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Needy or Greedy?: Elucidating Autarky and Capital in Inner Eurasia using a GIS

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Abstract

Recent historical scholarship has made great strides in elucidating Inner Eurasian, society, cultural gifts, and contributions of world historical significance. However, with few written texts of its own, the ontology and historical development of pastoral-nomadic civilizations and polities is still an open question, beleaguered by interminable truisms related to environmental adaptation and economic autarky. I propose a hypothesis, grounded in a Geographic Information System, that Eurasia more than supports nomadic-pastoralism and that, in part, nomadic expansion may be related to widening the sphere of pastoralist capital accumulation and connecting to the Silk Roads peripheries.

I. Introduction

Western scholarship regarding Central Asia and the greater Inner Eurasian region is at least a century old and travel accounts spill over that threshold. Primarily, the vast, oceanic steppes which provided the homeland for the conquering, horse-riding warriors of earlier epochs become the locus of attention. Historical developments and agencies are now being uncovered by historians and archaeologists to better elucidate nomadic adaptations, decision-making, and global impacts in the past. Though interest is relatively healthy regarding premodern, Inner Eurasian cultures, much remains elusive.

Though a select few primary texts were written and disseminated by nomadic peoples such as the *Secret History of the Mongols* or runic carvings, many texts analyzed for relevant material have been produced by the historically literate cultures of the world who in one way or another came into contact with the steppe riders. Whereas much may be known of China, with a continuous literary tradition, the same cannot be said of, say, the Turkic polities of a comparative period except through the Chinese literature. One might find a similar asymmetry in the Persian, Indian, or Russian tradition as well.

Representations of nomads are typically negative emanating from the settled cultures, but a common thread running through many representations including those modern belonging to more modern pens resides in the land itself. The arid grasslands of Inner Eurasia, where the vital livestock of nomadic-pastoralists graze, act as a proxy for more direct and nuanced self-representations. Historical causation, such as a series of raiding of frontier territories by nomads, is seen as a function of the natural environment—a homeland lacking the abundant resources and fixedness of their settled cousins to the south and west. Lack of food and random, intense shifts in seasonal climate help observers explain a wide range of events including raids, migrations, starvation, alliances as well as more inherent characteristics of society including more “warlike” or “pragmatic” worldviews.

Investigations of Inner Eurasia must reckon with the often opaque relationship between the environmental characteristics and development of the steppe and pastoral-nomadic societies while avoiding, as much as possible, theoretical hand-waving towards the “settled” fact of destitution-centric historical causation. The question of autarky on

the steppe, and in the river valleys for that matter, should be one of extent and duration rather than a binary assignment.

A broad multidisciplinary survey of literature including history, archaeology, rangeland management, climatology, anthropology, and geography reveals that no single discipline holds a monopoly of method or knowledge regarding historical causal relationships and the scholars in these disciplines can contradict each other based purely on the idiographic researches in which they are engaged. A holistic literature review is necessary to find the principal idiosyncrasies between disciplines for an updated intellectual history of representations of Inner Eurasia, but perhaps more importantly and more productively new methods of synthesizing theories and data is necessary to work towards a more diverse context of analysis. This context might include researchers being versed in both quantitative and qualitative data, located in deeper understandings of spatial interrelations.

In this paper, I employ a Geographic Information System (GIS) to synthesize environmental and cultural data currently available. Approaching from an interdisciplinary avenue, equipped with theories of centrality, spatial distribution, and the framework of World-Systems, I seek to find relationships between the steppe homelands of Inner Eurasia, human adaptations, and historical developments. Variables such as distance and distribution of ideal rangelands are spatially analyzed and validated by known historical places and archaeological sites. In addition, estimated variability of rangeland value is calculated as well as biomass yields and human and animal carrying capacities. In this paper and the resulting model, I argue that Inner Eurasia has a greater carrying capacity than otherwise believed when the nomadic-pastoral lifeway is centered in analysis. In addition, economic autarky is highly plausible if regional variation and interconnection, a historical reality, is incorporated into any investigation of economic dependence. Furthermore, the economic opportunities inherent in livestock and luxury good accumulation plausibly account for increasing social complexity, stratification, and projection of hegemony counter to theories of pure plunder economies.

The method of interdisciplinary investigation that this paper explores is a significant meta-analysis, providing tools to cross-reference different types of knowledge and interrogate idiosyncrasies and our own assumptions (which this study will introduce or reproduce as well). The raw results of this the ideal rangeland model are summarized below (Figure 1), manifesting in my hypothesis. Following the results is a review of literatures, methodology, and a deeper discussion and validation of the model's findings.

Figure 1: The GIS model, visualizing the ten core regions.

Table 1: Results table outlining, per region, "steppe units", estimated grassland biomass, sheep units, estimated number of families, and estimated total population.

Region	Steppe Unit	Biomass (Tons)	Sheep Unit	Families	Population
Region 1	16.40263967	194,525,448	118,613,078	2,161,394	10,806,970
Region 2	10.08844512	119,642,896	72,952,985	1,329,366	6,646,830
Region 3	6.588730128	78,138,379	47,645,353	868,204	4,341,020
Region 4	11.50742997	136,471,204	83,214,149	1,516,347	7,581,735
Region 5	9.40134008	111,494,243	67,984,295	1,238,825	6,194,125
Region 6	6.376560566	75,622,176	46,111,083	840,246	4,201,230
Region 7	8.303646209	98,476,254	60,046,496	1,094,181	5,470,905
Region 8	4.86436344	57,688,427	35,175,870	640,983	3,204,915
Region 9	3.981761822	47,221,302	28,793,477	524,681	2,623,405
Region 10	10.31814214	122,366,965	74,614,003	1,359,633	6,798,165
Total	87.83305915	1,041,647,294	635,150,789	11,573,860	57,869,300

II. Locating and Placing Inner Eurasia

In order to approach the topic of Inner Eurasian world intellectually, or any topic for that matter, one must unpack syllogisms in order to find the visible and covert principles. I attempt here a broad but non-exhaustive survey over the long term — an admittedly non-idiosyncratic approach which unites seemingly disparate topics under the unifying topic of knowledge about Inner Eurasia as a geographic and inhabited place,

though each is nested within ideological and material motives. I understand "place" as a space that holds meaning for the people interacting with it, whether materially or intellectually (Cresswell 2004). As typical of studies of Inner Eurasia, I will begin with a review of geographic categorizations of Inner Eurasia. A survey and explanation of negative stereotypes linked to geographic understandings will follow. Lastly, I summarize frameworks of world-historical interpretation and how geography, history, and archaeology can overlap through spatial analysis, constituting the foundation of my investigative lens.

The Space of Inner Eurasia

Opening almost any scholarly work about the region known as Central Asia, Inner Asia, or Inner Eurasia one will find a map—either a physical map or a schematic one (Sinor 1990; Grousset 1970). One might also find generalizations about where steppe grasslands are located, sprawling across the Eurasian continent as unbroken seas and rivers.

Historically, Inner Eurasia was mapped piecemeal by Westerners during the age of colonialism as Russian, British, and other European scholarly and political interests converged on Central Asia (Curzon 1889; Hedin 2001), a rich archive well known in historical and colonial studies. John Mackinder was one of the first scholars to articulate Inner Eurasia as a whole region, having the luxury of writing at the time when the objectives of the "age of discovery" were complete and colonial administrations drew up maps of the entire globe. Mackinder argued that it was the appropriate time to "with some degree of completeness, [attempt] a correlation between the larger geographic and historical generalizations" (Mackinder 1904, 422). It was during his study of the global geopolitics of pre-WWI European empires that he attempted to elucidate the "world organism" and environmental determinants outside the confines of the Western Civilization bias, concluding that control of Eastern Europe meant control of the Eurasian "heartland" and therefore, the world (Mackinder 1904, 423, 437).

More recent scholars have also defined Inner Eurasia on different terms and for different purposes. David Christian, without the urgent political interests of Mackinder, argues again that Inner Eurasia is a coherent world region and should be engaged as a "unit of world history." Christian defines Inner Eurasia as all space of the former Soviet Union, Mongolia, and parts of East Turkestan (Christian 1994, 180). This large region is politically distinct due to its large terrestrial empires, and ecologically unique due to its interiority which "condemns Inner Eurasia to aridity and great seasonal fluctuations in temperature" resulting in human adaptations much different from those of "Outer Eurasia" or the settled, agrarian world (Christian 1994, 179). Denis Sinor also attempts a definition of "Inner Eurasia," constituted by Christian's inclusions with the addition of Tibet, Manchuria, and Eastern Europe. Sinor draws his boundaries between zones of settled, river valley agriculture and other economies such as pastoralism (Denis Sinor 1990, 6). In this paper, I will use the term "Inner Eurasia" as Sinor has defined it, though, with the caveat that Inner Eurasia is a diverse region of variability and human adaptation is as important to an analysis as a physical or climatic characteristic.

Like Mackinder, Christian and Sinor seek to break from a previous, confining framework, though this time it is the strict boundaries of the modern nation-state so prominent in area studies and orientalist research of the past century. In addition, any study concerned with the geography of Inner Eurasia must also widen its scope beyond a single culture, polity, or confederation. Much of the detail beloved by historians is naturally lost in such a broad study but, in turn, the objective becomes a wider context of comparison and interaction, informed by particular studies, which, in turn, can cross-reference and inform the particular, providing a new scope of analysis and synthesis crucial for the study of world history.

