Simulating Past Human Landscapes: Models of Settlement Hierarchy in Central Anatolia during the Old Assyrian Colony Period

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Alessio Palmisano & Mark Altaweel*

UNCORRECTED PROOF OF:

Palmisano, A., and Altaweel, M, 2015. Simulating Past Human Landscapes: Models of Settlement Hierarchy in Central Anatolia during the Old Assyrian Colony Period. In: F. Kulakoğlu, and C. Michel (eds.), *Proceedings of the 1st Kültepe International Meeting. Kültepe, September 19-23, 2013. Studies Dedicated to Kutlu Emre*. Subartu 35.Turnhout: Brepols, 131-146.

This paper introduces a spatial interaction model to understand past human settlement hierarchy in Central Anatolia during the Old Assyrian colony period (*c.* 1970-1700 BC).

The distribution of settlement sizes in this region was relatively broad; numerous small and medium sized sites arose, while few sites became large. These settlement size structures reflect the actual political landscape in the early 2nd millennium, which was divided into several independent city-states governed by a king or a ruling couple.[1] It is not well understood how such settlement size structures developed on the basis of inter and intra-regional interactions and socio-environmental factors. Therefore, a methodology is needed for understanding the causal logics behind past human settlement structures and, based on this, we propose applying a novel method to predict which sites and areas would have become prominent in this period by using known archaeological sites as point data and historical information for calibration purposes. The case study's modelling results can be checked against empirical results of archaeological surveys undertaken in Anatolia in the past decades. The model addresses to which extent geography, transportation, external contacts, and socio-economic factors make locations attractive for trade and settlement and why some archaeological sites become relatively major urban centers in the period discussed. This includes how political and geographic constraints affect regional settlement transformations, while also accounting for uncertainty in the archaeological data.

This methodology builds on a series of spatial interaction and settlement evolution models that were originally developed in the 1960s and 1970s in urban and regional geography to predict flows of goods and people in spatial systems,[2] and then applied to archaeological settlements datasets in a series of academic papers published some twenty-five years ago[3] and more recently in the last couple of years.[4] These entropy-based (Boltzmann) models have the advantage to explain how specific causal factors (e.g. population pressures,

* Institute of Archaeology, University College London (UCL); a.palmisano@ucl.ac.uk; m.altaweel@ucl.ac.uk.

[1] Barjamovic 2011, 6.

[2] Wilson 1967; 1970; 2008; 2010; see Wilson 2012a for a recent overview.

[3] Batty et al. 1991; Rihill – Wilson 1987.

[4] Wilson 2012b; Bevan – Wilson 2013; Davies et al. 2014; Altaweel 2014.

political and territorial divisions, topographical boundaries, etc.), difficult to isolate and quantify from the archaeological record, could have affected settlements expansion or contraction occurred under given geographic settings. Hence, the target of this paper is to present a simple simulation model that not only explores how major settlements emerge, but how such emergence develops at the expense of other sites and because of political circumstances or external factors affecting a region. At a more general level, the results demonstrate a quantitative model useful in explaining emergent urban settlement hierarchies across landscapes at different scales.

The paper begins by providing background information and data on the case study. Then, we introduce and explain the methodology of entropy maximizing and structural dynamics modelling approaches. After this, the modelling results, including outputs from different possible scenarios, are provided. These results explore different factors that may catalyse or diminish urban population growth. Finally, conclusions are drawn with regard to the methodology and its potential for understanding the development of settlement hierarchies in central Anatolia during the Old Assyrian colony period (*c.* 1970-1700 BC).

1. Background

1.1 Landscape and Middle Bronze Age Settlement Patterns

The Anatolian plateau may be divided into several and different areas, each one with its own well defined characteristics and resources. The main and most densely populated area is the central part of this plateau, which has an extent of about 200,000 km^2 and is confined between the Pontic Mountains to the north and the Taurus mountains to the south. The Kızılırmak River plays as a natural border dividing the central Anatolian plateau into a northern and a southern part.

Archaeological excavations and regional surveys carried out in central Anatolia by Turkish and foreign teams have provided a large amount of data. Regional surveys, in particular, have produced the largest body of data on spatial extent at both regional and local scale as well as periods of occupation at sites (see Table 1 and Fig.1 for a list of surveys carried out in central Anatolia).

Nevertheless, the actual available data can be problematic as in Anatolia the archaeological surveys have been generally extensive and mostly focused on the valley, a small proportion of settlements was mounded and then easy to identify, and most sites have been buried under alluvial deposits or destroyed by later anthropogenic activities. A major problem that needs to be addressed here is the issue of comparison between regions surveyed by different teams according to very different (quality) standards. In fact, the sites density of the surveys carried out in central Anatolia (see Table 1) is far lower (ranges from 0.4 to 5 sites per 100 km^2) than the one recorded in systematic and extensive regional surveys performed in Upper Mesopotamia[5] or in other parts of Anatolia (range from 6 to 10 sites per sq. km.; e.g. Abay 2011; Boyer et al. 2006). In addition, publications indicate just the overall extent of mounds but neither the size for each chronological phase, nor the extent of the surrounding lower

[5] Around ten or more sites per 100 sq. km; e.g. Ristvet 2005; Ur 2010; Ur – Wilkinson 2008; Wilkinson – Tucker 1995.

town.[6] Therefore, we can provide just rough estimates about the real extent of Middle Bronze Age sites in central Anatolia. As consequence, the results derived from the analyses of the archaeological surveys data have to be interpreted as settlement patterns of relatively large, sedentary and farming communities.

Table 1: Table with details of the archaeological surveys carried out in Central Anatolia.

