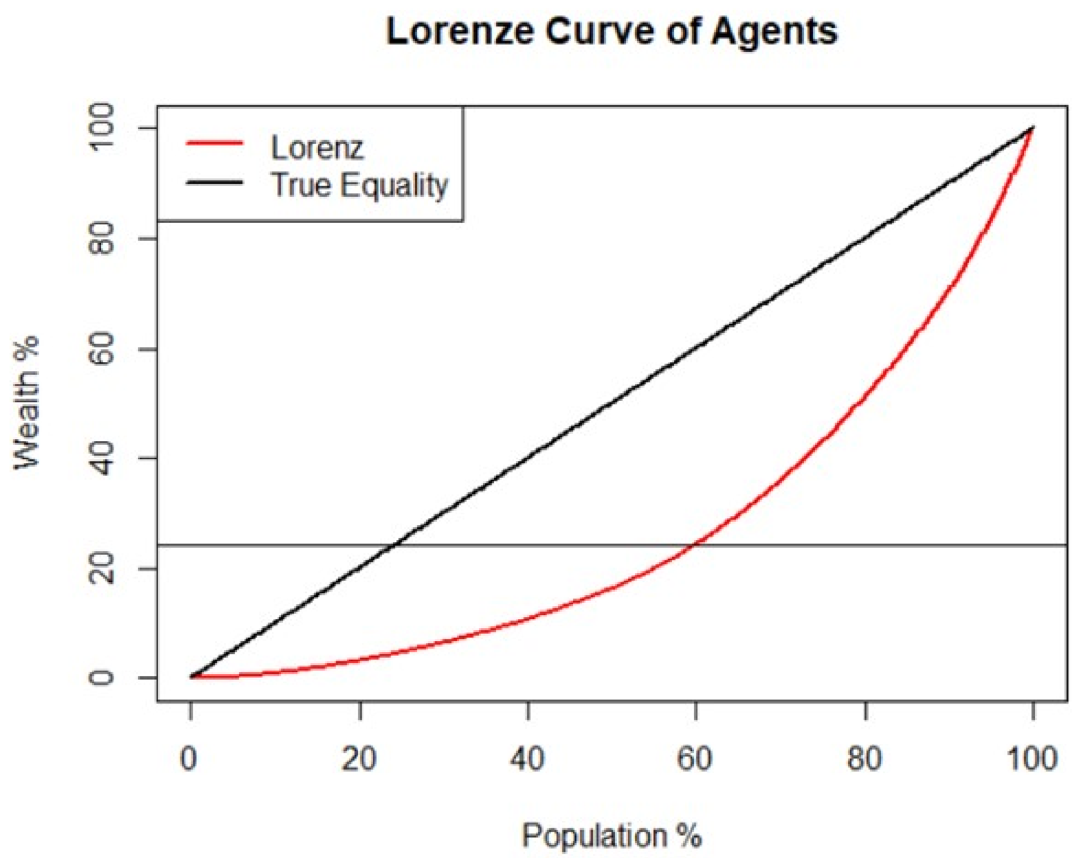

Figure 4.3: Lorenz Curve of the population of agents after 200 rounds of the model. The red curve represents the Lorenz curve, and the black, 45-degree sloped line is the line of true equality. The horizontal black line crosses at x = 60 and y = 24, meaning that the poorest 60% of the population own about 24% of the wealth.

distribution does not always reach the threshold for true scale-free status, the distribution is heavy-tailed like a scale-free distribution. The heavy-tailed distribution is significant because without preferential attachment, many agents would have a small number of clients since many of them would meet the requirements to receive links. If the model produces many patrons with small networks, then there is no competition and no large-scale hierarchical networks.

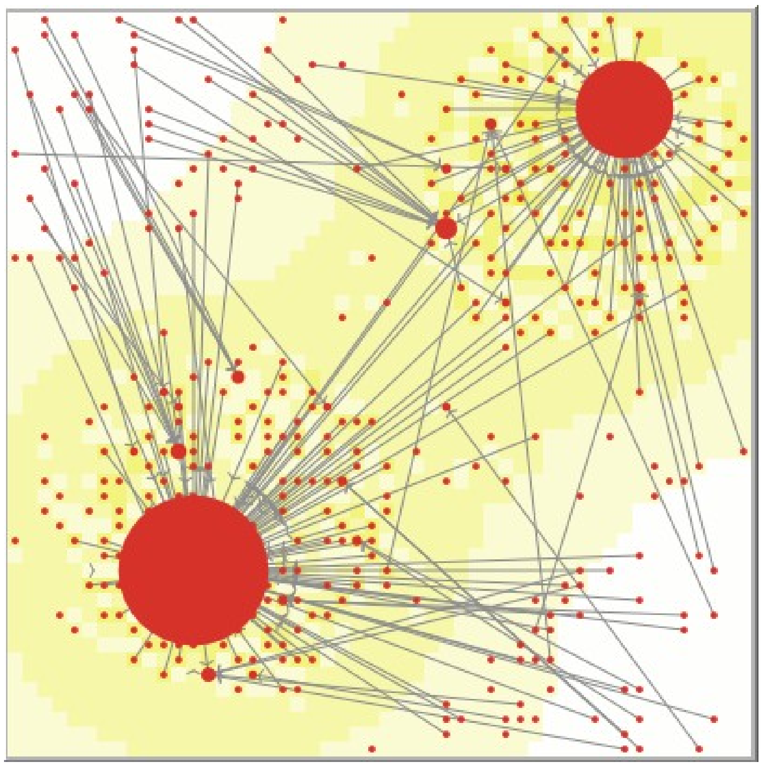

Figure 4.4: Preferential attachment rule applied to patron-client interactions. Like real-world human systems, attachment such as in social networks is not completely random and some nodes (people, institutions, even memes) receive much more connections than others and the "rich get richer."

While we can investigate graphs of state variables to understand how networks are evolving across the entire simulation, having spatial markers of where the highly-connected agents or nodes end up is also of interest. Having a record of where these

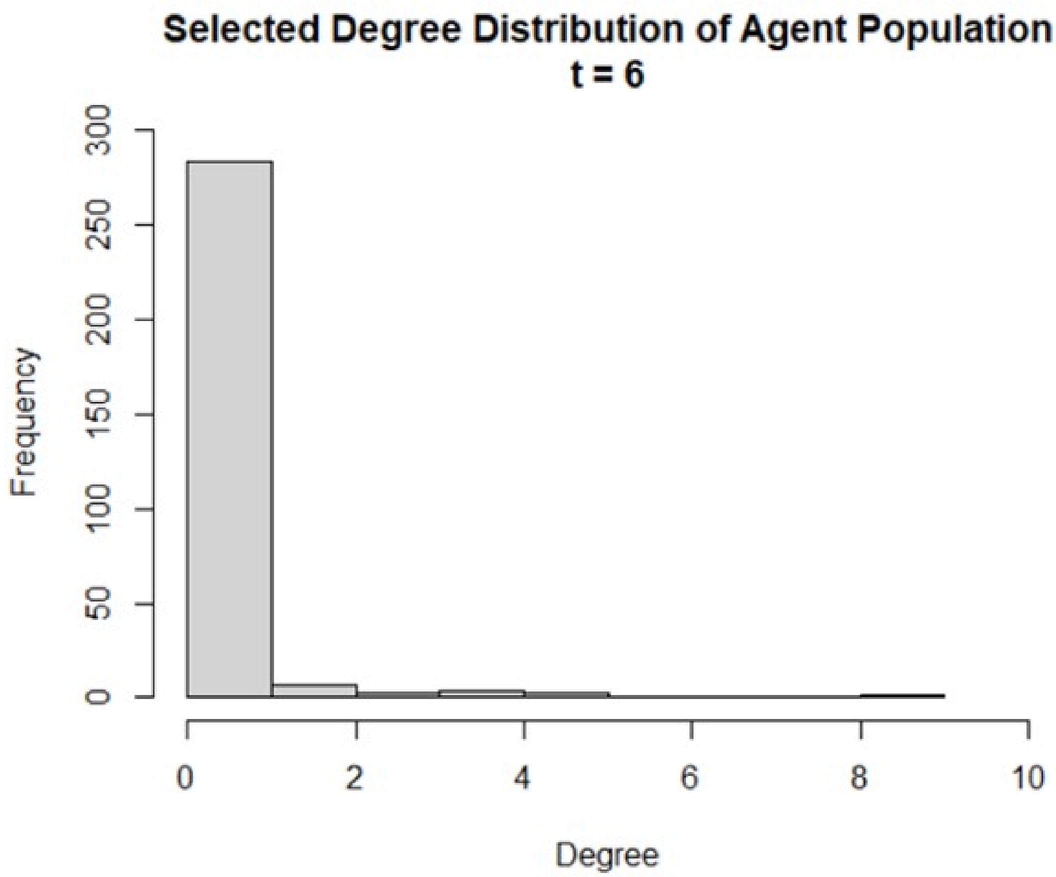

Figure 4.5: Histogram of degree distribution of agent population after 6 rounds. The first 100 zero degree agents have been removed so that the one 9 degree agent can be seen in the graph.

agents "died" should suggest where the cores of the spatial networks are located. We will call these kurgans after the burial mounds of Scythian elites and make up another set of agents, though agents that do not perform any tasks. They can then be isolated in the visualization as magenta markers with no other agents appearing.

These three new rules—adaption, preferential patron-client attachments, and elite "burials"—preserve the initial dynamics of Sugarscape while also generating new dynamics that propel a complex-systems understanding of nomadic societies. Moreover, as has been alluded to above, these dynamics are not only applicable to pastoral societies but many different kinds of societies or perhaps, to some degree, all human societies of the past and present. However, this assertion should be tempered as there are always outliers and unique cases depending on the scale and cultural adaptations of the society in question.