The Beggar and the Barbarian

Regarding representations of nomadic pastoralists, two popular archetypes, for better or worse, have weathered the test of time**.** The first archetype is that of the barbarian — a person or persons living on the outskirts of proper civilization, waiting to pounce on the unsuspecting and relieve them of land, luxury, and life. This archetype has been curtailed in academic circles as of the recent century. However, the second archetype is perhaps just as old but lives on in modified form — the "needy" nomad. This character lives in the poor, arid, and cold Eurasian steppes, making ends meet, but no more, on the backs of their herds and hoping that the vicissitudes of climate are kind to them.

Thomas Barfield theorized that because nomadic society lacked the means to survive on their own, the organization of raiding parties constituted the only native political organization and only when Chinese states became unified and wealthy, presenting both hapless targets for invading nomadic horsemen and riches to be stolen (Barfield 2001). These nomadic polities were "shadow", secondary empires which were ephemeral tools for plunder to supplement the scarce resources of the Eurasian steppe (Barfield 1989, 37). Khazanov argued, against Owen Lattimore who held a more moderate view, that a pastoral nomadic economy was ultimately non-autarkic and unable to sustain a human population on its own (Khazanov 1984, 81). Others went still further, arguing that nomads not only desire Chinese goods (grain and luxuries) and would fight to obtain them but that steppe polities and societies were wholly dependent on China for their subsistence (Jagchid and Van Symons 1989: 165). This "needy" or "greedy" theory has historical rather than scientific roots however.

As a general perception, nomadic neediness can be traced back to scholars and writers of previous eras. Diana K. Davis has revealed the colonial bias against arid lands, including the Eurasian steppe which constitutes a vast majority of the continent's arid climates. Davis argues colonial administrators, stepping into administrative roles requiring management of productive forces in their respective jurisdictions, saw pastoralism and the grasslands it operating within as poor quality land-use practices and, further, destructive to progressive agrarian ideals (Davis 2016). Medieval and Classical writers echo a more cultural distaste for nomads. The *Commentary of Zuo*, a Chinese text produced in late 4th century BCE, compares people living in the semi-steppe zone of northern East Asia as "wolves," wild and dangerous (Di Cosmo 1994). Somewhat later,

Sima Qian, writing in *The Records of the Grand Historian* produced during the Han Dynasty, reports that the nomadic and semi-nomadic peoples (Rong, Di, and Hu) living to the north of the growing Chinese empire were greedy and aggressive (Dennis Sinor 1978; Honey 1992). Even more modern works which rightly receive and deserve praise for their insights invoke the term "barbarian" (Grousset 1970) or assume nomadic neediness as a "truism" (Moghadam 1988). I present these representations not as a polemic—I have no interest in scolding—but only as a way to trace assumptions which influence academic research. Much more modern scholarship, especially historical scholarship, is cognizant of primary source bias on the level of cultural representation.

Recent work in the field of Inner Eurasian studies has nearly eclipsed the older orientalist scholarship of "vast grasslands" where "barbarians roam." Nicola DiCosmo reveals the explanatory power in his excellent work on Inner Eurasia, challenging long-standing assumptions such as the "needy theory", arguing that steppe soil can and did support farming as an additional subsistence strategy and that interconnections across the continent meant exchange was nearly always at hand, not dichotomous separation, with the rest of Eurasia (Di Cosmo 1994). Christopher Beckwith provides a continent-wide study of religio-political contributions made by nomadic peoples to the rest of Eurasia including institutions like the *comitatus* described by Tacitus and even common etymologies of words arising from Indo-European origins (Beckwith 2009). Jonathan Skaff has also forwarded scholarship which finds close ties and an the co-development of international political ritual between China and nomadic polities rather than pure antagonism or greedy opportunism on the part of the nomads (Skaff 2012). The study of Inner Eurasia is evolving past the old stereotypes with broadening perspectives, but further interrogation of the relationship between nature and society will be crucial to developing new perspectives of the space, place, and history of the region. However, perhaps the Other is a deeper phenomenon than merely culture considering its continuity across cultures and time periods and applying new frameworks merely add a new layer to a fundamentally similar relationship.

Using Central Place, Regional Systems, World-Systems and Comparative Past Studies

This paper aims to synthesize and find connections between different humanistic theories and frameworks that straddle quantitative and qualitative methods to find expression. Due to the nature of the data sets employed — both environmental raster data and historical texts — containing implicit or explicit spatial position and distribution, centrality, regional connections, and the idea of a macroregional world-system can accommodate such data. While some are quite dated, I argue that their fundamental principles regarding the significance of space as well as a drive towards measuring relationships is undoubtedly useful.

Heinrich von Thunen was perhaps among the first modern scholars to emphasize the economics of space in Europe. His land use model concludes that moving outwards from an urban center, land takes on specialized uses based on the relationship between distance to market and employment in an industry. For example, grazing occupies the

furthest periphery from an urban center due to the easy transport of wool or of the animals themselves while dairying takes residence close to the urban center due to the need to move heavy milk jugs to market while keeping the product as fresh as possible. Therefore, "land use zones are arranged in the order of decreasing transport cost of the acre output produced with equal amounts of labor" though it is possible that a zone could contain multiple land uses given that there is no competition between uses (Beckmann 1972, 7). A typical critique of this theory is that such a state of homogenous soil quality and unbroken terrain is impossible in the real world and therefore the model cannot be used in application. However, this model introduced the important relationship of quantitative distance and land use to understand human society, albeit in the neoclassical time and place of von Thunen.

Walter Christaller (1893-1969) was an early applied geographer as well who studied local government and the organization of towns and cities in Weimar Germany. His research on patterns of variation between neighboring towns manifested in what is known as "central place theory" beginning with his work *Central Places in Southern Germany*. This concept assumes, on a featureless and infinite plain, economic relationships between places in space will form hierarchies based on goods distribution, market locations, and distance (von Boventer 1969). Spatially, this creates a lattice of relationships (transportation, administrative, and marketing) between points. Criticisms leveled against Christaller's theory similar to those of von Thunen and have primarily centered around the fact that featureless plains do not exist, historical and geographic factors are influential in determining where settlements are located, and therefore the theory cannot apply to the real world. However, from a macroregional, macroeconomic approach, one finds the value of Central Place Theory in its simplicity and its focus on determining dependent spatial relationships.

Finally, G.W. Skinner (1925-2008), following a lead from Central Place Theory, was more concerned with the consequences of spatial relationships of the pre-agrarian economies China, Japan, and France on family and social dynamics. Skinner was, however, primarily interested in explaining social relationships (sex ratio, fertility, agricultural wages) of the modernizing Chinese nation but by mapping these variables abstractly found great importance in their spatial relationships and regularity which became a series of models known as Hierarchical Regional Systems (HRC) (Crissman 2010, 37). HRC at the national scale were fundamental to explaining how demographic processes in China, France, and Japan were the result of the push and pull of a nested marketing logic. Skinner's clear research progression from collecting empirical data, abstracting the data into spatial relationships, then devising models to account for these relationships justifies Skinner's work, beyond the conclusions alone, as mandatory reading for any historical geographer or human geographer engaging a GIS. Christaller, von Thunen, and Skinner all point to productive ways in which economic and social relationships can be abstracted and modeled as spatial relationships and especially, nowadays, in a GIS. That being said, when studying dynamics of the Inner Eurasian past, we do not have access to the extensive census data the Skinner did, or have the luxury of studying our hometowns like in the case of Christaller. Instead, models are ever more important in their investigative and explanatory power.

The World Systems Approach, popularized by Immanuel Wallerstein in the 1970s, provides the scope of a macroeconomic model of capital and power that may be employed to understand Inner Eurasian pastoralism. Wallerstien's interest in explaining the modern world system. A world system is an independent network of relations and exchanges but one that contains many cultures, polities, and labor divisions that becomes an empire in the pre-modern context or a world economy as the one that formed around 1500 and exists today (Wallerstein 1976). Cores and peripheries, according to Wallerstein are typically nations or multinational business entities which either primarily produce raw materials and goods for the core or consume goods and materials from the periphery. The cores, semi-peripheries, and peripheries of the modern world economy roughly align with the first, second, and third worlds of Cold War logic. Breaking with the dominant perspective of modernization, Wallerstein sought an alternative model to area studies. Wallerstein also sought a multidisciplinary approach that dissolved boundaries between the humanities, social sciences, and sciences—arbitrary divisions made by Western universities in between the 18th and 19th centuries. This return to a holistic understanding of human society was necessary to even begin to discuss the world system (Wallerstein 2013).

While Wallerstein contributed much to the understanding of the modern world system, what of the premodern world? After all, the modern world system must have arisen from world systems before 1500, in a context of complexity and interconnection (Abu-Lughod 1990). However, as summarized by Chase-Dunn and Hall, one should not assume that a unified world system, like the modern iteration, existed thousands of years ago; several world systems existed before 1500 which can varying amounts of interaction in their information, goods, and military networks over time (Chase-Dunn and Hall 2011, 99). David Wilkinson hypothesized that a "Central Civilization" world system began with Egyptian and Mesopotamian civilizations and grew over millennia into the modern world system (Wilkinson 1987) while Chase-Dunn added the "East-Asian" world system which increasingly interacted with the Central system over time, overlap culminating during the Mongol Empire (Chase-Dunn and Hall 2011, 98). However, comparing this conflation of nomadic pastoralist polities in the East-Asian category may be an overreach given that Inner Eurasian polities did not accumulate capital through land rents and agrarian taxation schemes.