Map no.	**Season**	**Reference**	**Area (sq. km)**	**Total no. sites**	**no. MB sites**	**Sites density (x 100 sq. km)**
1	2000	Bahar 2002	5,825	120	52	2.06
2	1958	French 1970	1,127	51	7	4.50
3	1993	Gülçur 1995	1,341	61	9	4.54
4	2008-10	Kulakoğlu et al. 2009 and 2011	19,194	87	43	0.45
5	1990	Omura 1992	58,847	53	36	0.09
	1991	Omura 1993	6,899	30	11	0.43
	1992-93	Omura 1994 and 1995	4,322	102	48	2.36
	1994	Omura 1996 a-b	12,143	54	25	0.44
	1995	Omura 1997	1,634	43	12	2.75
	1996	Omura 1998	1,037	51	8	4.91
	1999-2000	Omura 2000 and 2001a	6,152	66	18	1.07
	2000	Omura 2001b	2,057	64	18	3.11
	2001	Omura 2002	4,555	68	33	1.49
	2002	Omura 2003	1,786	106	10	5.95
	2005	Omura 2006	2,672	46	13	1.72
	2006	Omura 2007a	3,529	40	13	1.13
	2003-2006	Omura 2007b	7,988	190	56	2.39
	2007	Omura 2008	1,435	53	20	3.69
6	1997-98	Senyurt 1998 and 1999	5,804	53	16	0.91
7	1988-89	Süel 1989 and 1990	1,440	28	9	1.94

Within our study area there are 274 sites that were occupied during the Old Assyrian Colony Period (*c*. 1970-1700 BC) (Fig. 2). Other nearby archaeological surveys have been left out of the analysis because these are not as continuous with the others and there are gaps in the archaeological dataset.

The settlement system in the Anatolian central plateau is characterized by few large sites such as Kültepe (*c*. 50 ha), Acemhöyük (*c*. 55 ha), Bögazköy (*c*. 65 ha), Yassihöyük (*c*. 25 ha), Varavan Höyük (*c*. 25 ha), and Alişar Höyük (*c*. 20 ha),[9] with many surrounding small settlements. This pattern is further highlighted by the third quartile of a numerical summary of the distribution of the settlements sizes, which shows that 75 percent of sites have an extent below 3 hectares (see Table 2).

Table 2: Summary of central tendency and dispersion of settlement sizes (in hectares).

Settlements	minimum	1st quartile	median	mean	3rd quartile	maximum
Size (hectares)	0.2	1	1.5	3.11	3	65

6 See Abay 2011; Ur 2010; Ur – Wilkinson 2008; Wright et al. 2006-2007, for the potential of intensive survey around mounds as tool to understand expansion and contraction of settlement size in different periods.

9 The extents of the sites are just rough estimates based on the sizes of their mounds. Intensive archaeological surveys of the presumed lower town surrounding a mound have never been carried out in Anatolia.

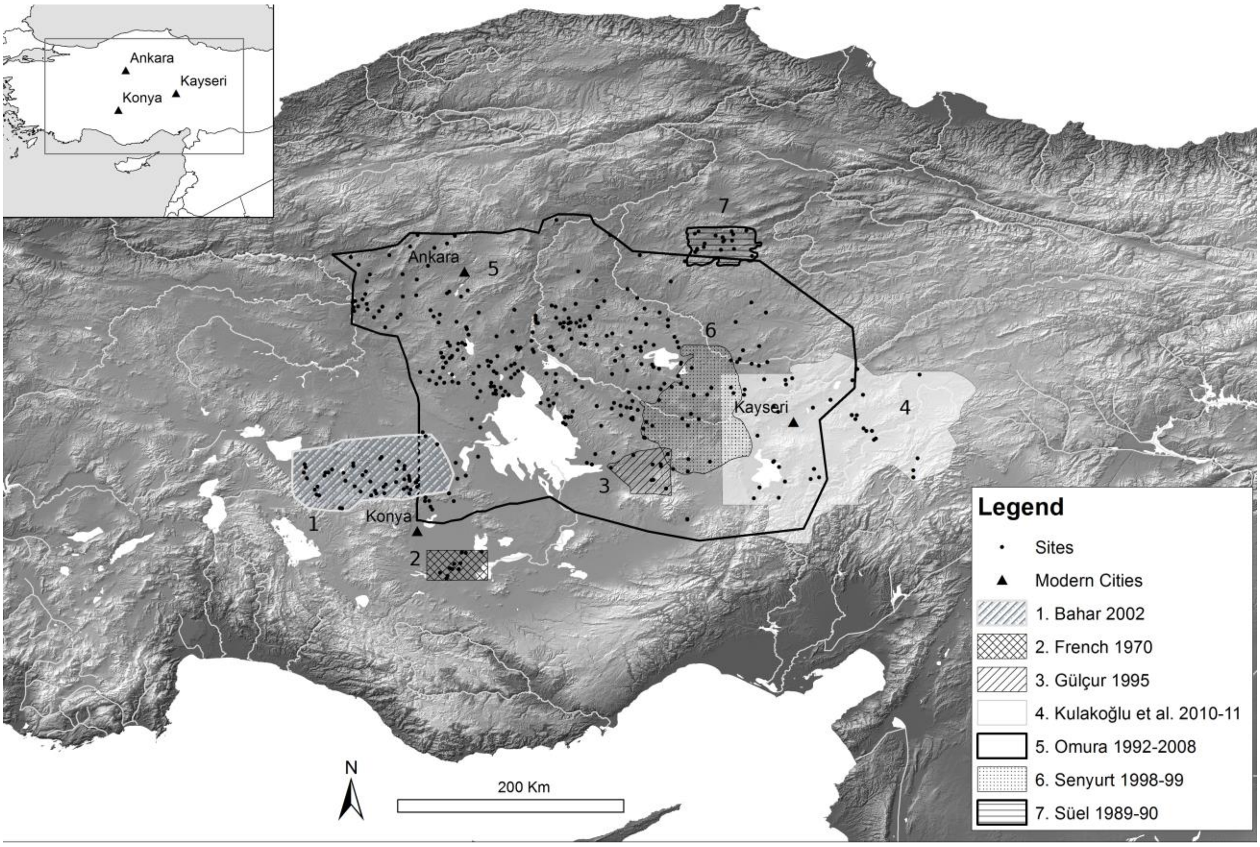

Figure 1. Map showing the archaeological surveys carried out in central Anatolia.