4.4 Expanding the World

The world of nomadic societies globally is very large though rather peripheral to many histories currently available. The African Sahel still sustains nomadic, transhumant, and agro-pastoral societies, the North American Great Plains and Southwest once hosted Native American mobile societies after the introduction of the horse, the Tibetan Plateau still allows for at least partial pastoralism, the many hilly and mountainous meadows around the world host goat herders, not to mention the Eurasian steppes, though greatly fractured by national borders, still provides a livelihood for nomadic pastoralists. There are many more specific and general ecoregions not mentioned here that can or once did sustain some form of non-sedentary lifestyles.

For the sake of modeling purposes, only the western part of the Palearctic grasslands as defined by the Terrestrial Ecoregions of the World (Olson et al. 2001) will be used for this research. This roughly corresponds to the Western tip of modern Ukraine to the Altai Mountains and from the forest-steppe of Siberia to Khorasan, Khorezm, and Transoxiana to the south (Figure 4.6). This provides a very broad ecological context but also includes the entire classical realm of the Scythian territorial expanse and the periphery of the sedentary world. This is already very large and potentially too broad of a study area, but attempting a model of the Turkish Seljuk or Mongol imperial domains would expand this even further.

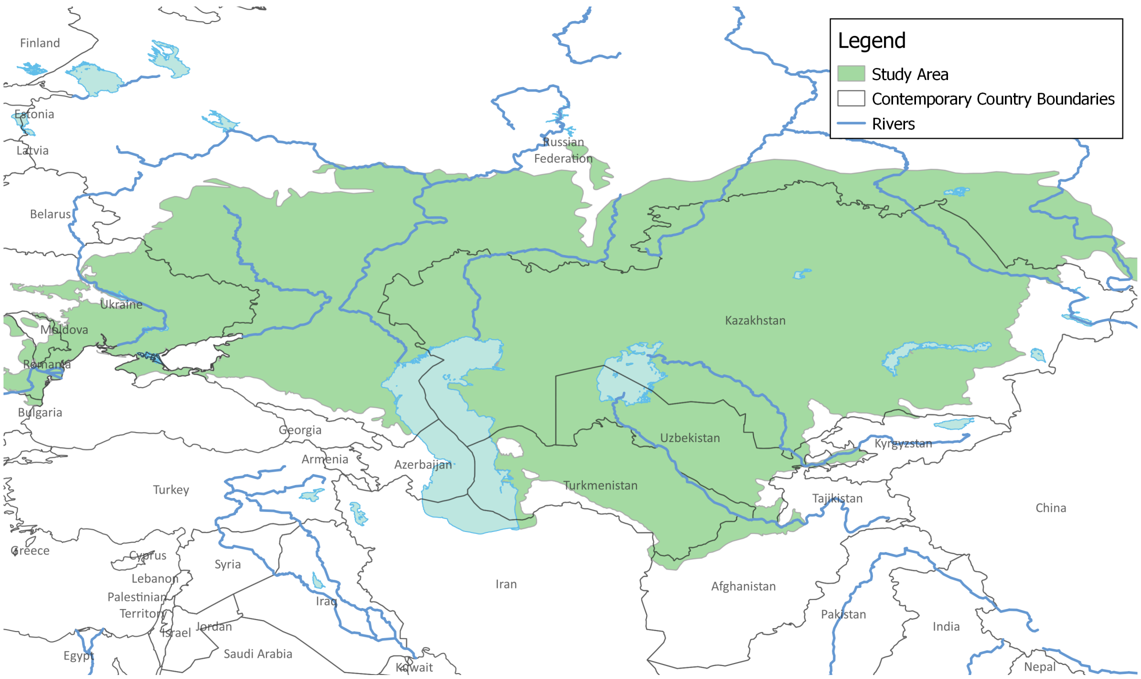

Figure 4.6: The green shaded area conforms to the grasslands of the Palearctic realm as defined by the Terrestrial Ecoregions of the World (See: Oslen et al. 2001). Lake data provided by the Global Lakes and Wetlands Database (Lehner and Döll 2004).

Many variables can be considered in order to determine which areas within this expanse are better or worse for pastoralism and, further, for wealth accumulation, spatial hierarchy, and cultural hubs. Biomass production, primarily in the form of grasses and graze land, is conditioned by climate variables such as rainfall, snowfall, number of growing days, soil types, temperature trends, as well as human activity such as cultivation or grazing. However, much of this data exists independently of each other and thus difficult to add them together into a affordance surface at the same resolution. For the purposes of this model, only biomass estimates, river buffers, and land cover are assembled.

Biomass estimates form the basis of the resource surface as horse-centric pastoralists ultimately rely on the production of grasses and graze lands. Biomass data used in the model came from the Oak Ridge National Laboratory Carbon Dioxide Information Analysis Center (ORNL-CDIAC) and consists of a raster—spatial data characterized by rows and columns of cells or pixels that form a continuous surface—representing the density of carbon stored in living plants in metric tons per hectare for the year 2000 (Ruesch and Gibbs 2008). The data has a cell resolution of 1-kilometer. However, this resolution becomes further reduced after processing and resampling into Netlogo. Datasets reflecting NDVI (Normalized Difference Vegetation Index) or "greenness" is potentially another source of information regarding richness of grass lands. However, it was found that the NDVI of a large region provided large homogenous regions of high values and thus less differentiation.

Rivers and their valleys are also important. We can use historical accounts and archaeological finds to help narrow these variables. For example, we know that many royal kurgans—burial mounds—of the Scythian elite were constructed near rivers and in river valleys of the Pontic steppe as well as around the Ural river farther east. More kurgans have been found far to the east near Lake Issyk, bordering the Tian Shan Mountains as well as the Pazyrik Valley near the Sayan and Altai Mountains. Reliable sources of water, as well as the sheltering effects of valleys, clearly became important for nomadic peoples in the premodern past, particularly during the winter months. Therefore, areas around rivers up to 20 kilometers receive a bonus. A buffer of 20 kilometers was generated, rasterized, and added to the biomass surface via raster addition (adding the cells together that overlap).

More variables can increase the realness of the simulated world, as can an increase in resolution, but by adding together these three variables, we arrive at a world that seems to conform to what we know about the premodern steppe and the attractors of Scythian elite burials. In a sense, this landscape can very well predict where those kurgans are likely to be located with some degree of accuracy. However, this isn't very interesting. Instead, we are interested in how mobile societies, not spatially isolated ones, can develop socio-economic networks and hierarchies that then lead elites to place their tombs where they did. We need rules that make sense to sustain nomadic-pastoral agents on their own but also as networked societies.

There are some important limitations to applying such an agent-based model to real-world data. First, historical data regarding land cover, biomass, or greenness of the steppe is non-existent. Any NDVI or biomass data regarding these areas clearly reflect contemporary land cover, which includes intensive wheat cultivation and thus heavily skews biomass as well as NDVI, especially in the Pontic Steppe (Khazanov 1994, 173). Moreover, the phase space of a software package like Netlogo more or less abstracts varying qualities of resources. For example, it doesn't really matter where on the Earth's surface a "sugar rich" location is, only that agents are exploiting it and that it has a semi-periphery and periphery.

In addition, creating client-patron links relies on a gradient of resources where patrons can collect resources at the high end of the gradient while clients forage to survive in the low of the gradient and still be within communication distance. Modern data on biomass and NDVI indicate that no clear gradient exists in the Pontic Steppe though it does exist in the Kazakh Steppe. In this way, variation has the potential to create many patrons in the northern Kazakh Steppe but not directly around the Dnieper River, where we know many Scythian sites are located. Any real-world data, therefore, would ideally need to be of high quality and allow for much local variation. Adding bonuses to rivers helps to some extent. Then again, including more cultural features such as political economy and coercion would swing the discussion farther away from geographic determinism to forces beyond the simple facts of biomass.

Second, using real-world data forces the modeler to scale up. A larger space means more agents, and more agents mean adjusting resource parameters for patches or cells as well as what constitutes survivability for the agents. In Sugarscape, an agent depleting a cell means it is consuming much of the available resources within its range that other agents are not exploiting. If we scale up the geographic world, then without a commensurate increase in the number of agents, each agent will have a world of its own to exploit, and regrowth will never be slow enough to threaten sustainability. If Sugarscape has a agent patch ratio of something in the order of 400:2500 or 0.16, then increasing the world space from 50x50 to 100x100 would mean the modeler would need to include at least 1600 agents. Netlogo is rather slow compared to other programming languages such as Python, but even then, a modeler would need to take advantage of distributed computation such as what is found in a computing cluster. However, even with the computing power, the data challenge makes scaling up potentially fruitless. Limitations aside, the model was able to manifest similar patterns in the different environments provided proper scaling.

4.5 Running the Model

The agent-based model runs for 400 time steps. All agents move, consume, metabolize during each time step. They also can make connections when necessary within one time step. To simulate a significant climate event, the program was instructed to depress all resource patches by 1 (all patches initially have a resource value between 0 and 4) at step 300. At step 350, the resources return to normal. Below are four screenshots of the model running within NetLogo 100 time steps apart. One may note the changes in the Gini Coefficient, Link, and Maximum Client plots which will be further discussed in the next section.