Comparing premodern world systems models with recent historical scholarship reveals that Inner Eurasia is a unique cultural system that interacted with the Mediterranean and East Asian systems. Thomas Allsen makes the salient points that nomadic-pastoralists did not have the same marketing and city structure as sedentary societies and that material accumulation took the form of light, transportable goods such as silk textiles used for investiture—a Eurasia-wide custom (Allsen 1997, 102). Economically, Inner Eurasians depended much more on the meat, milk, and furs of herd animals than their Outer Eurasian counterparts, in turn shaping cultural forms and ways in which society was organized and how the state and society interacted. For example, it is argued by David Sneath that Inner Eurasian political organizations took the form of a "headless state", lacking a supreme ruler and that most power was in the hands of local rulers free from a single top-down bureaucracy (Sneath 2007). Much debate remains about the dependence of Inner Eurasian societies and whether or not they can be

considered peripheries of China, West Asia, and Europe or cores of their own. Perhaps the application of historical and archaeological research is also required to supplement more spatial variables.

World History, or Universal History or Big History, should not be taken lightly as "the history of the Other" or as regional history but rather an emerging theoretical framework with rapidly expanding methodology which scholars are employing to create new knowledge. Universal history was once a mainstay of historical explanation, but became scorned by the empiricists of the late 19th century and its intellectual legitimacy displaced by positivist and source-based, particularist history (Hoefferle 2011). This new methodology, reading and analyzing primary sources and making logical conclusions based only on the chosen media, has largely defined modern historiography in the 20th and 21st centuries, excluding emergent social and ethnic histories. However, Christian concludes that positivist research has professionalized and narrowed the focus of historical research "without generating new unifying ideas, and the discipline broke into many isolated islands of knowledge" (Christian 2010, 14). However, even Leopold von Ranke, the leader of the empiricist movement in history, recognized the importance of never losing "sight of the whole" while conducting specialized research (Stern 1970, 61). The shuttling back and forth from specificity to general in order to isolate universal laws of civilization is, to a large extent, what makes the Moroccan scholar Ibn Khaldun's (1332-1406) *Muqaddimeh* so significant and continually the subject of theoretical interest and why he is considered by many to be the "father of modern sociology"(Dale 2006, 435). Universal history has a significant new role to play in contemporary historical research as a body of questions which seek to find the conclusions that are greater than the sum of its parts.

Christian predicts, perhaps correctly, that universal history is making a comeback despite lingering fears of the nationalist grand narrative, due to a radical transformation of the historical database. Centuries of in-depth research and building archives has yielded insights on all topics of history, especially non-Western civilizations, leading to constant revisions of theories including Marx's "Asiatic mode of production" or "parallel evolutionism" which superimposed European historical development upon regions and peoples with historiographies not yet coherent to Westerners (Christian 2010, 16–17). Just as an increase in understanding of primary sources as well as the number of sources made available opened the field of history to a new methodology in the nineteenth century, the same can be argued for the 21st, now so rich in historical data that the situation beckons new methodologies to synthesize and answer universal questions of historical development. An attempt to articulate this emerging approach is outlined in Jo Guldi and David Armitage's *The History Manifesto*, which stresses the need to widen the methodological basis from which we engage historical questions, taking advantage of digital methods and "big data" to ease the crisis in professional history and make the field more relevant to the public and the rest of the academy[1] though it should also be understood as a development of the field and the conjuncture of different kinds of digital

[1] Jo Guldi and David Armitage, *The History Manifesto* (Cambridge: Cambridge University Press), 2002. The entire text is open-access and free online at https://www.cambridge.org/core/what-we-publish/open-access/the-history-manifesto.

data—knowledge from many disciplines including environmental science, archaeology, biology, economics, and social sciences. A return to universal history might very well be the productive synthesis and framing of these data in the style of the *longue-duree* of Fernand Braudel (Guldi and Armitage 2014) or embracing a more cosmological approach to history like the "Big History Project"[2], but is being pioneered in many different ways with different focuses including the study of Inner Eurasia.

Embracing a new trend in historical inquiry is not significant enough on its own, of course, but different methodologies can answer long-standing questions that remain intractable with traditional source-based methods, and propose new questions. One relatively recent avenue of historical investigation has found manifestation in Historical Geographic Information Systems (HGIS). Environmental and regional history have found footing in the combination of history, the study of when, and geography, the study of where; and not just historians, but anthropologists and humanists of various fields (Knowles 2002, xii). With few primary textual sources surviving from pastoral-nomadic polities, the door lies open for alternative methods of elucidating nomadic economy at the regional scale. *The Secret History of the Mongols* is perhaps the best such written source directly from the Mongols themselves and the *Jami al-Tawarikh* by the Persian statesman and scholar, Rashid al-Din, could be considered a text edited heavily by Ghazan Khan of the Mongolian Ilkhanate, but these texts are histories and do not yield quantitative data relevant to modeling (though they provide invaluable information regarding culture, politics, and much more).

The field of archaeology provides ample literature of its own on pastoral-nomadic polities of the Bronze Age but also employs GIS, geographic concepts, and complexity theories to help explain politics and society with the evidence of material culture and the landscape at hand. In fact, any major study of nomadic history is nearly always foregrounded with a geographic section detailing extent and ecology of Inner Eurasia (Denis Sinor 1990; Grousset 1970). I do not intend to overanalyze this point, but it should be noted that geography, ecology, and climate are all integrates in one way or another when discussing the history of Inner Eurasia yet the connection between the steppe environment and nomadic society is still not well understood (Rogers 2012). Yet, this connection between the productive forces of the steppe and nomadic history can be further investigated through the use of a regional GIS approach.

Michael Franchetti has contributed greatly through his use of GIS, particularly to nomadic mobility, interaction, and social complexity at the regional scale. His work on the site of Begash, Kazakhstan and the surrounding landscape reveals non-uniform mobilities and challenges any singular understanding nomadic seasonal mobility and how the landscape both shapes nomadic land use while also shaped in permanent ways by nomadic culture (Frachetti and Mar'yashev 2007). Specifically using GIS, Franchetti theorized movement between summer and winter pastures in the Intermountain Region of Inner Eurasia, possible routes using least-cost pathing techniques, and how this mobility shaped interaction and the transmission of goods and ideas across Eurasia (Michael D. Franchetti et al. 2017). Franchetti's work reflects an Inner Eurasia, stretching back 4000

[2] https://school.bighistoryproject.com/bhplive

years, that is dynamic, influential in the spread of goods and ideas, socially complex, and also proves the explanatory power of landscape archaeology and digital tools.

John Daniel Rogers has also contributed significantly to new theories of nomadic power and the construction of the nomadic polity supported by effective agent-based, and decision-making models. Like Franchetti and others, Rogers argues for nomadic autonomy and social complexity by theorizing models of the nomadic polity on alternative criteria than how scholars have thought about the evolution of river valley civilizations. By centering mobility, diffused hierarchies, and multiresource pastoralism, a more autonomous and less stagnant picture of Inner Eurasia emerges (Rogers 2012). Within a framework of noted autonomous adaptations, and turning away from the dependency models, nomadic variations of polities, states, and empires are illuminated (Rogers 2007). This line of thinking yields tremendous possibilities and avenues of investigation, particularly by centering Inner Eurasia as the means of economic, political, and social life, rather than assuming dependence.

Given that much scholarship argues that Inner Eurasian peoples were complex, evolving, and culturally influential (Reuven and Biran 2014; Beckwith 2009), more research must investigate more closely economic dependence and capital accumulation in order to place Inner Eurasia within a world system or world history framework, perhaps by using an interdisciplinary approach (Rogers 2012). This literature review, which is hardly exhaustive given the breadth of the combined fields, forms a foundation upon which I begin to compare and harmonize different methodologies, epistemologies, and theories under the analytical theme of geographic distance and distribution.

III. Geographic Information Systems

In this paper, I employ a GIS (geographic information system) in order to analyze and hypothesize a regional model of Inner Eurasian grasslands to quantify natural resources. A Geographic Information System (GIS) is, put simply, "a sophisticated database management system designed for the acquisition, manipulation, visualization, and display of spatially referenced (or geographic) data" obtained from satellite imagery, standard aerial photographs, digitized maps, and vector (points, lines, and polygons) or raster (continuous surface grid) files generated by a user related to specific natural, cultural, or derived variables (Aldenderfer and Maschner 1996, 4). Each set of data, say a distribution of city points and a raster of land use ecology of the surrounding hinterland, would each be rendered as separate but overlapping layers within the software. The diversity, amount, and spatial scope of more complex problems or research questions necessitates the use of computer-assisted mapping. Rather than one, new-fangled technology, a GIS is comprised of a variety of hardware and software components packaged together and provided with a convenient label" (Wheatley 2004) and the history of this combination of technologies goes back to the 1970s while the individual components can be traced back much farther.