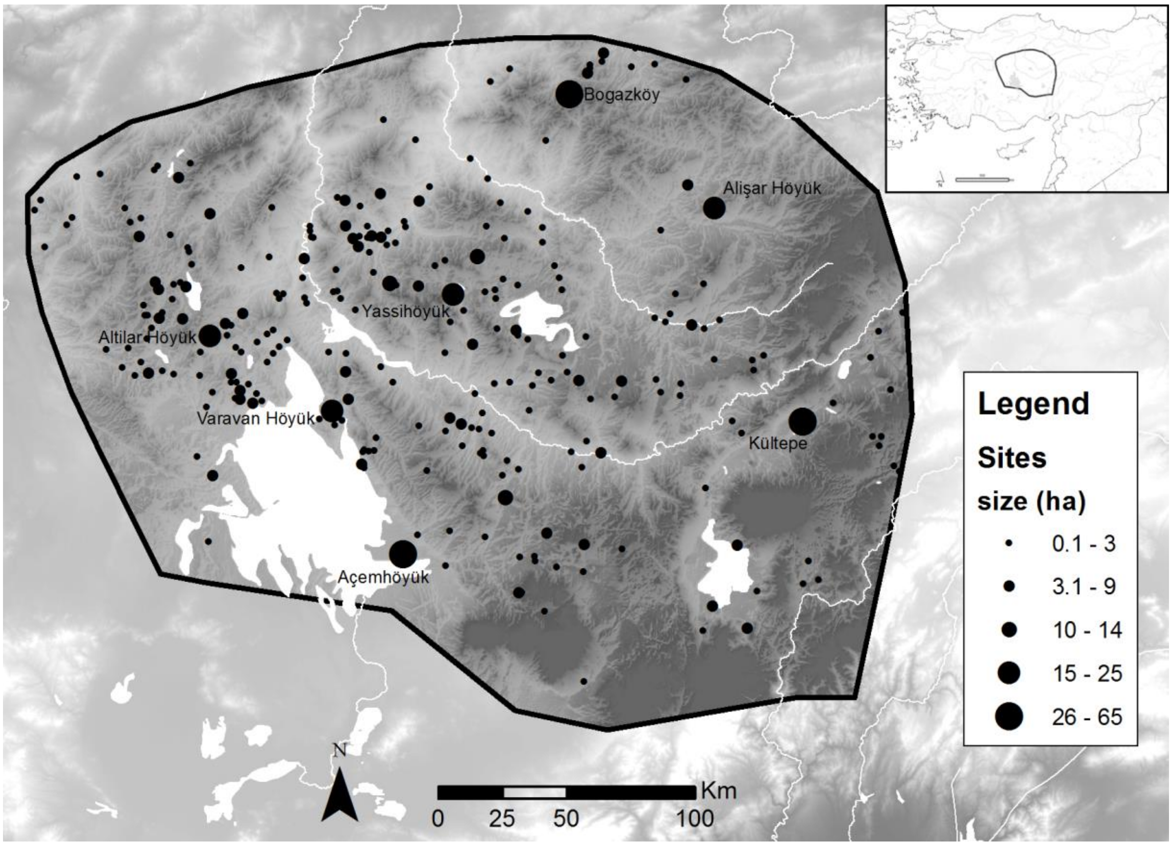

Figure 2. Distribution of settlement size within the study area.

Given these general trends, a natural log scale showing settlement size and hierarchies, ranking from largest to smallest, is displayed in figure 3. The rank-size plot of the 274 sites within our study area shows a convex distribution (Fig. 3) resulting in a stepwise ranking, which may reflect a central place settlement system where highest-order large sites of equivalent political-economic function are equivalent in size (see Falconer and Savage 1995, 40-41). Therefore, this distribution may reflect the unstable and fragmented political situation occurring in central Anatolia in the early 2nd millennium BC, where few big large urban centres exerted their power over their neighbouring rural lands and played as important trade hubs hosting the Old-Assyrian commercial settlements.[10]

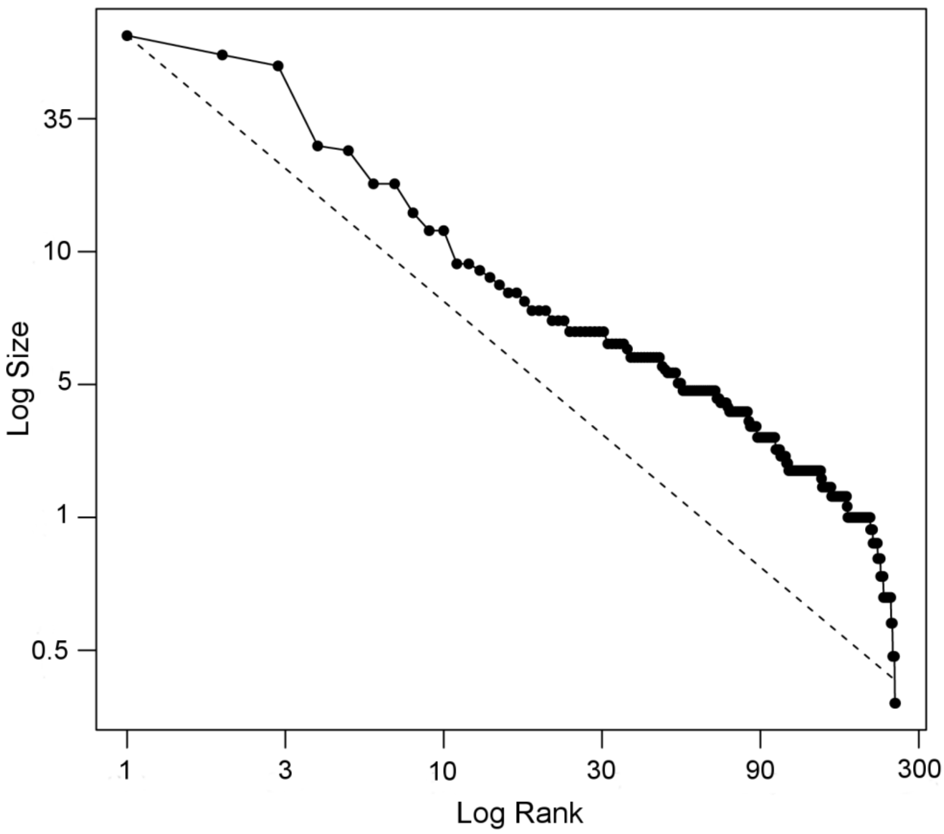

Figure 3. Site size hierarchies, using a natural logarithmic scale for size of settlements (ha) and rank (ordinal) in central Anatolia.