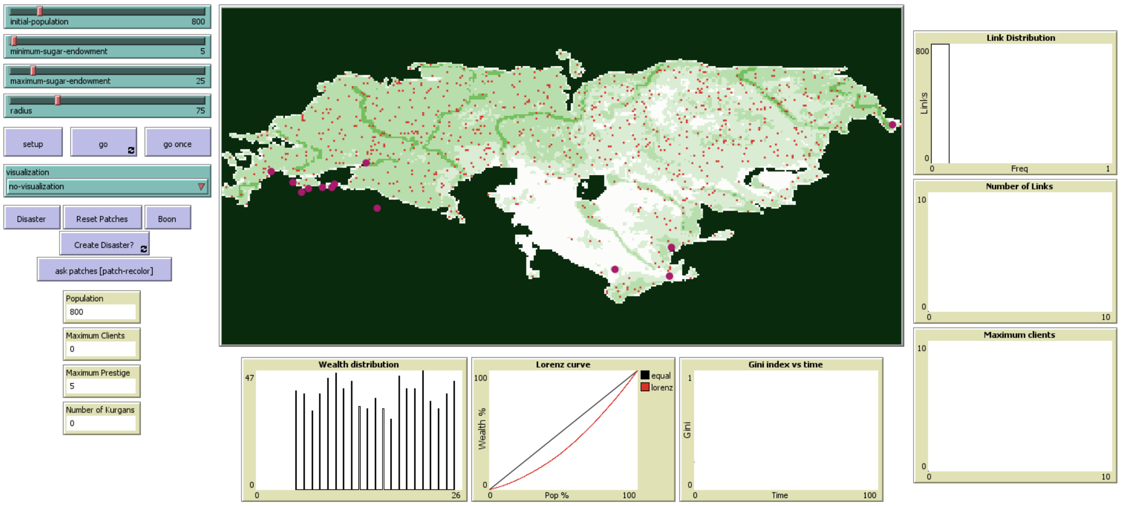

Figure 4.7: Screenshot of model interface at time step 0.

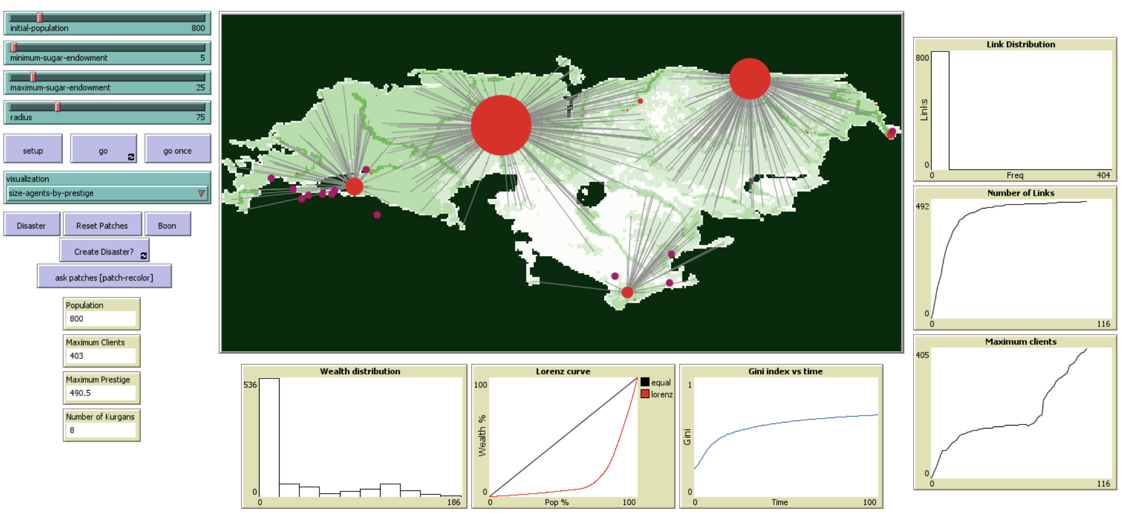

Figure 4.8: Screenshot of model interface at time step 100.

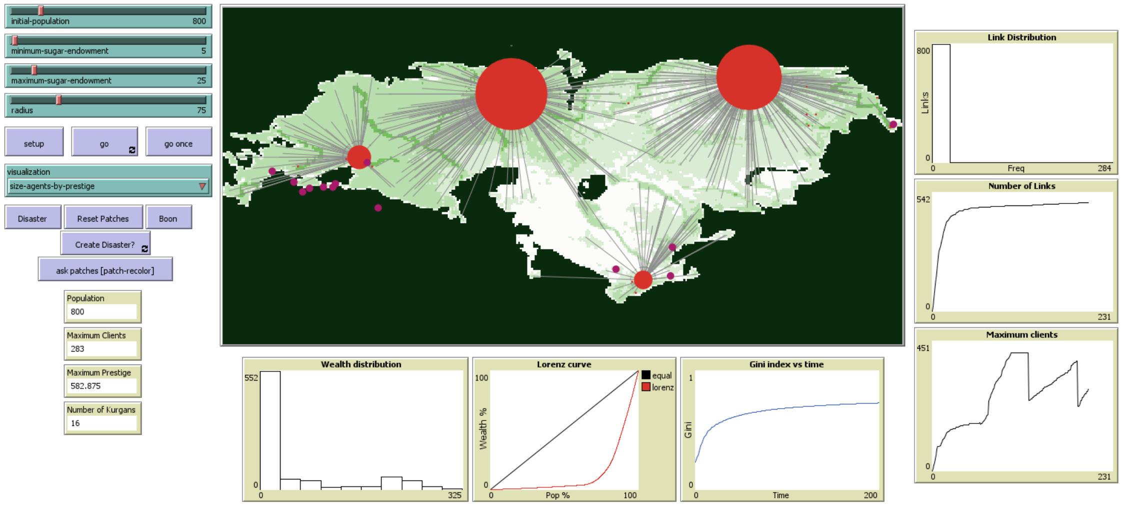

Figure 4.9: Screenshot of model interface at time step 200.

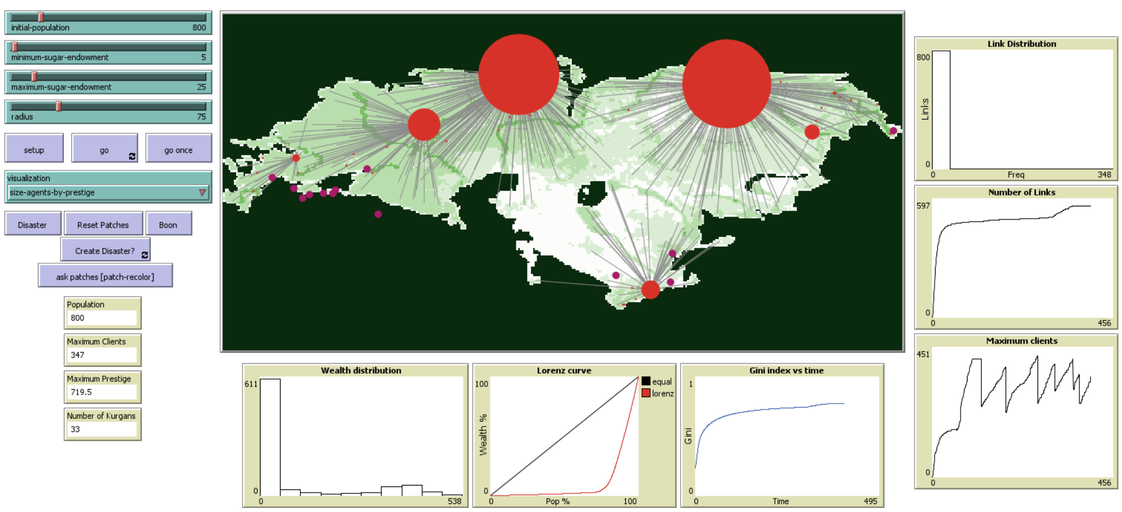

Figure 4.10: Screenshot of model interface at time step 400 to show the results of the "climate shock."

4.6 Results

The model yielded recognizable patterns after many runs. First, the wealth distribution of the agent population quickly tilts, creating inequality. Second, the distribution of links also becomes highly unequal, even more so than wealth, and the rich get richer again.

4.6.1 Wealth Inequality

Like Sugarscape, wealth inequality manifests clearly within the agent population. A heavy-tailed distribution where few agents have many resources and many agents have few emerges from the interaction with the simulated landscape and rules. Plotting the Gini coefficients of 10 consecutive runs of the model reveals a similar trajectory to all model runs with some variation (Figure 4.11). This trajectory consists of a quick rise in inequality through the first 100 time steps of the model, then a flattening out to an asymptote. As programmed, at time step 300, a disaster sweeps the model space and all resources patches are reduced which creates a noticeable spike in inequality as the wealthy agents have control of a healthy stockpile of resources and likely greater vision while the poor agents or agents just above the client threshold now seek patrons. At time step 350, the disaster abates and the resource patches return to normal where the flat asymptotic curve prevails for the remainder of the simulation. Therefore, rather than dissipating the artificial social structure, the reduction of resources—we might consider this analogous to a region-wide drought to winter precipitation event—actually leads to greater inequality. In addition, the return to normal resources does not lead to an immediate reduction of inequality but an ossification of disaster-level inequality.