Spatial analysis is a function of the GIS. The spatial relationships between data layers is significant and goes beyond the simple visualization to spatial analysis. As J.B. Owens explains, "all human interactions, with others or with their environment, have

inherent spatial characteristics, although this is often implicit in historical work rather than explicitly addressed" (Owens et al., 6). As Tobler's first law of geography states: "All things are related, but nearby things are more related than distant things" (Tobler 1969). Quantitative methods are used to model the relationship between two or more layers and the index of correlation; for example, if one variable increases the other will increase too or vice versa (e.g. the closer one is to a large city, the greater the likelihood one is to find a greater presence of theaters, hospitals, etc.). The use of geography to explain social phenomena is often critiqued as environmental determinism, but this arises from a misunderstanding between the use of environmental data as one of several variables and pure determinism based on a single environmental variable (Llobera 1996, 613). A simple separation of variable categories is forwarded by Barcelo and Pallares consisting of natural space—"the existing exploitable resources that are geographically arranged" and "independent of social action"—and social space—"given shape by social agents arranged to social distance relationships between them" (Barcelo and Pallares 1998, 12).

Rather than simply presenting the same social science problems in a visual space, a GIS can be used to provide new solutions and even produce new questions based on spatial relationships too implicit in traditional historical studies. Owens created a paradigm known as "Geographically-Integrated History" which finds itself at the integration of "natural, social, and cultural variables distributed across place, space, and time" (Owens et al., 3). Conceptually, this paradigm argues that historical problems are not (fully) explained by historical sources and methodology but must be studied at a broader level of data analysis. Though archaeology lends itself almost automatically to the spatial relationships of artifacts and monuments found on the earth's surface, historical data can be coded as well. The flexibility and analytical capabilities of a GIS are unmatched when dealing with the spatial context of historical and pre-historical data (Scianna and Villa 2011, 337). Further, "midput" information, data generated from spatial analysis, is the end goal of a GIS rather than a static map. In this study, the GIS model will be considered a hypothesis and the data created as something greater than the sum of the parts will be the unique contribution. The next section will outline all but the minutest steps I took to develop the GIS.

IV. Methods

To summarize, the objective outlined below aims at isolating useful variables in order to identify high-yield rangeland cores in Inner Eurasia, preparing the hypothesis upon which to compare with historical data. Below is a flow chart of each action taken within ArcMap to produce the model. There may be more than one aspect of each step so more explanation is given in the narrative coming after the chart.

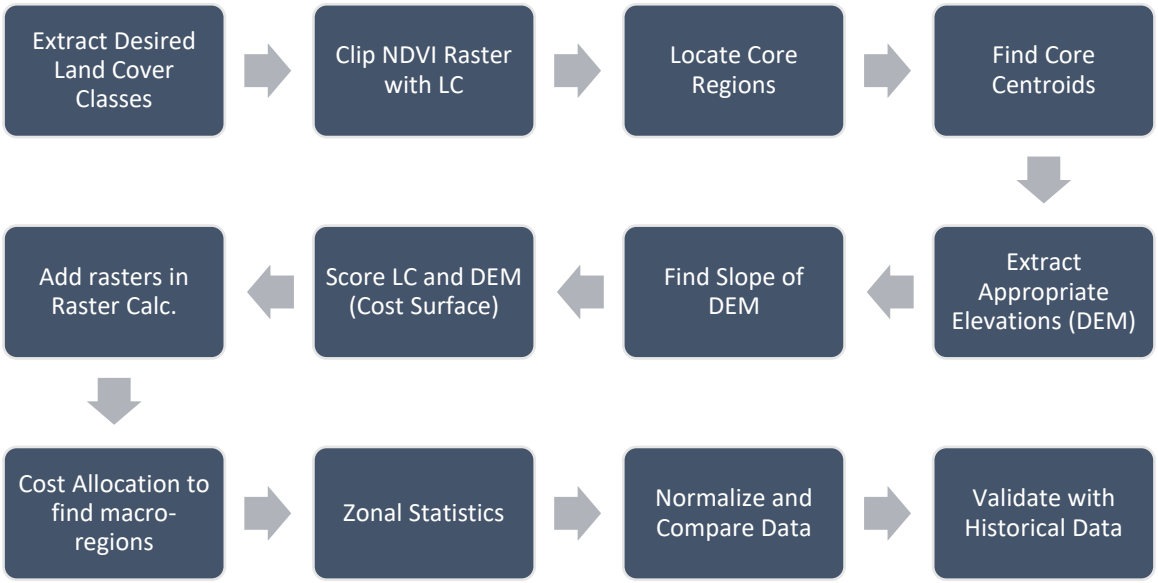

Figure 2: A simplified workflow chart

Land Cover

Finding the pastoral cores begins with filtering out croplands and isolating grassland, shrubland, and semi-deserts from the available landcover classes to be analyzed. A landcover data set visualizes, and provides for spatial and other analyses, available vegetation and land-use types such as where crops are grown, where tundras are located, where forests begin and end, and so forth. This information, especially at the global scale, is collected in raw form using remote sensors equipped to orbiting satellites. This data is then parsed using algorithms which organize the infrared and near-infared values to produce datasets to fit various needs.

For landcover classes, I used the USGS Eurasia Land Cover Characteristics Data Base Version 2.0 product, using the Eurasia Seasonal Land Cover Regions Legend with 253 unique classes. Because the datasets were produced continent-by-continent, the Eurasia set is particularly suited to provided fine-grain and comparative value. Data resolution is derived from 1 kilometer AVHRR (Advanced Very High Resolution Radiometer) data collected by NOAA's (National Oceanic and Atmospheric Administration) POES satellite (Loveland, Estes, and Scepan 1999). One-kilometer resolution is the finest resolution for global landcover. While each cell is large when compared to a city, this study is amenable to this resolution as it seeks a regional understanding and contiguous economic areas over the particular.

One drawback of this dataset, and perhaps every environmental dataset that does not directly regard historical reconstructions, is that it reflects a composite of data collected in the 1990s. Clearly, landcover as it has been affected by human use, climate change, and desertification, has changed over time and does not necessarily fit identically

to past times, especially during the Holocene Climactic Optimum, the Little Ice Age, or other notable climatic events that modified landcover extent. In addition, averages do not reflect a "default" climate. However, working with available data was a priority for this paper, rather than reconstructing landcover types from pre-modern times, which, while different, can correspond to general conditions of location and abundance of long-lasting ecosystems. For example, the steppe is still the steppe, though its contours are likely to be changed by the introduction of wheat farming during the modern period, diversifying available landcover in a given area. However, the general shape remains similar.[3]

Next, before isolating landcover types, I simplified the types by conflating dozens together into custom categories using the **Reclass by ASCII File** tool.[4] This allowed me to inspect the new landcover classes and validate my hypothesized classes of grasslands, shrublands, and desert as the targets of analysis. Overlaying a Silk Road Sites shapefile obtained from Harvard World Map and created by Peter Bol[5], most of the points fell within my target landcover types. However, this set does not include points of reference (urban centers or archaeological sites) for the steppes. This will be rectified for validation later in the process.

Using the **Extract by Attributes** tool, the target landcover types were isolated, removing completely any inhospitable or cropland existing in the dataset. As discussed before, historical grassland likely occupied more, if not much more, area and was more primarily grassland as estimated by potential vegetation reconstructions (Ramankutty and Foley 1999). Below is a map for reference including grassland (light green), shrubland (dark green), and desert (sand). With landcover types constrained to only those most profitable for pastoral nomadism in Eurasia, a mask is created to focus upon our area of study which we can use to isolate this study area in other raster datasets. At first glance, we might recognize that Inner Eurasia is difficult to visualize if taking only land cover and land use into consideration.

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[3] See: "Historical Land-Cover Change and Land-Use Conversions Global Dataset" *Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign*. https://www.ngdc.noaa.gov/docucomp/page?xml=NOAA/NESDIS/NCDC/Geoportal/iso/xml/C00814.xml&view=getDataView&header=none

[4] Landcover types after reclassification included (forest, grassland/steppe, cropland, tropical forest, swamp/bog, shrubland, tundra, desert, barren, inland water, and ocean).

[5] https://worldmap.harvard.edu/data/geonode:silk_road_sites_0b3

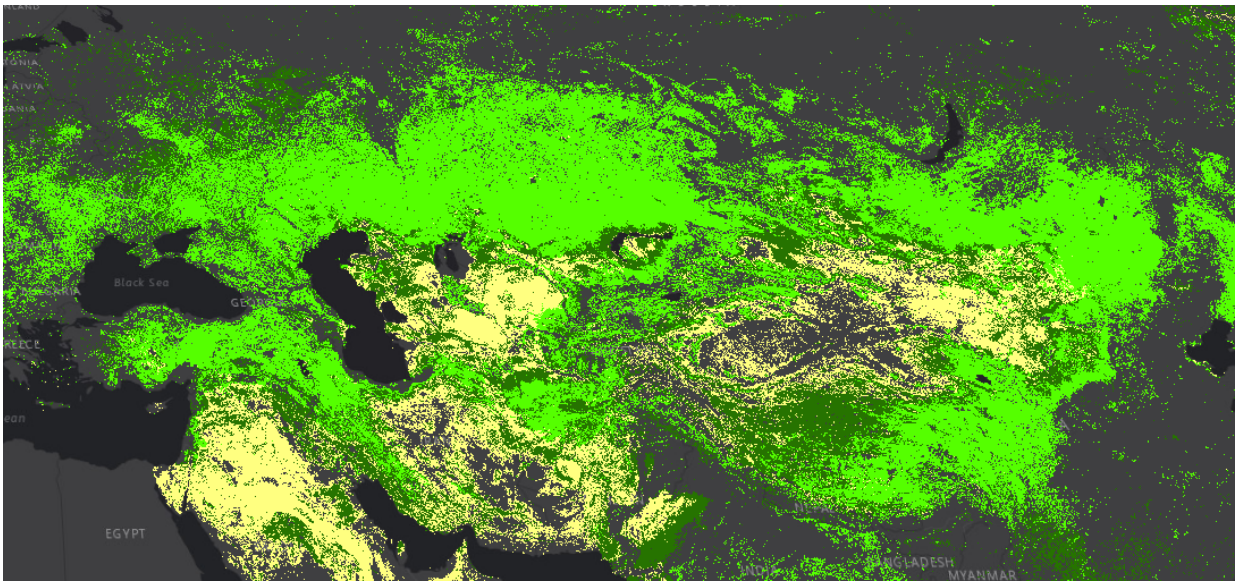

Figure 3: Land cover extraction operation. Grassland/steppe is represented in bright green, shrublands in dark green, and semi-desert grasslands in tan.