1.2 Historical Background

Our knowledge of Anatolian cities, town and villages is restricted because the written sources provide us with only a few hundreds of toponyms that, unfortunately, are problematic to identify and locate geographically. Most written sources (*c.* 22,500 clay tablets) come from the archaeological site of Kültepe and a few hundred from other sites in central Turkey.[11] In

[10] Bachuber 2012, 576–582; Dercksen 2001; Veenhof – Eidem 2008, 147–182; Barjamovic 2011, 3–15; Barjamovic et al. 2012 43–80; Forlanini 2008.

[11] Michel 2003; 2006; 2011.

fact, seventy-two clay tablets were found in the lower town of Bögazköy,[12] sixty-three from Alişar Höyük,[13] two from Kaman Kalehöyük[14] and another one from Kayalıpınar.[15] However, we know from the written sources coming from Kültepe that the political situation in central/south-eastern Anatolia was characterized by several city-states distributed in five different zones:[16] the Middle Euphrates (Nehria, Batna, Zalpa, Uršu, Hahhum, Mamma); the territory within the Kızılırmak basin (Kaneš, Amkuwa, Samuha); Konya plain (Purušhaddum, Ulama,Wahšušana, Šalatuwar); the Halys region (Hattuš, Karahna, Durhumit) and the Pontus (Zalpuwa).

In the 18th century BC the conflicts gradually changed the political landscape of Central Anatolia from a patchwork of small numerous city-states fighting with each other to the rise of sizeable territorial states framed into opposite alliances. In Central Anatolia Kaneš imposed its power over Amkuwa, Lakimišša, Salahšuwa and Taišama.[17] Then, the king of Kuššara Pithana, a city likely located to the southeast of Kizilirmak basin, conquered Neša (Kaneš) and captured its king Waršama.[18] After his death, Pithana's son and successor Anitta extended his kingdom by undertaking military campaigns northward against Zalpuwa and Hattuša and westward against Wašhaniya, Ulama and Šalatuwar. Thus, by the end of his reign (*c.* 1725 BC) Anitta was effectively the lord over the southern half of Central Anatolia, and he took the title of Great King.[19] However, Anitta's power was not long to last, and a successful revolt of vassal cities raised around his death (*c.* 1725 BC) resulted in the destruction of Neša and in Anitta's empire fall. The political landscape of Central Anatolia returned instable and fragmented, and in this new situation Zuzu, king of Alahzina, conquered Kaneš and took himself the title of Great King; he ruled at the end of the 18th century BC.

2. Methodology

2.1 Spatial Interaction Model and Settlement Structures Dynamics

Entropy maximising methods have been widely used to predict urban economic or population growth in spatial systems.[20] In this paper, they are used to model spatial interaction between settlements in terms of both migration and trade. These models have been used to describe not only urban growth in a given geographical context, but also on smaller scale settings such as the growth of modern retail outlets and particular areas within modern cities.[21] These methods combine Boltzmann's equations from statistical physics and ecological models of Lotka and Volterra.[22] In this approach, we use entropy maximizing models to predict likely

[12] Dercksen 2001: 49–60.
[13] Dercksen 2001: 39–49.
[14] Yoshida 2002.
[15] Sommerfeld 2006.
[16] Barjamovic 2011.
[17] Barjamovic et al. 2012, 49–50.
[18] Hamblin 2006, 293; Hoffner 1980, 291; Carruba 2003.
[19] Barjamovic et al. 2012, 50.
[20] Wilson 1967; 1970.
[21] Birkin – Heppenstall 2011; see Wilson 2012 for a broad overview.
[22] Wilson 2008.

areas of population growth or decline in specific spatial systems under conditions of uncertainty. In this case, several factors such as distance, topography, economic and political relevance, and movement capability become the generalized variables to explain urban transformations. These variables allow one to detect general social and environmental conditions responsible for the growth of specific areas and/or urban centres and the decline of others. Specifically, our aim is to produce simulations which predict the urban layout of a given spatial system, in order to explain under which dynamics certain sites may have acquired relative prominence. The validity of the model will be assessed by comparing the correspondence between the simulated outputs and the available archaeological and textual data. Entropy maximizing models allow feedback and interaction systems between settlements and explain how the urban growth of some urban centres/areas may affect surrounding regions. In fact, positive feedback allows major urban centres and region to grow to a greater extent, while negative feedback diminishes the economic and social positions of other regions.[23] In pre-industrial societies one can likely assume that lower rates of natural population growth prevented urban growth,[24] while "pull" factors such as geography, environment, transport, economy, and social institutions may have contributed to positive feedback enabling major urban centres to expand further and simultaneously diminishing the population and economic potential of the surrounding regions or centres.[25] However, some factors could have played a more relevant role in the growth, stabilisation or decline of a given settlement. Put simply, the analysis we present uses a well-established formulation of spatial interaction model, which offers general trends and factors that may have affected the urban development and the settlement hierarchies in central Anatolia in the early 2nd millennium BC. The spatial data required for the model are 274 sites within a well-defined study area. We have rough estimates of the extent of each site, based on the published archaeological surveys reports, which provide a relative proxy of the settlements population. The topographical data are represented by an Aster Global Digital Elevation Model (GDEM) of the whole study area downloaded from the NASA's official website.[26] A digital elevation model is a digital map, which provides a three-dimensional model of elevation (or part) of the Earth's surface.

2.2 Model Structure

For the purposes of this paper, a spatial interaction model of the type which has been already used in other contexts,[27] has been applied to understand which general factors may have affected the growth or the contraction of settlements in central Anatolia during the Old Assyrian Colony Period (*c.* 1970-1700 BC). Here, we define the following variables for each of the sites (see the Appendix for further details about the method):

- S_{ij} = volume of flow (e.g. people and/or goods) originating at a given site *i* in relation to another settlement *j*;
- X_i = population at a given site *i*;

[23] Krugman et al. 1995.

[24] McNeil 2000.