It appears that the model conforms to the basic lessons of the Lorenz Attractor visualization. Although each model run's Gini Coefficient follows a similar trajectory, no two runs are exactly the same. The agents within the simulation have a slightly

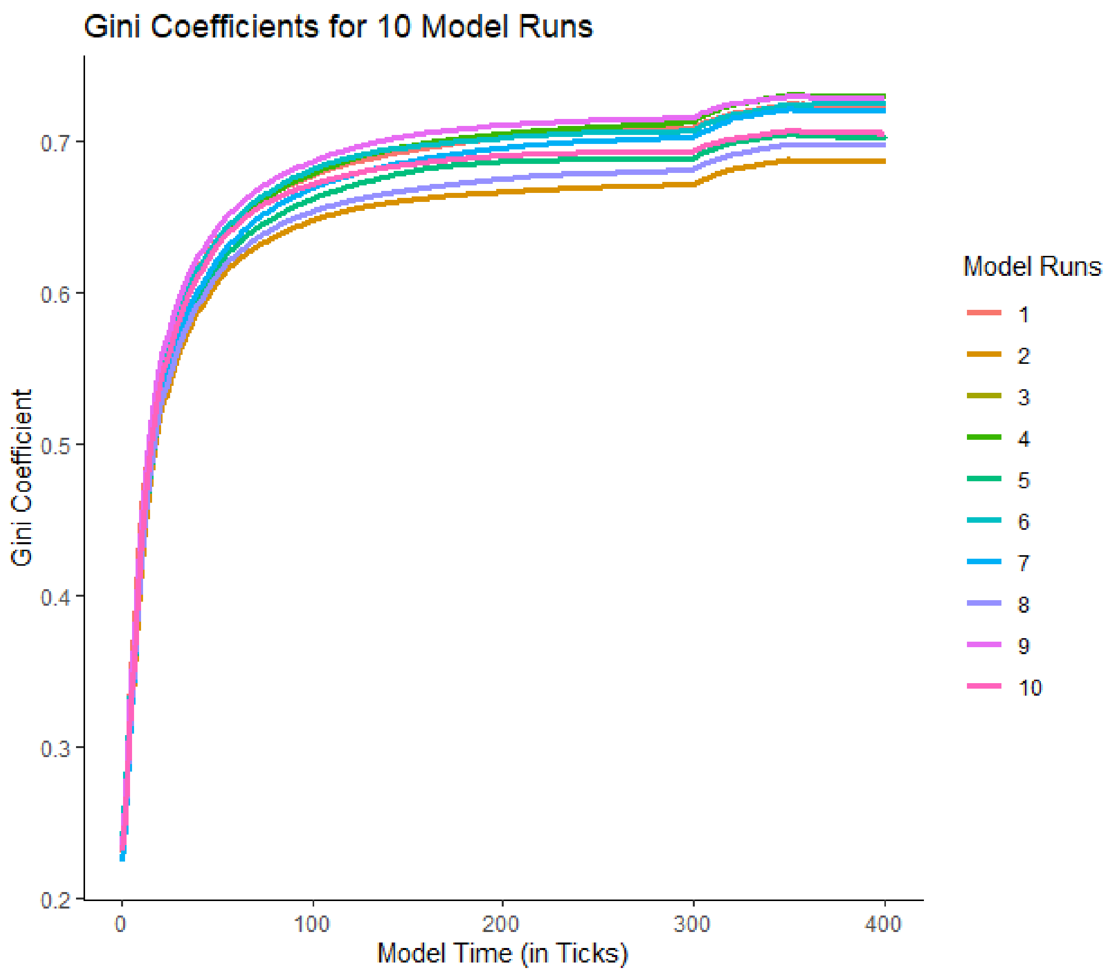

Figure 4.11: Change of Gini Coefficient over time between 10 different runs of the model. Notice that the coefficient begins to rise after the regional resources become depressed as programmed but then remain high even after resource levels return to normal.

different configuration and form slightly different networks each time leading to a nominally but not fundamentally different pattern.

4.6.2 Patron-Client Networks

How networks emerge and their size varies depending on the communication distance of the agents. If agents can only see six patches in either direction, on a large surface they will barely communicate with anyone else. The exact "correct" radius of communication is impossible to know or predict. Different radii were tested in a parameter sweep to ascertain how communication distance changes the size of networks as well as the distribution of kurgans (Table 4.1). Summarized below is a summary of network-related variables using different radii from 25 to 100 in steps of five. After reviewing the results, a radius around 75 produced less spatially random kurgan sites and enough to ascertain a spatial distribution. Moreover, if the radius is too high, only one agent per generation collects all, or nearly all, connections leading to far too few kurgans and a completely connected network. If the radius is too low, there are far too many patrons that leave traces nearly everywhere in the study area and little prestige competition is evident.

Wealth inequality increased over model time and so did the interconnectedness of the patron-client networks. Agents quickly formed connections up to a baseline between 250 and 350. A flat but steadily increasing trajectory prevails after that until time step 300 (Figure 4.12). In a more dramatic fashion than the Gini curves, the number of links quickly rises by around 100 links as newly shocked agents seek patrons. The new networks then settle into their expanded iterations as conditions return to normal suggesting that, in this case, networks are much quicker to form than disassemble and that shocks to resources increased hierarchy which becomes semi-permanent into the future.

Radius	Max. Clients	Kurgans	Pop.
25	90	142	758
30	165	182	748
35	194	153	755
40	200	124	758
45	299	120	750
50	275	97	757
55	307	93	751
60	369	92	741
65	349	76	750
70	448	37	800
75	501	41	800
80	513	32	800
85	520	25	800
90	584	23	800
95	596	23	800
100	675	30	800
300	800	16	800

Table 4.1: Results of parameter sweep on different radii of agent communication distance. An increase in radius yields increases in the maximum number of clients that patrons accumulate as well as the total population at the end of the simulation. On the other hand, kurgans decrease as radius increases due to there being less local variability and thus less patrons.

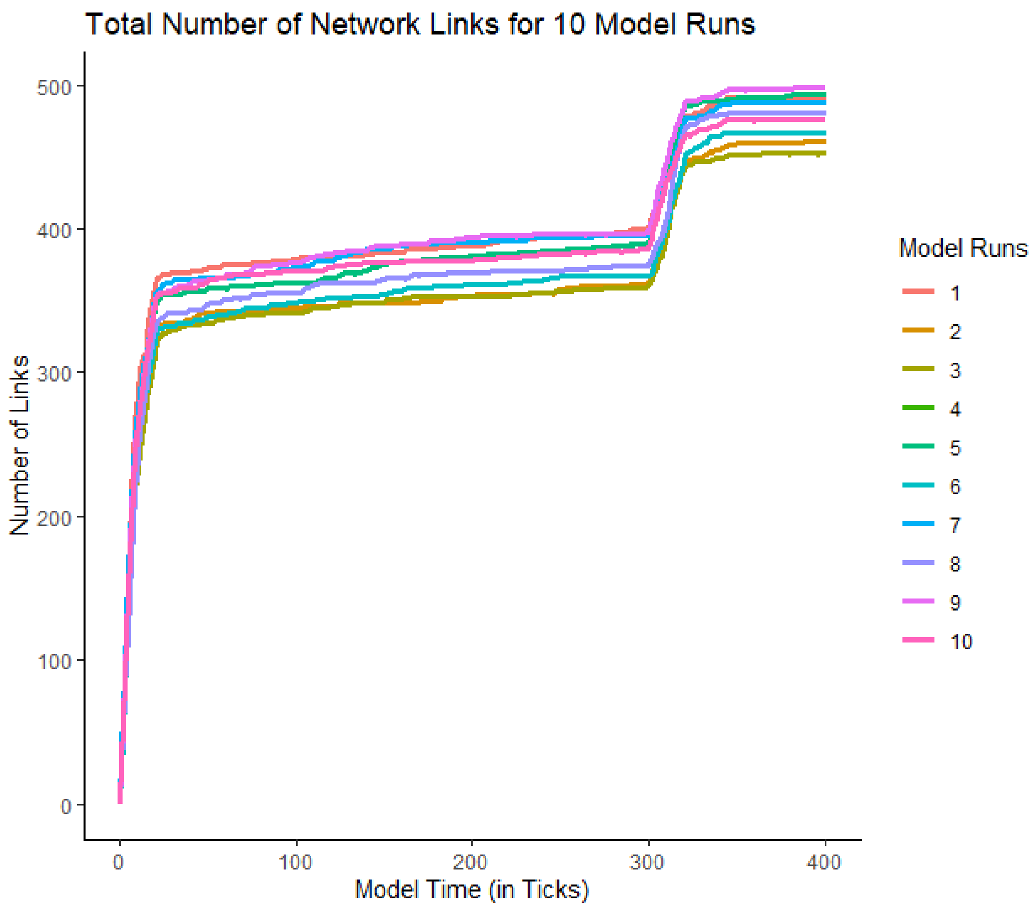

Figure 4.12: Change of link frequency over time between 10 different model runs. Like the Gini Coefficients, links tend to follow a similar trajectory and spike when resources become depressed. The curve then settles into a new normal after resources return to normal.

4.6.3 Spatial Distribution

Examining the spatial distribution of "kurgans" or final sites of wealthy patrons, a general pattern emerges that conforms to known Scythian site distributions. Kurgans are widely distributed but tend to frequently clump together in the Pontic Steppe as well as in the far east of the study space. Plotting 10 consecutive runs of the models reveals this pattern more clearly, revealing that the pattern manifests in independent iterations of the model and not simply by chance (Figure 4.13).

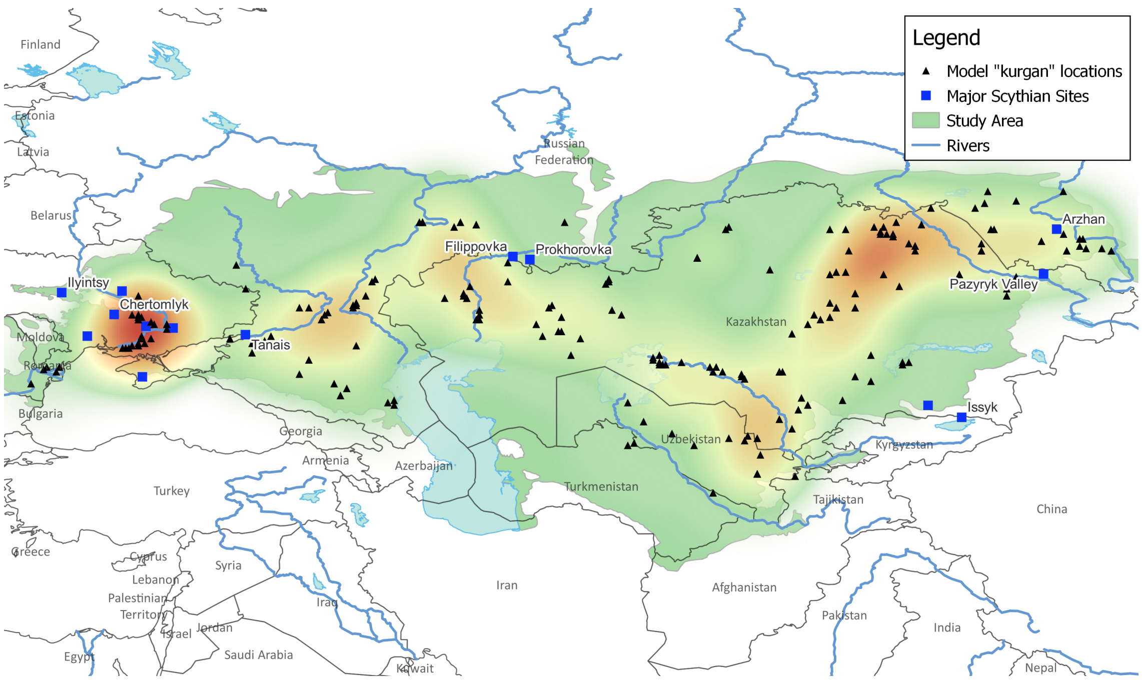

Figure 4.13: Heat map of kurgan locations deposited by patron agents combined over 10 different model runs. Obvious hot spots—places where points cluster most tightly—appear in the Pontic Steppe as well as the Eastern Kazakh Steppe and Forest Steppe. A third weak hot spot appears in Transoxiana.