Normalized Difference Vegetation Index

One of the most important data sets to determine ideal range lands for nomadic pastoralists is an NDVI (Normalized Difference Vegetation Index). These indices are gathered through remote sensing in the visible, infrared, and near-infrared light spectrums. The data set used in this study was NASA's MODIS (Moderate Resolution Imaging Spectroradiometer) 13A3 monthly global one-kilometer product. I selected to project the yearly average index, though other options by season were available. This data, basically, reveals the level of "greenness" across the globe. Shading represents a normalized, or comparative, difference in greenness with tropical rainforests being very dark and deserts displaying as very light or not at all. An NDVI is further helpful in synthesizing information regarding precipitation, evapotranspiration, spring locations, and more as areas of higher or lower vegetation growth will be seen in the NDVI data rather than getting at it through this host of other variables. Running **Extract by Mask**, using the land cover types as the mask, yields a clipped NDVI data set relevant only to the target landcover types. This prepares the dataset for locating regions of core values.

Locate Regions

Next, with data set prepared, locating the best regions of high NDVI levels requires running the **Locate Regions** tool. The objective was to find the largest regions of contiguous, high-quality cells in the data set. I set the tool to search for "core areas", in line with the focus of the study. I instructed the tool to find ten core areas, as a number must be specified. Four and five regions were tested but ten core areas seemed to cover every corner of the map.

However, some parameters of the tool detract from a truly bottom-up approach. First, the tool requires additional information regarding maximum size of cores and minimum distance between cores. As the hypothesis was constructed with an exploratory rather than a strictly structured shape, any valuable information regarding the maximum size of a rangeland found on the Earth or the minimum distance found between pastoral cores must be set aside. Second, core areas must, by default, occupy ten percent of the total area which does not necessarily limit cores to *only* the most productive rangelands, but those areas that are most productive in addition to a periphery connected to the original space in which the core began to grow. Lastly, the simple shape of the cores was set to "circle" though pastoral cores might very well be a crescent, such as the one likely to be found straddling western Iranian Plateau and eastern Anatolia.

Each core area can be analyzed for total vegetative productivity but this ignores the peripheries of these core regions. Macro regions were required to fill in the gaps between the core regions and determine the shapes and inclusiveness of periphery to be attached to each core. However, as in Skinner's original regional approach, the cost of distance and ease of travel are two variables used to estimate when an area stops being core or near-periphery. For this analysis, landcover will be relevant again but also elevation.

Centroids and Slope

Creating a cost surface for movement across the continent was required to create the macro regional model based on distance and accessibility. First, centroids were found for each core region located in the previous step, creating a simple point at the center of each region. Next, a DEM (Digital Elevation Model) was used to spatialize elevation values. One-kilometer DEM tiles were employed from the GLOBE database.[6] Four large tiles were mosaiced using **Mosaic to New Raster** into a single raster dataset. A **Slope** was then generated using the DEM to calculate where certain areas are steep, creating a harder journey, or even too steep to navigate. This slope raster was then reclassified into a 1-10 scale in preparation for joining with landcover.

The same prepared landcover was recycled to join with the slope layer to model both horizontal and vertical obstacles to travel. The three landcover types were reclassified on a 1-10 scale (grass = 1, shrubs = 5, and desert = 10), estimating the favorability of these areas for travel. These numbers are arbitrary but do well in differentiating them, especially when joining them to the slope values.

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[6] *GLOBE Task Team and others (Hastings, David A., Paula K. Dunbar, Gerald M. Elphingstone, Mark Bootz, Hiroshi Murakami, Hiroshi Maruyama, Hiroshi Masaharu, Peter Holland, John Payne, Nevin A. Bryant, Thomas L. Logan, J.-P. Muller, Gunter Schreier, and John S. MacDonald), eds., 1999. The Global Land One-kilometer Base Elevation (GLOBE) Digital Elevation Model, Version 1.0. National Oceanic and Atmospheric Administration, National Geophysical Data Center, 325 Broadway, Boulder, Colorado 80305-3328, U.S.A. Digital data base on the World Wide Web (URL: http://www.ngdc.noaa.gov/mgg/topo/globe.html) and CD-ROMs.*

Raster Calculator and Cost Allocation

Lastly, I used **Raster Calculator** to join the slope and landcover layers which subsequently clipped the DEM to the landcover extent as well. This created a cost surface, a layer representing the total "cost" of movement from one location to the next. Least-cost paths, critical to determining the macro regions and the service areas of the cores, are calculated on the cost surface. Using this layer, then, a **Cost Allocation** was produced using the centroids of the cores to determine where peripheries belonged to the ten cores as being either close enough to one core or closer to another, creating a patchwork across the entire study area.

Measuring Distance and Regions

Next, by using the centroids again, I created least cost paths to all other regions. A model was used to automate this process which includes creating a cost distance raster, a backlink raster, and then converting raster lines into vector lines to best visualize the least-cost path from one region centroid to the other. Least-cost paths can be used in more focused, local contexts to estimate historical routes but in this case, the total cost, rather than the accurate path, was the goal. Historically, people did not only travel on the least-cost path and various factors such as political control, safety, profit, bridge construction, river fording, season, transportation, and more were crucial variables determining which path was chosen. Instead, determining the network connections was more relevant to this study. Each line was then symbolized to represent how difficult the journey was from one core to the other.

The preparation of these rasters allows us to determine the vegetative value for each microregion, with most of the value residing in the core area. Vegetation used for pastoral purposes is typically calculated as kg/ ha and determined most accurately from in-situ analysis of dry grass. However, for the entirety of Inner Eurasia, this proved a problem. As the NDVI dataset provides a normalized and therefore arbitrary number value for cells, proxies for biomass values would need to be compared to the arbitrary NDVI values to normalize the data based on real-world values based on substantive fieldwork.

The first sample used in determining normalized NDVI values is taken from John Masson Smith, Jr.'s study on the Mongols in 13th century Azerbaijan, specifically, the Mughan plain (Smith 1999). He uses Soviet era agronomy studies and contemporary sources (William of Robruck, Rashid al-Din, Juwaini) to estimate the carrying capacity of winter and summer pastures around northern Persia as Hulegu Khan's army moved back and forth. Because no exact numbers are used to describe the Mongol army, he seeks the answer by estimated biomass yields.

He argues "good Inner Asian steppe" as providing 600 kilograms of grass per hectare; therefore, the Mughan plain, some 2 million acres, provided about 534,000 tons of grass per year (Smith 1999, 47). Smith estimates this quality and quantity of steppe could support 18,000 families of five to six Mongol persons for four months of the

summer season. The demographic information is most helpful though the agronomy should be compared to other sources. Still, Smith realized the investigative power that remote sensed rangeland data and GIS stating "the other [winter pastures] cannot be so conveniently delimited, but with the aid of large-scale maps, data on vegetation, and perhaps satellite photographs, it should eventually be possible to work out their size, productivity and pastoral carrying-capacity in considerable detail" (Smith 1999, 48). He is correct and thus we turn to a more robust data-driven study to compare.

Jin, et. al. uses NDVI composites as well as field sampling to study biomass estimates in Xilinggol League, Inner Monoglia (Jin et al. 2014). They found a considerable relationship between the satellite-gathered NDVI values, that is simple level of greenness) and field sampling of vegetation weight and caloric value. Over the course of seven years, the 196,185 sq. km Xilingol grasslands averaged 605 kg/ha and 11,859,399 tons of total caloric biomass (dried and removed of water weight)(Jin et al. 2014, 1504). Comparing the ratios of area to biomass production, the Mughan, according to Smith's estimates, produces 66 tons of biomass annually while the Xilinggol League grasslands produces, according to Jin, et. al. 60.45 tons of biomass annually. A 90% correlation between these two studies which included field sampling and being decades apart validate a cautious use of these study areas as normalized variables to extrapolate to the rest of Inner Eurasia. Jin et. al's study, however, could easily be incorporated into the model by taking the boundaries of Xilinggol and calculating **Zonal Statistics as Table** to retrieve the NDVI mean and cell count within my model.