[25] Batty 2005; Braudel 1995; Wilson 2012a.

[26] The current ASTER Digital Elevation Model (DEM) product was implemented using new production software at the Land Processes DAAC starting on May 24, 2006. This is the final validated version of the DEM product derived using bands 3N and 3B from an ASTER Level-1A dataset (http://reverb.echo.nasa.gov.).

[27] Bevan – Wilson 2013; Davies et al. 2014; Harris – Wilson 1978; Wilson 1967; 1970.

- α = attractiveness or size of site j;
- l = external contacts outside the modelling study area;
- β = willingness or travel capability of individuals to travel a given distance to a settlement;
- d = distance between any two sites i and j.

In summary, the equation above determines how much flow of people and/or goods to a given site on the basis of attractiveness (α), external links and exogenous factors outside a given study area (l), willingness or ability to travel (β), and distance (d) in relation to the population (X_i) of a given settlement. More precisely, the distance (d_{ij}) between each pair of sites is modelled through a matrix of travel movement costs generated by considering the topography and the geographical features (e.g. hills, mountains, rivers, etc.) of a given study area that may have constrained the movement.[28] Another way to define d include also the use of a probabilistic framework taking into account of social factors (e.g. political or territorial divisions) that may have affected the movement between settlements. The attractiveness of a site (α) is a general variable used to determine which political, economic, religious, social or environmental factors may have made specific settlements more attractive than others. Another important factor is the one defining each site's interaction (l) with sites outside the study area, which would be manifested as an additional flow of goods and people for each site. For our purposes, this variable (l) is useful for modelling any sort of external trade contacts between the sites in central Anatolia and other regions. Finally, the variable (β) defining the willingness, the freedom, and the capability of movement it is worthy of some notes. In fact, as β increases, an individual's preference to travel shorter distances increases for any reason, while as β decreases, individuals travel longer distances. So, this variable may be used for determining general factors that may have favoured (e.g. roads, privileged pathways between settlements) or constrained (e.g. rivers, territorial or political boundaries, warfare) the movement between settlements. Therefore, using entropy maximising methods, the most likely set of flow, given that the total flow originating at each site is known, is then found under specific parameters of generalized variables.

3. Results

Based on the above model, in this section we will make use of simulations in order to explore any possible variation within the model, in terms of parameter choices, manipulation of the underlying dataset, and synthesis of results. More precisely, the model features three general variables (α, β, and l) that can be modified to give different outputs, for a given set of initial conditions. Results are then able to provide insights into how human settlement hierarchies may have developed in central Anatolia in the early 2nd millennium BC. Given these assumptions, here the results of three different scenarios will be showed and assessed. The first scenario will provide a baseline case where the values of all variables will be equal for all sites, so that it will be possible to test the role of geography and transport in shaping urban growth and settlement size structures. In the second scenario, we will investigate how foreign contacts and trade from outside our study area may have affected urban growth. In the last scenario we will test which values of general variables (α, β, and l) are required for specific sites in order to recreate urban layouts similar to those known from the archaeological and textual evidence.

[28] Fontenari et al. 2005 for the algorithm used; Palmisano 2013, 774–781, for a discussion about modelling past human movement.

3.1 Scenario one: The Benefit of Geographic Location

In this scenario our aim is to identify which sites could have taken advantages from their geographic location and to which extent site attractiveness (α) and willingness to travel or capability of movement (β) could have affected urban growth in a given specific area. In this context, as α increases, any given sites becomes more attractive, while the increase of β indicates more constraints to movement and then less capability to travel long distances. In this scenario initial condition values such as size and population are equal for all sites at the beginning of the simulation, and an incremental changes of parameters is done to the α and β values. This is done to see how variations of site attractiveness and movement impedance affect populations and if certain sites consistently appear as relatively larger or smaller settlements. The simulation ends until the population and size results are considered stable, resulting in runs being twenty simulation ticks long. In this scenario, α is incrementally increased to 1 and β to 40. Figure 4 shows the outputs of this scenario according to specific α and β values and the population of each settlement. Population values should not be read as absolute values but as relative values of sites size in relation to others.

When comparing sub-scenarios, it is evident that when the attractiveness (a) increases for all sites, the population of settlements does not substantially differentiate because all sites are increasing in size together (Fig. 4a-b). Therefore, in this case we have the least differentiation in sites growth and a relatively even distribution of population. In contrast, the willingness of travel and capability of movement (β) have a greater effect in the differentiation of sites population, so that more distant and less centrally located sites become less attractive as β increases (Fig. 4c-f). In summary, incremental changes of attractiveness (α) for all sites do not affect dramatically settlement hierarchies, while an increase of β has a more pronounced effect on population differences.

In this baseline scenario the lowest values for α (=0.1) and β (=1) provide an output where any individual is free to travel between settlements through the landscape (Fig. 4a). In this case, the area to the north of Lake Tuz Gölü and Kızılirmak River between the Bozok and the Haymana Plateau result as the more likely to attract a greater portion of people. Nevertheless, these results do not show a high population values for the known major sites and therefore do not correspond with the assumed settlement size structures for the Middle Bronze Age.

The scenario drastically changes as β increases and the less capability of movement due to any kind of constraint (e.g. political and territorial divisions, topographical and natural boundaries, etc.) make individuals to travel on shorter distances (see Fig. 4c-f). In this case, we recreate a more realistic scenario where people are less free to move through the landscape given the fragmented political situation occurring in central Anatolia during the Old Assyrian Colony period (*c.* 1970-1700 BC). The incremental changes of β values result in a greater difference in population and with a concentration of flows (of people and goods) towards fewer larger settlements. Therefore, these parameter sweeps provide an output where known big centres such as Açemhöyük, Altilar Höyük, Yassihöyük and Varavan Höyük acquire high population values. On the other hand, in this scenario other known large sites such as Alişar Höyük, Bogazköy, and Kültepe do not become prominent. In summary, the present scenario shows how the geographical location associated to any kind of movement restriction may have benefited the urban growth of some known Middle Bronze Age settlements, while it does not explain the urban growth of other important sites (Alişar Höyük, Bogazköy, and Kültepe).