Represented here are the core territories of the Scythian and Sarmatian societies. For example, many Scythian kurgan burial mounds were discovered along the Dnieper River, Black Sea, and Sea of Azov. The hotspot also extends gently to the northeast as far as the Caspian Sea and the Ural River which is coincident with the Pontic Steppe extent as well as more Scythian burial sites. This core area is confirmed by (Juras et al. 2017) using DNA analysis, specifically mitochondrial lineages (Figure 4.14). Another hotspot appears in the far east of the study area between the Irtysh and Ob Rivers and abutting the Sayan Mountains. Two important Sythian sites at Pazyryk Valley and Arzhan are in this region though more eastward than the center of the hotspot. A third, subtle hotspot appears in Transoxiana between the Amu and Syr Darya Rivers (Oxus and Jaxartes Rivers). This generally equates to Sogdiana and Northern Khorasan and not necessarily a center of nomadic power. However, this area was rich in trade and oasis towns which became conquests of the Gokturks, Mongols, Timurids, and Uzbeks.

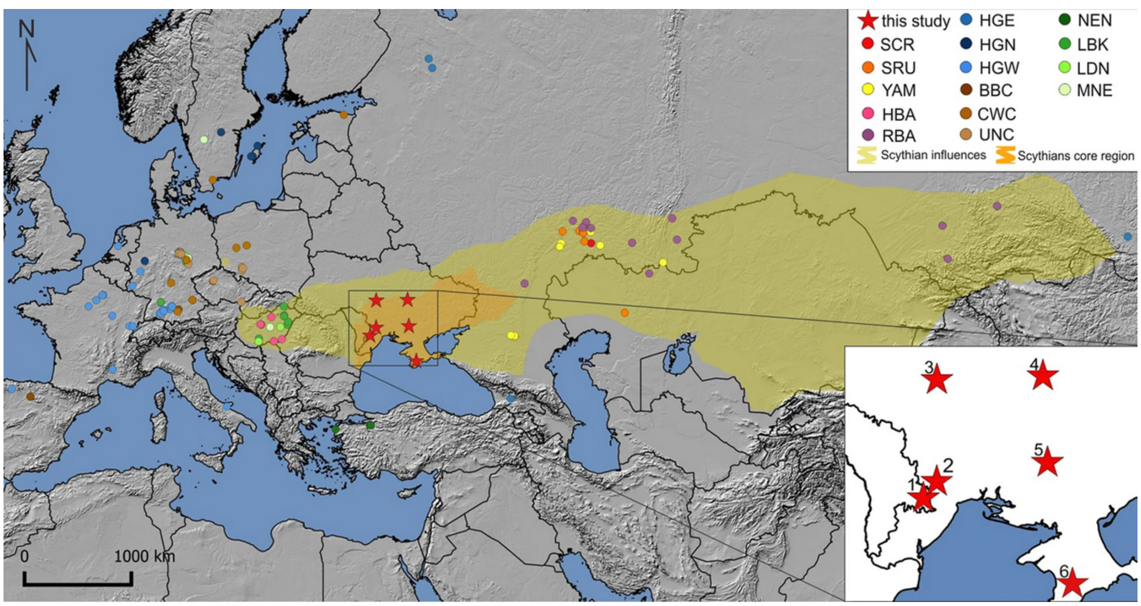

Figure 4.14: Map of Iron Age Scythian influence using spatial DNA analysis; reproduced from (Juras et al. 2017). Especially notice the orange shading denoting the Scythian core area as well as the yellow shading denoting areas of Scythian influence. The model results seem to replicate this West-East core dynamic at least for the steppes.

These three hotspots emerged due to several factors. First, in Pontic Steppe, the presence of four major rivers ensured that agents had good access to high-resource patches as well as relatively rich grazing patches in general. However, the local variability in resources, especially in the eastern part of this region, ensured enough clients to match with patrons. Second, access to many trade cities along the Black Sea provided the means for patrons to convert resources into prestige goods and thus bolster their chances of receiving preferential attachments. Lastly, patrons benefited by being located in a more inland area due to the maximization of a periphery. For example, the Eastern European forest steppe provides a wide northern periphery while the area north of the Caucasus mountains provides another to the south. The wide Kazakh Steppe to the east which contains less overall biomass provides a periphery as well.

In the northeast, the hotspot emerges due to the two major rivers and access to “trade” with the Mongolian Steppe and the Chinese world. This hotspot also seems to benefit from the patchiness of biomass resources where islands of high-resource patches are surrounded by poorer ones—a recipe for patron generation within the model.

4.6.4 Limitations

Some unexpected absences and patterns also arose. First, no hotspot arose near Lake Issyk despite its rich resources. It was here, near the Talgar alluvial fan, that the Scythian Golden Man’s burial was found. Second, no hotspots emerged in Khorasan in the southern portion of the study area, adjacent to the Iranian Plateau. Both areas are very important to nomadic history particularly for the history of the Uzbeks, Massagetae, and Parthians.

Some factors may have led to these areas being considered peripheral and not fertile ground for the modeled patron-client relationships. First and most obviously, this part of the study area either received a "0" or "1" for most of its patches. This means that agents could rarely survive except as clients here. The low or non-existent resources was a byproduct of the reclassification method which grouped biomass values into four bins resulting very low biomass values being lumped together into the lowest group. Much of the area around Lake Issyk also received low values though lone patrons could form there, just not enough to form a hotspot.

Another important limitation of bounded surfaces in spatial analysis or agent-based models are edge effects—patterns or lack thereof shaped by the bounded world where agents lack neighbors and resources that would otherwise be adjacent to them. For example, any agents located at the edge of the world map have less access to a wide selection of patches and potential clients and face more restrictions on the resources available as movement is restricted. In contrast, agents in the middle of the modeling space will have the greatest access to diverse resource patches and have neighboring agents on all sides. While one way to ameliorate this effect would be to transform the world into a torus (a doughnut shape) and thus make the world wrap around to connect to itself on the other edge, this makes little sense historically. However, it was also historically true that nomadic societies had access to areas beyond the extent of the model world whether that be trade relations, clients, or resources. The limitations of selecting only areas of predominate grasslands become clear even when discussing nomadic societies and should encourage more trans-ecological models. In addition, perhaps diverse societies of agents can and should interact with their own sets of rules though this introduces considerably more complexity.

4.7 Summary

Overall, the results of the model are satisfactory. Building off of the original Sugarscape model and including a few new rules inspired by existing models, an artificial society of patron-client networks left spatially coherent and historically recognizable patterns. Spatial hierarchies in the form of networks emerged from hundreds of agent interactions—networks that surely existed in the past in some form despite a dearth of material culture that captures often unseen and ephemeral connections. Moreover, the rules generated an economically and socially stratified society using a mix of endogenous (patron-client foragers) and exogenous (trade) forces. Although the model is by no means perfect and is limited in important ways, even modest successes in formal modeling are not the end point of investigation. Rather, the ability to grow artificial societies that look familiar and recreate human dynamics spatio-temporally only mean that we need even better, more complex ways of thinking about complex social systems that take us beyond simple ABM or inductive strategies derived from scattered material clues.

Chapter 5

Identifying Historical Processes

Deep in the human unconscious is a pervasive need for a logical universe that makes sense. But the real universe is always one step beyond logic.
—Frank Herbert *Dune*

5.1 Introduction

Human societies can be understood as complex systems, and tools such as agent-based models such as the one found here can aid in theory-making, theory-testing, and assumption-checking. While computational and mathematical models can also lead to greater foresight, prediction requires very precise data, a pre-existing understanding of key system dynamics, and a deep understanding of the research question. The field of Central Eurasian history is not quite there yet, but we can still use models in the former capacity—as tools the think within and across disciplinary boundaries.

In this chapter, key model findings on essential dynamics such as the emergence of wealth inequality, spatial socio-economic hierarchies, and the effects of shocks on vital economic resources will be explored in conversation with disciplinary literature. The following discussion will also act as qualitative validation of model results.

5.2 Wealth Inequality in Nomadic Societies

As pure nomadism is rare, so is egalitarianism, except in some instances where the society is exceedingly small or where wealth is difficult to control unilaterally. Even if relying solely on herd animals for subsistence, societies can become significantly unequal based on an uneven distribution of resources in time and space, power of redistribution invested in particular individuals, theft, and natural disasters. The ABM model also produces an unequal society without rules specifying political economy or unfair restrictions. Instead, given a diverse allotment of metabolism, location, and vision, "living" on a heterogeneous resource surface, inequality manifests as fitter agents that can take advantage of the best resources and can develop their surpluses continually. In contrast, the more poorly adapted agents are left to make do. Moreover, the growth in inequality is not necessarily the result of eventful decisions or individual policies. Over time, it can emerge as humans interact with their environment, society, exchange, and wealth transfer of their own volition in a complex interplay with political, cultural, and legal frameworks (Bendrey 2011).