The mean NDVI value found in the zonal statistics table for Xilinggol was multiplied by the total number of raster cells found within the regional boundary. This total represents 11,859,399 tons of digestible biomass per year according to Jin et. al. Therefore, this simple comparison forms a bridge of comparison between the study and my model within the GIS. This calculation, summarized below, will form a "steppe unit" which I will used to calculate the biomass of other regions using the arbitrary NDVI scores.

Finding comparable "Steppe unit":
2571.649013 (NDVI) x **7798** (cell count) = **20,048,658** (total NDVI) = **11,859,399** tons of yearly biomass = 1 steppe unit

Calculating biomass via Steppe Unit:

1. **Region X mean** (NDVI) x **Region X total** (cell count) = Non-normalized value (NNV)

Then**:**

2. Region X NNV / **1** steppe unit * **11,859,399** tons = total est. biomass of Region X

From a calculation of biomass, we might infer other estimations as well. First, if we assume an average sheep consumes approximately 0.75 tons of grass per year, we can find a simple estimate of sheep carrying capacity of a particular region (Smith 1999, 48). A "sheep unit" assumes the entire herd is sheep but a mix of five animals (horses, sheep, goats, oxen/yak, and camels) should be considered, significantly reducing this raw number depending on the herd composition. Smith argues that an average Monogl family

might have 100 sheep and 10 horses, but if this ratio is changed to include at least 20 horses, or mostly horses, than the other estimates would see a drop. In addition to sheep units, one can estimate the number of families based on Smith's estimation that a family could get all it needs from 89 tons of grass per year. Finally, base also on Smith's estimate, if a Mongol family, conservatively, consisted of five people, we simply multiply the number of families by five. Refer to Table 1 to review these results.

These results suggest that Inner Eurasia could potentially support many more people than previously believed, especially when considering that nomadic-pastoralism was not the only mode of subsistence and trade was common.

V. Validation

Many tests and comparisons can be performed to validate the model as a hypothesis. Below are just a few different ways of validating the data spatially and qualitatively including a deeper look into the visualized GIS as well as a discussion of arguments trending towards Inner Eurasian autarky and independence.

Looking into the Cores

Comparing historical place data, we find some common-sense as well as some counterintuitive results in the GIS model. Capitals, oases, and tombs are considered in relation to the spatial distribution of rangeland cores. Returning to the method of core search, the problem of size becomes quite apparent at smaller scales. Even only 10% of the total area occupies very large swaths of the continent. In response, I will also reveal the more raw NDVI data as a means to validate distributional significance.

To begin, the Mongol capital of Karakorum, the ancestral Orkhon Valley lie within the core are of their respective region. The more forested sites of Noin-ula and Ivolga, both sites of Xiongnu burials and fortresses lie in the near periphery. Khara Khoto lies in a peripheral area within the Gobi Desert while Xingching, the capital of the Tangut Xi Xia kingdom, lies in the far periphery. Region 6 contains the recently excavated Turkish royal tomb at Dongoin Shiree as well as Xanadu, the royal retreat of Kubilai Khan of the Mongol Yuan Dynasty. While more point data could be included and more in-depth spatial analysis could be performed, it seems, at least in this corner of Inner Eurasia, the core areas capture major cultural areas as well. However, Ulytau, the sacred mountain of the Turks, does not lie within a core region. Changing the parameters or methods of the model could change this outcome as regions 2,3, and 4, are actually part of a continuous rangeland system.

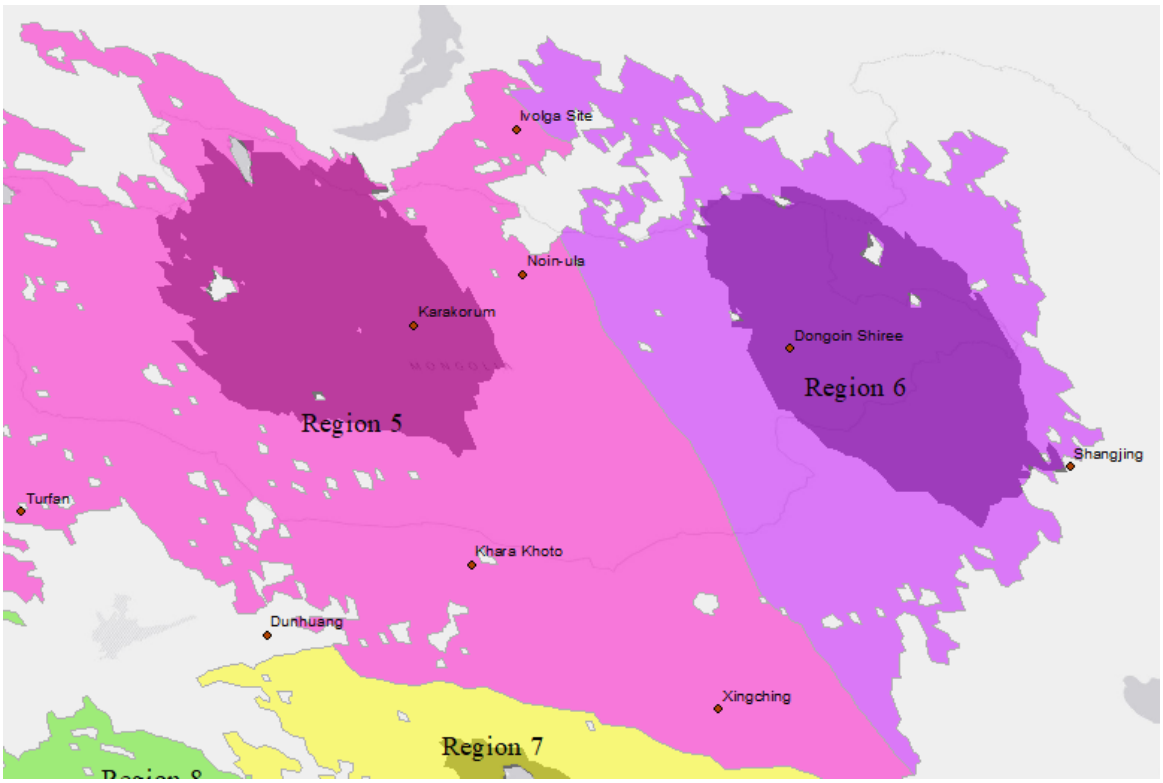

Figure 4: A closer look at Region 5 and Region 6

Region 3 (Figure 7) is perhaps more purely a steppe than Mongolia and Manchuria. Fewer settlements can be found here but burials, or *kurgans*, can be instructive. In this case, Tasmola Barrows, a significant Saka burial site, lies within the core pastoral area. Begash, a place of periodic settlement and seasonal return according to Franchetti (Michael D. Franchetti 2008) reasonably lies at the periphery of ideal pastoral lands, sitting within a transitional zone. Similarly, Balasgun, a trade capital of the Uighurs, lies at this periphery where intensive pastoralism ends and the economic opportunities of the Silk Road begin. Rangelands begin to break up and become less regular here as shown in the pure NDVI dataset (Figure 8). Khwarezm is an oasis, surrounded by semi-desert and the towns of Silk Road Inner Eurasia hug the mountains and oases of Transoxiana.

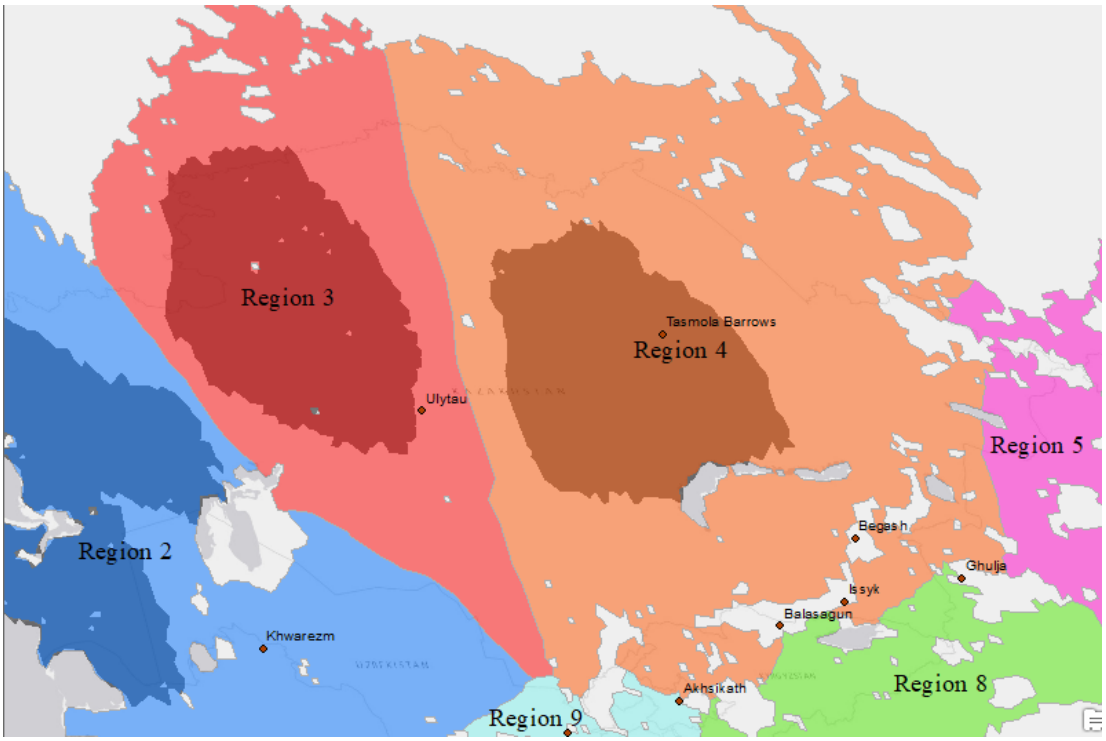

Figure 5: Close up of Regions 2, 3, and 4.