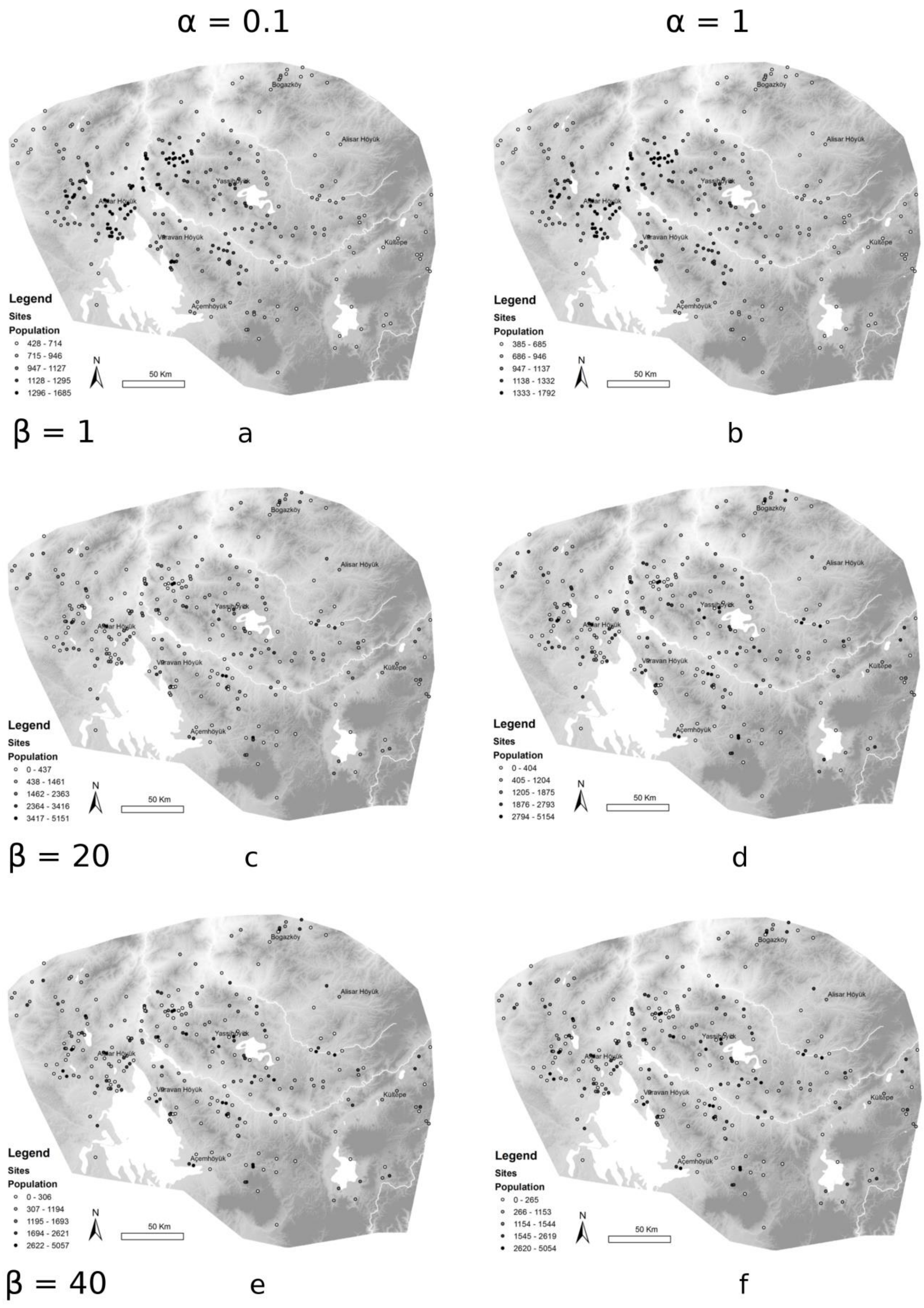

Figure 4. Final simulation results from the baseline scenario (a-f) showing variations of α and β and their effects. Settlement population variations are displayed using colour greyscale.

3.2 Scenario two: The Role of External Contacts

In the previous scenario we have intentionally skipped the role that external contacts with sites or regions outside our study area could have played on the development of settlements growth in central Anatolia. Basically, this scenario is similar to the previous one, but here the role of external contacts (*l*) will be considered. In particular, the values sweep of the variable *l* aims to explore how the increase or decrease of trade contacts and interactions with sites and regions outside the modelled regions may affect the urban growth of the sites located in central Anatolia. The simulation features exogenous areas that may positively or negatively affect flow of people and goods and thus population change within our study area.

As in the previous scenario, six sub-scenarios are modelled (Fig. 5a-f). As observed in the scenario one, incremental changes of β values significantly affect settlements population. In the sub-scenario with lower values of *l* (=0.5) (Fig. 5a, c, and d) there are no significant differences with the general picture showed in the previous scenario 1. The generalpicture markedly changes for the sub scenarios with higher *l* values (=0.5 and 1), where sites such as Bogazköy and Kültepe show higher population values if compared with the outputs of the scenario one, where the external factors have been skipped (see Fig. 5b, d, and e). Therefore, the outputs may explain well how the urban growth of sites with a more international attitude such as Kültepe and Bogazköy (in lower scale) may depend on trade and interactions with exogenous areas and settlements. In addition, we have to fairly admit that sites located in the edge of our modelled study region may be more sensitive to the flow of people and goods from outside.