Even at a basic level of random exchange, given an equal footing, a group of agents will create an unequal wealth distribution (Dragulescu and Yakovenko 2000). Even more so with agents with real-world self-interest and power. States and empires need not even exist. Hunter-gatherer societies also exhibit wealth inequality. Highly mobile hunter-gatherer groups differ less on material goods but might have differential access to resources or social networks while less mobile groups can better exploit high-resource patches and accumulate wealth (Smith et al., n.d.). The model introduced the variable of "vision" as a partial way to represent uneven access to resources and information. This head-start allowed some agents to have an advantage in mobility and information gathering, thus allowing them to take advantage of high-resource patches more effectively.

Wealth in nomadic societies is not only wide open, homogeneous grass for herd animals but particular locations with access to reliable forage, water, and shelter as well as trade routes and the goods carried across them. In addition, the more defensible a resource or resource location is, the more individuals and groups are able to control it (Dyson-Hydson 1980). For example, Xiongnu and Uighur habitation tended to be centered in the Egiin Gol Valley of Mongolia, which also tends to have high NDVI values and thus are richer graze lands (Honeychurch 2014). Here, elites could establish a base of surplus accumulation in herd animals and horses, used for meat, milk, war, transport, and ritual such as in the Orkhon Valley in Mongolia where the Mongols established their capital at Karakorum or the various river valleys in Central Eurasia. The "farming Scythians" mentioned by Herodotus grew grain not just for subsistence but for sale (Beckwith 2009, 65) and the control of cultivated areas was common in all large nomadic empires.

Pastoral wealth could also be converted into material wealth in the more classical forms of precious metal objects. Iron-age elite burials in Inner Asia began being so richly adorned that it led some scholars to assume new peoples have replaced the old, but pottery and burial rituals remained the same suggesting that an elite emerged from the same population (Di Cosmo 1999).

Nomadic groups were also actively engaged in developing and maintaining trade networks. The Silk Roads are a well-studied example of how pastoralists became architects and stewards of one of the greatest premodern trading complexes. Michael Frachetti illustrates using a spatial GIS model, that herders moving up the slopes and into the valleys of the Inner Asian Mountain Corridor between the modern countries of China and Kazakhstan could have generated regular and reliable flows of people and goods (Frachetti et al. 2017). There is sufficient evidence to show that even in the Late Bronze Age, the pastoralists were in productive trade relationships with Caucasian trading networks and Western Black sea networks (Sherratt 2003). Further, the Mongols of the Yuan and Ilkhand Dynasties actively traded artisans between realms and fed Middle Eastern tastes for exquisite ceramics (Soucek 1999).

The model captures the basic dynamic of a gradually expanding wealth gap as a process that unfolds as an interaction between agents and their environment. However, although the pattern is simple to make, the parameter values for initial resources of agents or the resources (biotic, abiotic, and/or social) that could be found on the landscape are still only general approximations. Whether a typical nomadic elite was twice or thrice as rich as a common herder in any particular period is difficult to estimate. Even so, the myth of nomadic egalitarianism or fundamentally needy societies should be put to rest in favor of cross-cultural comparison and contextualized ethnography. Wealth inequality, though, did not stand on its own and worked in connection to other dynamics in the model.

5.3 Hierarchies and Preferential Attachment

As societies are complex, trade cannot be singled out as only an economic activity and, especially for the premodern period, should also be strongly considered symbolic appropriation by elites. Rich agents within the model did not only get richer but also formed networks with poorer agents and competed for client connections. Like wealth distributions, social connections and political loyalties are also unequal due to competition and various social gadgets and material culture that make elites more attractive for association. In the bronze age, people in the Pontic Steppe region formed patron-client relationships much as they formed human-deity relationships all of which were mutually beneficial to some degree(Anthony 2007, 99). Though Khazanov argues that wealth inequality is inevitable, he also argues that rich patrons were temporary and client attachments were opportunistic (Khazanov 1994, 153–157). This is perhaps true of any society, but the kinds of nomadic elites that eventually established empires were not only betting on next year's grass growth.

As Grahame Clark argues that precious materials operated to help create stratification; "the concept of precious as distinct from merely useful substances could only have arisen in societies enriched by aesthetic sensibilities and sufficiently aware of persons to wish to symbolize relations between them as individuals and enactors of social roles" (G. Clark 1986, 6, 102). Over 100 years ago, Thorstein Veblen coined the term "conspicuous consumption" to refer to costs incurred beyond survival needs in order to increase social position (Veblen 1899). These costs have come under the "Costly signaling theory," which posits that individuals in a society will go out of their way and expend resources to gain/maintain social status and reinforce their control of resources even in good times (Boone 2000).

The prestige gained, as in our modern lives, could also mean a greater probability of advancement and beneficial social attachments. We might think of attachments in the framework of network theory in which individuals are nodes, and the edges that connect them are social, professional, or political engagements of various kinds. In most networks, particularly human social or human-made networks, the distribution of incoming links is skewed towards a few nodes. The scale-free distribution develops when a network continually grows and when new edges are created to nodes that already have a large number of attachments (Barabási 2001). A common example of scale-free networks is the internet and how a few web pages are highly connected to the rest of the internet. Another example more familiar to scholars is the network of citations in which few scholars enjoy many other scholars referencing their work, while many have few citations. Likewise, premodern human societies in which stratified social hierarchies formed must have also been scale-free-like in that whoever was the leader was likely highly connected among the elites and soldiers and commoners through other obligations.

The model recreated a long-tailed network by allowing wealthy agents to "buy" prestige goods from Greek Black Sea colonies, Central Asian trade hubs, and China via the Eastern Steppe. These goods increased their prestige and thus increased the chance that they would receive more client connections when available. Moreover, although the model did not add nodes to the network, agents aging out allowed for periodic rewiring and fresh competition (Newman 2003). This allowed patrons to pick up additional attachments that may have been engaged with other patrons. Lest we forget, elaborate burials that require many laborers are also a form of costly signaling, and as patrons aged out of the simulation, they passed on their prestige and legitimacy to the agent that replaced them—maybe their heir—and thus a dynasty of well-connected individuals could continue throughout the simulation. As far as nomadic history is concerned, preferential attachment, as well as generational prestige and legitimacy, was enjoyed by Chinngis Khan's descendants so much so that even hundreds of years after his death, Chinngisid princesses were the key to powerful positions in Central Asia. For example, the Turco-Mongol leader Timur or Tamerlane was a great conqueror and likely gained much prestige through military victories but still needed to marry a Chinngisid princess in order to be called *kuragan* or "royal son-in-law" to cement his power.

Although prestige goods are one way of costly signaling, there are of course, other ways in which to gain preferential social attachment and legitimacy. Nomadic rulers like Mongol Ilkhanid ruler might ceremoniously convert to a new religion such as Islam which is shared by many of the lower elites or commoners (Melville 1990). Royal hunts can also reinforce hierarchical positions and even condition loyalty and obedience through threat (Allsen 2006). Feasts and festivals also provide a stage for acts of skill as well as the spectacle of the written word and visual art. Finally, monumental architecture or even charitable institutions can help maintain current links and attract more. In any case, the particular strategy is less important here than the emergence of hierarchies horizontally among agents in one time slice and also through time.

5.4 Hierarchical networks in space

Patron-client networks formed over the course of the model and the patrons which functioned as the hubs of the networks left visible traces of their last location before leaving the simulation. These tokens—*kurgans*—have no attributes to their real-world counterparts but allows the modeler to understand the spatial patterns of patron-client networks. By gathering all these tokens over the course of ten runs, hotspots appear in the general areas of the Pontic Steppe and the Eastern Kazakh forest-steppe.

The northern Black Sea and Pontic Steppe are well-known to be hotspots of Scythian burials and settlements. The hotspot identified in the model also extends eastward and slightly northward following the Pontic Steppe grasslands. Although major sites have not been found in this region, many finds of daggers and swords have been found extending and tapering off in the same pattern (Topal and Golec 2017) suggesting that these areas were likely inhabited by predominately pastoral groups and were somewhat peripheral compared to the elites of the North Black Sea region. Ancient DNA analysis also confirms the North Black Sea as the core Scythian territories and the territory further east as an extension but tapering off of genetically similar people (Juras et al. 2017). Unfortunately, the model needs extra rules to understand not just where elite patrons ended up before reaching their maximum age, but also where clients were in relation to the patron. This can only be seen as the model runs.

However, the rough locations of patrons is too rough to break any ground on site prediction though the results seem to at least partially line up with known site locations and centers of power. Instead, more theory of how elites in their rich valleys interacted with clients and subjects surrounding them is needed to model a spatial network or sphere of influence. Hierarchy and its spatial control, perhaps as empire, “is best conceptualized as a complex web of interactions” and is a constant negotiation "carried out on a range of different cultural, political and social levels" (Glatz 2009). This included not just nomadic tents but settled and urban places too. For example, the Uighurs established Baibalik in northern Mongolia which may have been a "political and economic integrating hub" that provided benefits for mobile monitoring of regional subjects (Honeychurch 2014). Urban centers could and were used more fluidly than classic agrarian societies and did not necessarily figure into a linear evolutionary track towards permanent sedentarization (Kohl 2009). Primary questions remain about distance and hegemony. Though still unclear, the spread of Scythian-type burials and likely other forms of culture covered almost the entirety of the Central Eurasian steppes east of the Altai within a century between the 6th and 5th centuries B.C.E. (Järve et al. 2019). Many of the cultures at the time came to bear markers of a single spreading culture either by diffusion or elite dominance. Later in history, the migrations of the Turks into the western steppes transformed culture permanently.