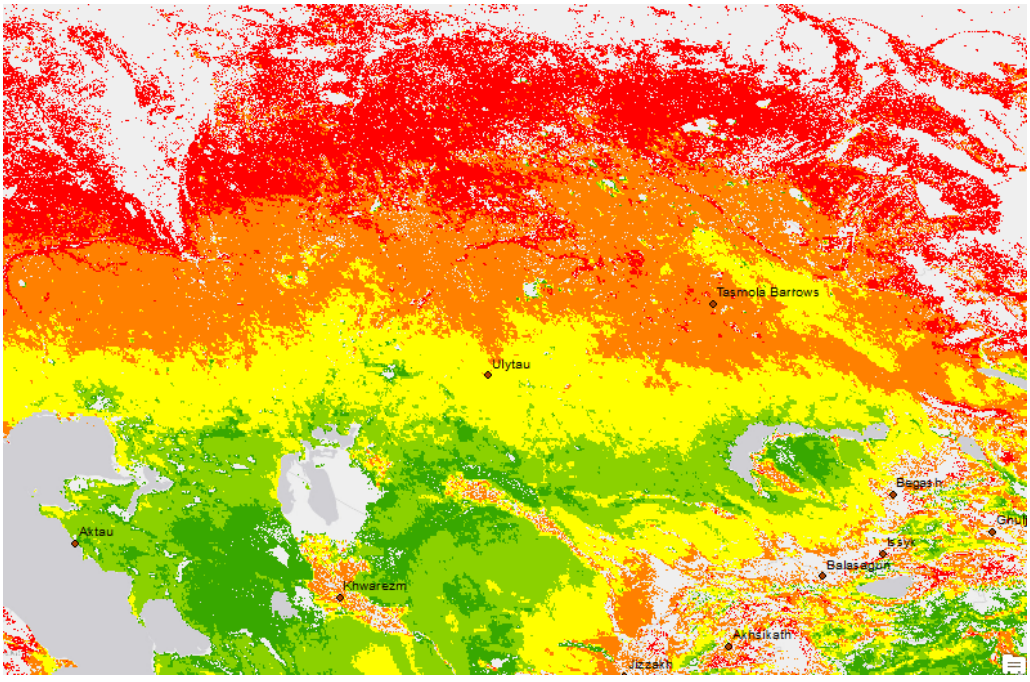

Figure 6: Close up of raw NDVI data symbolized as a green-to-red gradient, red symbolizing the highest greenness.

Finally, Region 10, encompassing the Iranian Plateau, Mesopotamia, and Anatolia (Figure 9), exhibits a narrow north-south core in western Iran. The Mongol Ilkhanid capital at Takht-e Suleiman lies reasonably within the core area as well as the edges of the Mughan and Arran plains to the north. Interestingly, eastern Anatolia exhibits higher NDVI values (Figure 10), but this area is more mountainous and less able to sustain large herds of horses. Overall, a short review of the spatial relationships reveals that the model identified significant core areas — spaces and places that exhibit both environmental boons as well as cultural hot spots. Ideal rangeland is, of course, not the only variable included in decisions to graze or settle and do not automatically predict successful pastoral ventures, but this hypothesis remains at least partially confirmed by the historical result.

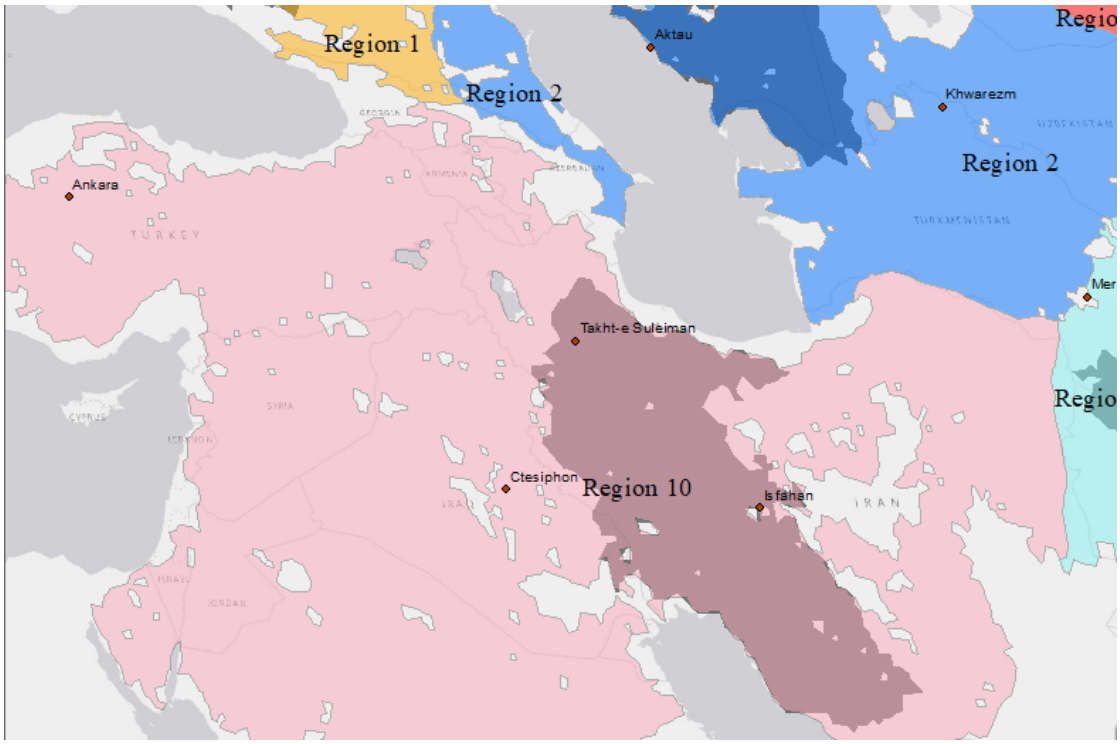

Figure 7: Close up of Region 10

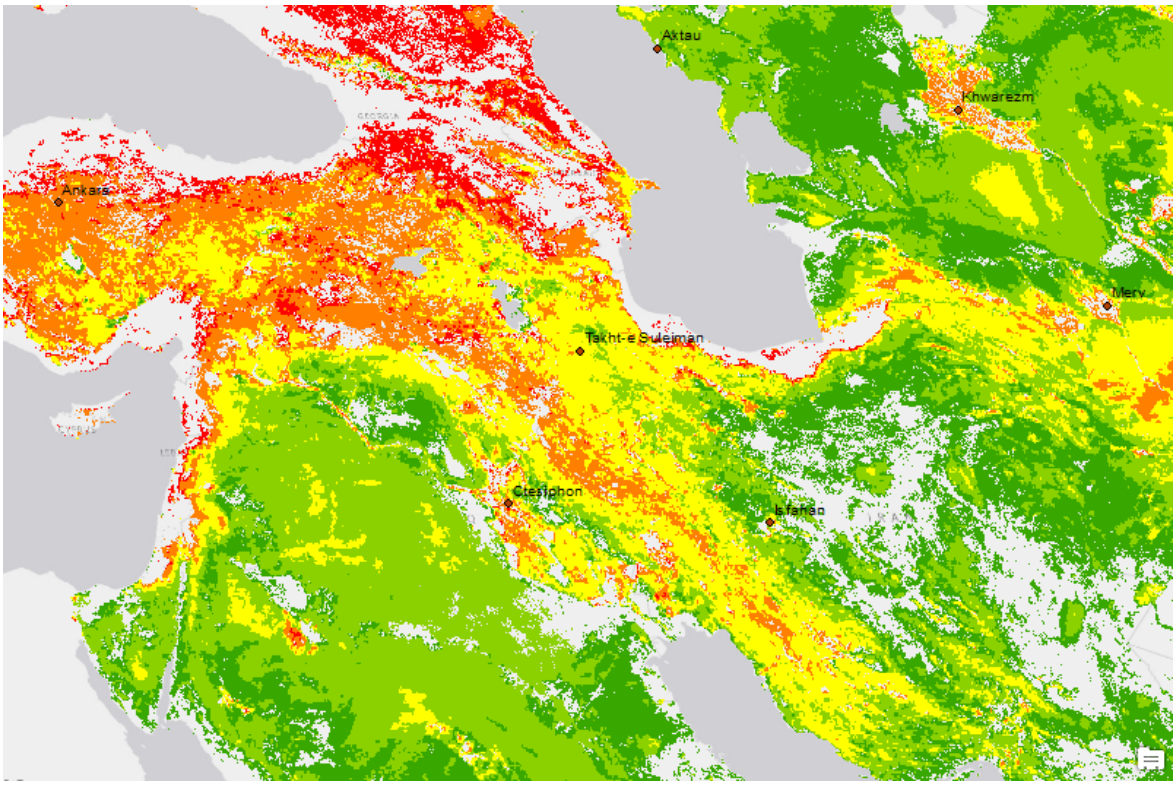

Figure 8: Close up of Region 10's raw NDVI results.