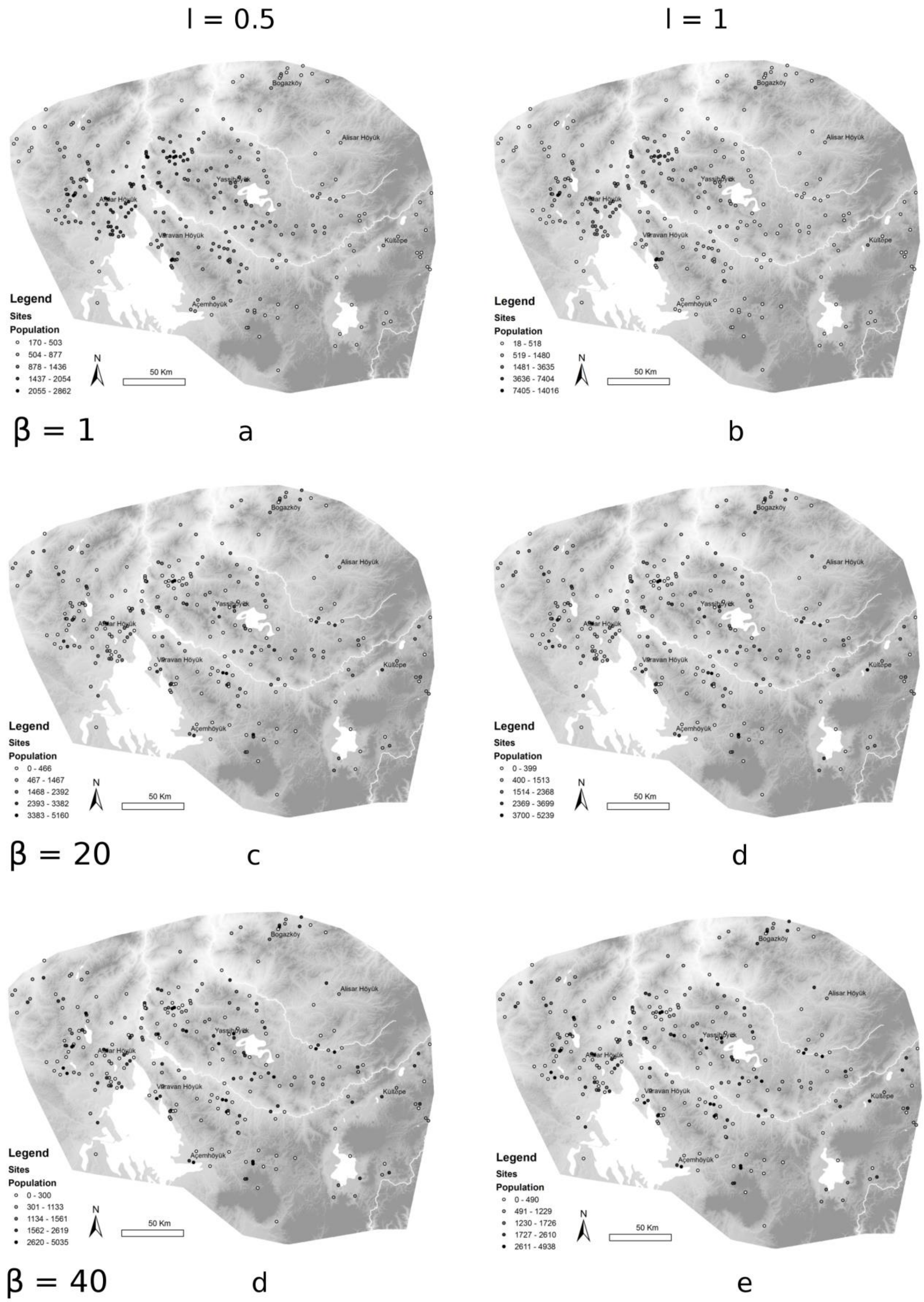

Figure 5. Final simulation results from scenario two (a-f) showing variations of α and *l* and their effects. Settlement population variations are displayed using colour greyscale**.**

3.3 Scenario three: Shaping settlement hierarchies

While the scenario one's outputs show that the local geographical location could have benefited some sites such as Açemhöyük, Varavan Höyük and Yassihöyük, other major Middle Bronze Age sites such as Alişar Höyük, Bogazköy, and Kültepe do not show a similar result. In the scenario two population values increase for Bogazköy and Kültepe, while Alişar Höyük is still a not prominent centre. Therefore, to create settlement hierarchies more comparable with the known urban layout (from the archaeological and textual evidence) occurring in central Anatolia during the Old Assyrian colony period (*c.* 1970-1700BC), we will test different parameters sweep of α, β, and l in order to see which general factors may have made those sites dominant (see Table 3). Put simply, conducting a parameter sweep on the variables by incrementing 0.1 for each variable, the intent is to see which minimum results produce a situation where Açemhöyük, Alişar Höyük, Altilar Höyük, Bogazköy, Kültepe, Varavan Höyük, and Yassihöyük are the largest sites (Table 3). This method allows us to understand how strongly any singular factor may have affected the urban growth of these sites. Naturally, the incremental changes of the variables will be applied just for the sites quoted above, while all other sites are set to α = 0.1 and l = 0.1. The results show that Altilar Höyük, and Varavan Höyük need to have α=0.2 and l =0.1 before they consistently become the largest sites, while Yassihöyük needs a slightly higher values of α (=0.3) and l (=0.2) to became dominant (Table 3). Açemhöyük starts becoming large with low values of α (=0.2) and moderate l (=0.4). On the other hand, Alişar Höyük, Bogazköy, and Kültepe need much higher values of both α and l to become large sites. Therefore, the outputs of the simulation indicate that sites such as Açemhöyük, Altilar Höyük, Varavan Höyük and Yassihöyük may have benefited of their respective geographical location and their predominance may be explained in terms of local authority exerted over their surrounding rural hinterlands. On the other hand, the urban growth of sites such as Bogazköy, and Kültepe could be explained mostly in an optic of trade and interactions with areas and sites outside the modelled study area. Instead, the high values of α and β required to make Alişar Höyük large could be implied to the apparent isolation of the site and partially to the scantiness evidence of the archaeological survey data in its areas.

Table 3: Summary of results for scenario 3. Sites indicates all sites except the ones in the table.