The model reflects the ability of elites to influence a large territorial area and potential clients throughout. Moreover, in order to somewhat replicate the long reach and quick diffusion of nomadic hegemony and cultural traits, a radius of 75 was needed, which amounts to 25% of the total length of the study area. Although 75 is rather precise and does not conform to the likely variability of different polities throughout time, the wide but still bounded reach of nomadic elites is evident. Rather than think of nomadic societies as territorial, it is wiser to think of them as wide networks that connect herding groups, metal-producing centers in mountainous regions, trade routes, and trade centers. The political and economic web of relations cannot simply be restricted to points or small areas.

Nomadic elites were the most highly mobile, not only to take advantage of the best resources but also to monitor their subjects, who are also mobile and widely dispersed (Kursat–Ahlers 1996). Mobility and distributed networks make mapping these phenomena quite difficult given static media. Modeling provides a starting point, but real spatial data synthesizing archaeological sites and historical records are necessary for creating effective reference materials. Solving this particular representational problem is beyond the scope of this research, but spatio–temporal, digital databases, and atlases will eventually be required.

Also taking into account lateral connections between clients or independent pastoralists and connections between other societies is necessary to understand communication, cultural affinity, and political influence. As shown by "small–world" networks that are neither completely regularly nor randomly connected but somewhere in between, communication is swift despite lots of clustering and only weak connections between clusters (Watts and Strogatz 1998). Thus, growing small worlds in which any two agents are around six degrees separated would yield more meaningful regional networks. Interaction with sedentary societies should also be considered within this web of relations, which was not always a hostile or culturally orthogonal relationship (Morgan 1996). Modes of communication and cultural blending took place across ecological and political boundaries, including elaborate diplomatic rituals (Skaff 2012). Additional models of these dynamics are needed.

5.5 Questions of climate effects

Climate change and its effects on nomadic societies are still very much an open question. Some argue that climate change in the forms of drought and severe winter storms are always bad for pastoralists, while others argue that good—warm and wet—times can help create empires. However, any linear approach is bound to oversimplify. As discussed above, some groups are "fitter" and able to adapt and adjust to abrupt changes in conditions. Further, when climatic stresses hit, the organization of groups or the conditions in years before might make mass migration necessary or not. Simple correlations also ignore time-lagged responses or multivariate causes. Trade for grain or control of other modes of production in the farflung network might be able to compensate. In addition, few studies focus on how climate change interacts with social structure and instead focuses on resulting events like migrations or raids.

The model could not address all the different variations of reactions to climate change, but one interesting pattern did emerge. When basic productivity was suddenly reduced, agents necessarily made more connections to wealthy patrons. The number of links and inequality rose sharply from their otherwise asymptotic trajectories. More importantly, the connections and inequality persisted after resources returned to normal and thus the hierarchical networks created thereof. Pederson and colleagues found that an increase in biomass productivity coincided with the rise of the Mongol Empire, but this period was also preceded by periods that were "extremely dry" and characterized by "warring tribes" and upheaval (Pederson et al. 2014).

Although the model itself is not enough to answer the question, may it be the case that the combination of droughty, uncertain conditions followed by wet, abundant conditions created both the need for strong organizers and the resources to sustain a strong organizational hierarchy? Such a scheme would, of course, not only be created by individuals but also by collective sentiment and the collectively organized views of legitimate leaders. Napoleon rose after the chaos of the French Revolution, Lenin after the Bolshevik Revolution, the innovative Song Dynasty after the fractious Five Dynasties Period, and Caesar Augustus from the civil war at the end of the Roman Republic. Many examples could be furnished to show how charismatic, though also potentially brutal and authoritarian, leaders provide needed stability and vision for the polity. Favors or other costly signals provided in hard times could create the loyalty necessary to jump-start an empire, especially when resources become more plentiful and increasingly controlled by the favored elite. Like models, institutions and social orders arise as needed to deal with uncertainty.

Current evidence is still too coarse to understand why the Mongols could put together such a competent invasion of much of the Eurasian continent after nearly 100 years of an unstable climate. It might have been equally as probable that they would have bided their time to restructure after a terrible drought or lost faith in their leaders than to take on the enormous risk of military operations. Where resources are plentiful, widespread, and lightly controlled, as in medieval England, why not a Mongol Magna Carta? Instead, Temujin was named Great Khan, and conquest—then world conquest—became the objective.

5.6 Conclusion: Interdisciplinarity and Approaches to Modeling

The modeling and validation exercise above illustrates a successful, if not perfect, representation of interdisciplinary research. With the aid of new technologies particulars can intermingle with general processes and knowledge generated in different disciplines can co–mingle to challenge assumptions and suggest new syntheses. Interdisciplinarity is not only about combining knowledge and methods but creating more complex epistemological frameworks to deal with the inexorable tide of new and extant information in the digital age and the demands of a dynamic world (Muzur 2018). Complex systems theory is one such framework but so is Universal History. Finding points of contact between humanistic and social scientific fields is of particular importance and not only those that are already aligned in vocabulary or topic (Pedersen 2016).

Despite enthusiasm, Myra Strober reveals that very little at the undergraduate or graduate levels of education in United States universities has been done to integrate the many disciplines engaged by students, leaving them to do so on their own and often to confusing, even hostile results because of different habits of mind or because academics tend to defend their epistemologies (Strober 2010, 65). Strober uses the term "habits of mind" as a general catch-all for "lenses, frames, orientations, cultural filters, paradigms, habits of expectation, mental models, and cognitive maps". Here I have used “model” interchangeably with “habits of mind.”

Practitioners have other problems in addition to confusion of terms and assumptions. For example, Leahey, Beckman, and Stanko conducted two studies to understand the impact of interdisciplinary research on the careers of scholars. Interdisciplinary research can and often is mentally taxing and takes longer to produce; sometimes being perceived by author or audience as broad but lacking depth—a "jack of all trades" scenario (Leahey, Beckman, and Stanko 2016). This is often invoked of World History and relegated to first-year survey courses in American undergraduate institutions (Allardyce 2016, 66).

When working alone, shuttling between different fields and their concerns can also be exhausting. As Ibn Khaldun put it centuries ago:

> It should be known that among the things that are harmful to the human quest for knowledge and to the attainment of a thorough scholarship are the great number of works available, the large variety in technical terminology (needed for purposes) of instruction, and the numerous methods (used in those works)... His whole lifetime would not suffice to know all the literature that exists in a single discipline, even if he were to devote himself entirely to it. (Ibn Khaldun 2005, 414–415)

The immense task of scholarly consumption let alone the risk of running afoul of specialists can be intimidating. In addition to reviewers, collaboration costs are likely to increase when working in a multidisciplinary group due to differences in approaches.

Interdisciplinary research can be high risk, high reward for the scholar. But the real significance of formal modeling such as the ABM presented here is what is yet undone. If we can "grow" patterns that we can find in the real world and understand the dynamics of the models well, it only means that we need even better models that can take into account the greater messiness of real-world systems which are influenced by a greater number of individuals and variables. Further, wrangling, archiving, and harmonizing historical data for use in formal models and cross-validating with verbal models can bridge the gap between disciplines and create more holistic pictures of the past. In addition, increasing the number of models of different methods creates interconnected knowledge about human societies.

Chapter 6

Conclusion

Scholarship on the history of the nomadic societies of premodern Eurasia has long emphasized their dependency on sedentary civilizations, lack of complexity, and environmental vulnerability. Historians, archaeologists, and anthropologists are now reinterpreting available records and revealing the unexpectedly complex roles that pastoralists played in world history as well as their adaptability to changing circumstances.

This dissertation has suggested that interdisciplinary frameworks are needed to more holistically synthesize the past few decades (and to some extent centuries) of new ideas about the evolution of past societies. Although certainly not the only way to think about the past, an intriguing intersection of complexity science and contemporary historical thought—non-linear change, emergence, path dependence or "history matters"—seems to offer a rare bridge between the humanities and the sciences. The old debates between quantitative or qualitative approaches might be blended into a critical-realist theory that allows for relaxed expectations regarding objectivity but also validates the evidence-based research of historians and social scientists. Moreover, Universal and World Histories become more valuable as they search for ways to productively compare past societies across time and space.

Further, a model was proposed to think about how the growth of wealth inequality, development of patron-client networks, cultivation of prestige, and change of climate could lead to the emergence of socio-economic and political hierarchies in the steppe regions of Eurasia. The agent-based model was programmed in NetLogo building off of the work of Epstein and Axtell's original *Sugarscape* model and patron-client dynamics suggested by Shultz and Costopoulos. This approach affirms the ability for nomadic pastoral societies to be inherently complex as distributed networks of social interaction, political hierarchies, and cross-cultural trade. Rather than dependency, models can invite us to think about our premodern and modern worlds as *interdependent* rather than dependent.

The hope for formal, computational models such as the one presented here is not to "prove" that historical people acted as the artificial agents did or that history unfolded in precisely the way as it does in the computer model. Rather, formal models provide additional ways in which to suggest vital dynamics of past societies and to, in turn, validate the generated patterns with the historical and archaeological records. Because theory creates data of interest, multiple theories could explain the emergence of a pattern, and multiple models could generate the same pattern. Modeling is an effective way to creatively explore concepts and logic in addition to, when high-quality data is available, prediction.

Seeking to understand and communicate the historical dynamics of human societies is always a daunting task and one that will never reach a satisfactory conclusion. There will always be gaps in the documentary and material records, logical assumptions that are burdened by cultural biases or blind spots, and limited cognitive and material resources that thwart sustained creativity. However, how we understand our realities of our world is through many models. These models explain dynamics, causes, and effects to ourselves and to others though they are rarely static or explicit.