The Landscape of Knowledge

The findings in this paper align with recent scholarship that, taken as a body, elucidate a quite diverse, composite, and autarkic Inner Eurasia (Rogers 2007; Sneath 2007). First, although polities like the Xiongnu certainly had productive trade relations with Chinese empires and used Chinese luxury goods to legitimate steppe kingship, it is also true that if steppe peoples could interact with oasis city-states in the Tarim, people in the Liao Valley, or those in the western steppe and Persia. The Xiongnu, the earlier predecessor to the Turks, Uighurs, Mongols, and others, coexisted and engaged in mutually beneficial relations with more agricultural societies much like the Scythians in the western steppe before them and the emergence of a dominant pastoralist mode of production from secondary animal products did not signal the end of agriculture in Inner Eurasia in all its forms (Di Cosmo 1994, 1115–16). Moreover, the Tagar and Tashtyk cultures of South Siberia were based on pastoral nomadism *and* agriculture and despite the rise of horse-mounted pastoralism, there is evidence of an increasing interaction with agriculturalists and a growth of economic specializations into the medieval era (Kyzlasov 1960; Imawura 1962). The Xiongnu material culture finds exhibit advanced agricultural productions, iron implements, metallurgy, sophisticated textiles, and even fortified settlements either constructed or conquered and administered (DiCosmo 1994). Far before the emergence of either the Xiongnu Confederacy or the even the first Chinese

imperial dynasty, there is ample archaeological evidence that Mongolian steppe resources, trade connections, and social systems developed complexity and autarky between 1400 and 700 BCE (Anthony and Brown 2007; M.D. Franchetti 2008; Honeychurch, Wright, and Amartuvshin 2009; Houle 2009).

However, we must also account for climate and its effect on society and historical development, especially as it relates to the dichotomous agrarian/nomadic split. As it turns out, the Turk and Uighur polities rose during times of weakness in the unified Chinese state and the collapse of the first Turk empire occurred suddenly in the 7th century during the height of the Tang (Drompp 2005) to say nothing of the rise of the Khitan Liao during the Five Dynasties Period and the expansion of the Tangut Xi Xia as allies of the Tang and Song until 1038 CE. Further, Inner Asian states, far from simply opportunistic raid parties, exhibit the same durations of endurance as polities arising in other parts of the world whether in the Inner or Outer Eurasia (Cioffi-Revilla et al. 2008; Sinopoli 2006; Taagepera 1997). Had these steppe polities generated the kind of bureaucratic documents or annalistic history, we may think very differently, but a dearth of "easily accessible information…from outside the region" relegates Inner Eurasia to an epistemological purgatory (Rogers 2012).

Scholarship has also forwarded a narrative, popular in world historical perspective, that climate change particularly and severely punishes steppe dwelling peoples and is the trigger for large nomadic movements including the Vedics, Gandharans, and the Chingisid Mongols among others. Without better alternative explanations at hand, nomads are passive subjects in this sweeping theory. In China, the explanation of nomadic raids outside of the more severe "raid or trade" or "barbarian invasion" narratives is that the harsh environmental conditions and harsher droughts and winter weather events push nomads to use every means necessary to acquire their livelihood (Y. Bai and Kung 2011; Toynbee 1987; Barfield 1989; Huntington 1907; Graff and Robin Higham 2002; Jagchid and Symons 1989; Khazanov 1984). Bai and Kung find that nomadic invasions are "positively correlated with increasing incidences of drought and negatively correlated with increasing incidences of flooding…nomadic rule of China proper, in contrast, appears to have reduced the incidence of conflict" (Y. Bai and Kung 2011, 275). Historical climate studies have supported the "needy nomad" argument into the 21st century.

Although Inner Eurasia indeed has a stochastic, continental climate, there seems to be no consensus across disciplines as to the extent to which climate fluctuations affect Inner Eurasian societies. Rogers argues that, despite the Chinese explanation in their historical works that climate change was the impetus for nomadic invasion, there is no definitive evidence that a strain on the steppe's carrying capacity or climate change encouraged state expansion; rather, climate change was a local event that produced local decision-making (Rogers 2012). In addition, historical periods of desertification, and thus less good pasturage, resulted from cold temperatures and a reduction of ambient moisture (C. Q. Bai 1996; Lu, Xiao, and Zhu 1996; Tian 1996). However, more than droughts, severe winter precipitation events, or *dzuds*, which make all grass inaccessible under thick blankets of snow are more deadly to modern livestock than droughts (Begzsuren et al. 2004). In fact, pastoral nomadism may have been an adaptation to increasing aridity in the continent (Khazanov 1984) and, further, grasslands and herbivores co-adapted in a

symbiotic relationship (Briske 1991). Herbivores fertilize the soil while also spreading grass seeds and aerating the soil with their hooves. Rather than herbivores, herded by humans, subsisting on what little the steppe provides, the lack of grazing in favor of "resting" the land actually has a negative effect on available fodder and stunting the growth of grass (Briske 1991). More animals grazing in more areas maximizes the available ideal grassland while fewer grazing animals leads to a downward spiral of overall grass health and total biomass available. (Savory and Butterfield 1998). In turn, an increase in hierarchy and rangeland management—be it modern governments, medieval lords like Chinggis Khan, or individual family units—the greater the sustainability of a pastoral enterprise at the local or regional level (Hill 2006). Far from being a simple or stagnate form of food and trade goods production, pastoralism existed and developed into more complex systems and traditions for thousands of years in the face of a dynamic climate (Weber and Horst 2011).

On the other side of the frontier, the assumption that China is impervious to climate fluctuations given its agricultural surplus is not ubiquitous. Hinsch argues that "an economy primarily dependent on agriculture, such as that of China, faced particular vulnerability to climate change" (Hinsch 1988) and Mark Elvin argues that "Chinese political history was linked, *gross modo*, with alterations in the mean annual temperature" (Elvin 1998, 733). Further, the rise and fall of Chinese dynasties are often linked with climate change (Bao and Zhang 1984; Feng and Jiang 1996) whether desertification, primarily caused by natural causes, increased or decreased (Wang et al. 2010, 157). In addition, it is known that Chinese farmers would flee an entire region in response to high taxes which makes nomadic movement in relation to climate change unremarkable (Rossabi 1987). Whether nomadic or agrarian, human societies are typically continually running up against issues of carrying capacity and energy limitations and the comparison throws into relief the misunderstanding that an agrarian economy is glutted with energy which increases population and complexity. Instead, complexity is an adaptation a lack of energy, precedes the availability of surplus energy, and encourages increases in production which leads to innumerable more impasses down the line (Tainter 2011, 94).

This brief multidisciplinary survey of research clearly reveals that scholars of different fields are taking against one another and making contradictory assumptions about the life and historical development in Inner Eurasia. This speaks loudly for the need to use interdisciplinary frameworks to synthesize and contribute to topics related to Inner Eurasia as a unit of world history and as a naturally interdisciplinary topic without a single home discipline. Comparatively, it seems Inner Asian societies are enduring, self-sufficient, and adaptable like their Outer Eurasian counterparts (Mott 2015) though to which extent is the question. This is not to say Inner and Outer Eurasia are pointless categories, but that Inner Eurasia has unique characteristics that do not necessarily make it more primitive, more desperate, or more warlike than any other place. Christian argues that "ecology and geography have combined to give a distinctive shape to Inner Eurasian history from prehistory to the present, by posing distinctive problems that required distinctive solutions" (Christian 1994). The Turkic general and counselor, Tonyukhukh, reveals this cognizance of adaptation when he said, "if we build castles and give up our old customs, we shall be vanquished" (Tkachev 1987). Beneath the textual silence, are historical agents of considerable intelligence, skill, and understanding and we may infer

this generally but must take roundabout journeys to learn the mechanisms of steppe autarky and independence.

VI. Conclusion

After comparing qualitative historical data to the results of the model, I tentatively conclude that Inner Eurasian societies enjoyed full autarky in the premodern past; to such an extent as to maintain settlement of the Eurasian steppes, deserts, and forests for millennia, develop complex socio-politic systems, and conquer/administer sedentary civilizations. Certainly, none of these developments would have been possible without a native source of economic stability. When combined with exchange with other zones of Eurasia since at least the Bronze Age, enough of a buffer against economic shocks could plausibly have existed as well as the accumulation of capital in the form of livestock. Moreover, Inner Eurasia was not simply the homelands of pure nomadic-pastoralists but multi-resource pastoralists who drew their livelihood from multiple sources.

Geographic information systems and spatial analysis of environmental data coupled with the validation of available historical information and trends promises a productive horizon for studying Inner Eurasia past and present. The model presented in this paper harnesses data and arguments from many disciplines, synthesizing them within an interdisciplinary methodology to produce a new hypothesis. A GIS can successfully bring qualitative and quantitative information under the same framework, united by the comparative significance of space, distance, and distribution. In turn, the hypothesis present in the model adds to a continually growing body of work on world-systems while also opening a critique of previous understandings of peripherality and complexity of the steppe within pre-modern world systems.

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