Appendix A

Appendix A: NetLogo Code

Below is a slightly truncated version of the NetLogo 6.2.2 code used to generate the model and is intended only for optional reference purposes while reading the manuscript. Please find the full code and required data at Harvard Dataverse: https://doi.org/10.7910/DVN/XLGPQB.

```
extensions [gis]

breed [herders herder]
breed [kurgans kurgan]
breed [trade-cities trade-city]

globals [
  gini-index-reserve
  lorenz-points
  ndvi-dataset
  cities-dataset
  borders-dataset
```

```
  max-clients
]

herders-own [
  sugar
  metabolism
  vision
  vision-points
  age
  max-age
  patron
  is-patron
  has-patron
  clients
  prestige
]

kurgans-own [
  prestige
]

trade-cities-own [
  trade-goods
]

patches-own [
  psugar
  max-psugar
```

```
  opsugar
]

;;
;; Setup Procedures
;;

to setup
  if maximum-sugar-endowment <= minimum-sugar-endowment [
    user-message "Oops: the maximum-sugar-endowment must
    be larger than the minimum-sugar-endowment"
    stop
  ]
  clear-all
  setup-patches
  create-herders initial-population [ turtle-setup ]
  update-lorenz-and-gini
  reset-ticks
end

to turtle-setup ;; turtle procedure
  set color red
  set shape "circle"
  set size 2
  move-to one-of patches with
    [not any? other turtles-here and psugar > 0]
  set sugar random-in-range
    minimum-sugar-endowment maximum-sugar-endowment
```

```
  set metabolism random-in-range 1 4
  set max-age random-in-range 60 100
  set age 0
  set patron nobody
  set prestige random-in-range 1 5
  set vision random-in-range 1 6
  set vision-points []
  foreach (range 1 (vision + 1)) [ n ->
    set vision-points sentence vision-points
        (list (list 0 n) (list n 0) (list 0 (- n)) (list (- n) 0))
  ]
  run visualization
end

to setup-patches

  gis:load-coordinate-system "block_test_11.prj"

  ; load elevation data from ascii raster
  set ndvi-dataset gis:load-dataset "block_test_11.asc"

  gis:set-world-envelope gis:envelope-of ndvi-dataset

  ; add elevation data to patch data and color accordingly
  let mx gis:maximum-of ndvi-dataset
  ask patches [
    set max-psugar round(
        gis:raster-sample ndvi-dataset self ) - 1
```

```
    set opsugar max-psugar
    if max-psugar = 3 [
      set max-psugar 2
      set opsugar 2
    ]
     set psugar max-psugar
    patch-recolor
    ;set max-psugar (max-psugar / max[max-psugar] of patches)
    ;set max-psugar (round(max-psugar) )
    ;set opsugar max-psugar
  ]
  set cities-dataset gis:load-dataset "trade_cities.shp"
  ;gis:set-drawing-color red
  ;gis:draw cities-dataset 2.5
  gis:create-turtles-from-points cities-dataset trade-cities [
    set shape "circle"
    set color magenta
    set size 4
    set trade-goods 10
  ]

end

;;
;; Runtime Procedures
;;

to go
```

```
  if not any? herders [
    stop
  ]
  ask patches [
    patch-growback
    ;patch-recolor
  ]
  ask herders [
    turtle-move
    turtle-eat
    herder-adapt
    check-max-clients
    borrow-from-patron
    check-if-need-patron
    stop-being-patron
    stop-having-patron
    set age (age + 1)
    age-out-patron
    age-out-normal
    sugar-out
    trade
    run visualization
  ]
  ask kurgans [
    run visualization
;     if any? kurgans [
;       set prestige (prestige - 0.1)
;     ]
```

```
  ]
  update-lorenz-and-gini
  tick
  if ticks = 300 [
    disaster
  ]
  if ticks = 350 [
    reset-patches
  ]
  if ticks = 400 [
    let tag random-float 1.0
    export-world (word "kurgans " tag ".csv")
    export-plot "Gini index vs time" (word "gini " tag ".csv")
    export-plot "Number of Links" (word "links " tag ".csv")
    stop

  ]
end

to turtle-move ;; turtle procedure
  let move-candidates (patch-set patch-here
    (patches at-points vision-points) with
    [not any? herders-here])
  let possible-winners move-candidates with-max [psugar]
  if any? possible-winners [
    move-to min-one-of possible-winners [distance myself]
  ]
```

```
end

to turtle-eat ;; turtle procedure
  ;; metabolize some sugar, and eat all the sugar
    on the current patch
  set sugar (sugar - metabolism + psugar)
  set psugar 0
end

to herder-adapt
  ask herders with [sugar <= 4] [
    if metabolism > [max-psugar] of patch-here[
      set metabolism [max-psugar] of patch-here]
    if metabolism < [max-psugar] of patch-here[
      set metabolism [max-psugar] of patch-here]
  ]
end

to age-out-patron
  ;if age > max-age and is-patron = 1 and
    prestige >= max [prestige] of herders * 0.2 [
  if age > max-age and is-patron = 1[
      ask my-out-links [die]
      ask my-in-links [die]
      set patron nobody
      set clients 0
      set age 0
      set is-patron 0
```

```
      hatch-kurgans 1
      set prestige (prestige / 2)
      hatch 1
      die
    ]
end

to age-out-normal
  if age > max-age [
      ask my-out-links [die]
      ask my-in-links [die]
      set patron nobody
      set clients 0
      set age 0
      set prestige 0
      hatch 1
      die
    ]
end

to sugar-out
   if sugar <= 0 [
      ask my-out-links [die]
      ask my-in-links [die]
      set patron nobody
      set has-patron 0
      set clients 0
      die
```

```
    ]
end

to borrow-from-patron
  ask herders with [sugar <= 4 and patron != nobody] [
    let basic-need metabolism - sugar
    set sugar (sugar + basic-need)
    ; ask patron [set sugar (sugar - basic-need)]
  ]
end

to check-if-need-patron
  ask herders with [sugar <= 4 and patron = nobody]  [
    ifelse one-of other herders in-radius radius
        with [sugar >= 20] = nobody
      [
        die
    ]
    [
        let potential-patrons turtle-set other herders
            in-radius radius with [sugar >= 20]
        let best-patron one-of potential-patrons
            with-max [prestige]
        ;set patron one-of other herders in-radius radius
            with [sugar >= 20]
        set patron best-patron
        create-link-to best-patron
        set has-patron 1
```

```
        let basic-need metabolism - sugar
        set sugar (sugar + basic-need)
        ask patron [set sugar (sugar + basic-need)]
        ask patron [set is-patron 1]
        ask patron [set clients (clients + 1)]
        ask patron [set prestige (prestige + 1)]
    ]
    ]
end

to stop-being-patron
  ask herders with [clients > 0] [
      if sugar < 10 [
        ask my-in-links [die]
        set clients 0
        set is-patron 0
        set prestige 0

    ]
]
      ask herders with [clients < 0] [
        set clients 0
      ]

end

to stop-having-patron
  if any? herders with [patron != nobody] [
```

```
    ask herders with [patron != nobody] [
      if sugar > 10
      [
        ask patron [set clients (clients - 1)]
        ask patron [set prestige (prestige - 1)]
        ask my-out-links [die]
        set has-patron 0
        set patron nobody
      ]
      if count link-neighbors = 0 [
        set patron nobody
      ]
  ]
  ]
end

to trade
  ask herders with [is-patron = 1 and sugar >= 100] [
    if one-of trade-cities in-radius radius with
        [trade-goods > 0] != nobody [
      set sugar (sugar - 10)
      set prestige (prestige + 3)
    ]
  ]
end

to disaster
  ask patches with [opsugar > 0] [
```

```
    set max-psugar max-psugar - 1
  ]
end

to mouse-disaster
  if mouse-down? [
    ask patches [
      ask patch mouse-xcor mouse-ycor [
        set psugar  0
        set max-psugar 0
        ask other patches in-radius 5
          [ set psugar 0
        set max-psugar 0
            patch-recolor
          ]
        ]
      ]
    ]
end

to boon
  ask patches with [opsugar > 0] [
    set max-psugar max-psugar + 1
  ]
end

to reset-patches
  ask patches with [opsugar > 0] [
```

```
    set max-psugar opsugar
  ]
end

to patch-recolor ;; patch procedure
  ;; color patches based on the amount of sugar they have
  set pcolor (green + 4.9 - psugar)
end

to patch-growback ;; patch procedure
  ;; gradually grow back all of the sugar for the patch
  set psugar min (list max-psugar (psugar + max-psugar * 0.1))
  ;set psugar min (list max-psugar (psugar + 1))
end

to update-lorenz-and-gini
  let num-people count herders
  let sorted-wealths sort [sugar] of herders
  let total-wealth sum sorted-wealths
  let wealth-sum-so-far 0
  let index 0
  set gini-index-reserve 0
  set lorenz-points []
  repeat num-people [
    set wealth-sum-so-far (wealth-sum-so-far +
        item index sorted-wealths)
    set lorenz-points lput ((wealth-sum-so-far / total-wealth)
        * 100) lorenz-points
```

```
    set index (index + 1)
    set gini-index-reserve
      gini-index-reserve +
      (index / num-people) -
      (wealth-sum-so-far / total-wealth)
  ]
end

to check-max-clients
  set max-clients max [clients] of herders
end

;;
;; Utilities
;;

to-report random-in-range [low high]
  report low + random (high - low + 1)
end

;;
;; Visualization Procedures
;;

to no-visualization ;; turtle procedure
  set color red
  set size 1
  ask herders [
```

```
    ask my-links [hide-link]
  ]
end

to color-agents-by-vision ;; turtle procedure
  ask herders [
  set color red - (vision - 3.5)
  ]
end

to color-agents-by-metabolism ;; turtle procedure
  ask herders [
  set color red + (metabolism - 2.5)
  ]
end

to color-agents-by-sugar
  ask herders [
    set color red + sugar
  ]
end

to size-agents-by-clients
  ask herders [set size clients / 10
    ask my-links [show-link]]
  ask kurgans [set size 1]

end
```

```
to size-agents-by-prestige
  ask herders [set size prestige / 10
    ask my-links [show-link]]
  ask kurgans [set size 1]
end

to show-only-kurgans
  ask kurgans [
    set color magenta
    set size 4
    set shape "square"
  ]
  ask herders [
    set size 0
    ask my-links [ hide-link ]
  ]
end
```

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