Site Name	α	l
Sites	0.1	0.1
Açemhöyük	0.2	0.4
Alişar Höyük	0.7	0.7
Altilar Höyük	0.2	0.1
Bogazköy	0.4	0.6
Kültepe	0.4	0.8
Varavan Höyük	0.2	0.1
Yassihöyük	0.3	0.2

4. Discussion

What the present paper has attempted to demonstrate is how entropy maximizing spatial interaction model is useful in describing past human settlement hierarchies and in explaining what factors, at some level, may have caused some sites to become relatively larger than others. Each scenario, by making use of generalized variables, has offered a hypothetical picture that display how different interplaying factors may have affected urban transformations. The simulation's results show how the local geography alone may have played an important role in determining why some settlements such as Açemhöyük, Atlilar Höyük, Varavan Höyük and Yassihöyük became larger than others. In particular, a larger percentage of the population is concentrated in fewer larger centres as the willingness of travel or the capabilities of movement are constrained (*β* values increase). This can be possibly explained by the fact that the intermountain valleys and the presence of natural boundaries such as the Kızılırmak and Delice Rivers may have provided some relative isolation, possibly minimizing exogenous factors from more distant regions and settlements outside our modelled study area.[29] In addition, the constrain of movement due to other factors such as political and territorial divisions could have made individuals travel on shorter distance and then concentrate the flow of movement and people of surrounding rural communities into few large local large urban centres.[30] This may reflect well the central Anatolian political landscape fragmented into numerous independent city-states during the Old Assyrian Colony Period (*c.* 1970-1700 BC).[31] The importance played by Açemhöyük during the Middle Bronze Age is reflected from the two palaces Sarıkaıa and Hatipler (level 3-4) that have yielded archaeological evidence (e.g. seals, clay bullae, pottery, etc.) showing long-distance contacts with upper Mesopotamian Amorite dynasties.[32] This site has long been identified with Purušhaddum[33] but recently Barjamovic has identifeid it with Ulama, the seat of a an Assyrian *wabartum*.[34] Therefore, the results provided by our interaction model show that Açemhöyük's growth may due to both local and geographical factorsand external and exogenous factors. On the other hand, we see that the geographical location does not explain alone why other sites such as Alişar Höyük, Bogazköy and Kültepe became prominent in the early 2nd millennium. The results show that the urban growth of those sites could be related to trade and external contacts. The simulation's outputs are striking for Kültepe, which requires the highest *l* values to start becoming large (see Table 3). This reflect the international character of this site, which hosted an Old Assyrian *karum*[35] and was one of the main hubs of the commercial trade network set up by the Assyrians in Upper Mesopotamia and Central Anatolia.[36] Put simply, the urban development of Kültepe is not to explain in terms of local interaction within central Anatolia, but it may be the result of external contacts and long-distance trade activities with other regions and settlements. In fact, the archaeological evidence from Kültepe's lower town (level II and Ib) such as cylinder seals and balance pan weights respectively belonging to different regional styles and weight systems, Khabur ware and Syrian Bottles show the involvement of Kültepe in long-distance contacts with Syria and Upper Mesopotamia (see Aubet 2013; Ascalone and Peyronel 2006, 401-421; Emre 1999; Oguchi 1997; Özguç 2006; Özguç-Tunca 2001).

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29 Barjamovic 2011, 81–85.

30 Bachuber 2012, 576–578. The Middle Bronze Age rural hinterland of the central Anatolian plateau is archaeologically elusive and under-investigated. No intensive archaeological surveys of the agricultural settlements surrounding major archaeological sites have ever been carried out for the Middle Bronze Age. The early second millennium farming hinterland is well attested in some textual evidence (see Barjamovic 2011, 232-235; Dercksen 2008, 139; Forlanini 1992, 176).

31 Barjamovic 2011, 6; Barjamovic et al. 2012, 44–49.

32 Özguç 1980, 67; Özguç-Tunca 2001, 128.

33 Forlanini 2008, 65–66; Kawakami 2006; Veenhof 2008.

34 Old Assyrian commercial station; Barjamovic 2011, 411.

35 Old Assyrian commercial colony.

36 Barjamovic 2008 and 2011, Veenhof 2008.

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The target of the present paper has been to present a specific method to explain how geographical settings and unspecified social, political, and economic factors may have affected the urban growth and then the settlement hierarchy in central Anatolia during the Old Assyrian Colony Period (*c.* 1970-1700 BC). In other words, a spatial interaction model makes use of generalized variables such as attractiveness (α), capability of movement (β), and exogenous contacts (l), translated into simulation's parameters, to test which of them may have determined a settlement to grow and become larger than others. The advantage of this modelling approach is to enable researchers to account for missing empirical data and to reproduce outputs matching the known historical and archaeological evidence for explaining which generalized phenomena (e.g. geographical location, political or religious importance, trade contacts, etc.) may have caused settlements growth, stability or decline. On the other hand, the weak point of the present method is that we do not know which specific factors caused observed results. Hence, the outputs may be used for highlighting general settlement hierarchy patterns and for providing general explanations about the development of past settlement size structures. In practical terms, the model is also useful for predicting general areas where larger or smaller sites are to be expected, providing its potential as tool for archaeologists to locate such sites. Nonetheless, the present work could be extended and further improved. For instance, our consideration of known sites sizes uses estimated extent while it may be more prudent to draw values from a weighted distribution. A further step will be to use a well-established statistical technique to simulate the location of missing settlements from archaeological surveys.[37] Given more detailed data, it could be possible to add a variable defining the role of rivers as impedance of movement[38] on a river-by-river basis, or by incorporating archaeological and textual data about crossings, bridges and fords.[39] In summary, spatial interaction model maximising entropy allows one to explore which general socio-environmental factors may have affected past human settlement hierarchy dynamics and provide broad explanations based on the available empirical observations.

Appendix

In the model, impedance, and therefore restrictions in moving to sites, is represented by β, which incorporates various factors that cause movement to be difficult (e.g., political restrictions, physical barriers, etc.). On the other hand, α can vary for sites, as a site could be more important than other sites and can potentially mitigate the effects of transport limitations. In this case, α (i.e., attractiveness) can be a variety of factors, including political, economic, religious, or other social and environmental reasons that make a settlement attractive for migration or commerce.

The flow S_{ij} between each pair of nodes i and j is calculated using the following formula:

$$S_{ij} = X_i \frac{Z_j^{\,l_j * \alpha_j} e^{-\beta d_{ij}}}{\sum_k Z_k^{\,l_k * \alpha_k} e^{-\beta d_{ik}}} \qquad (1)$$

[37] Bevan – Wilson 2013, 2418–2419.

[38] Davies et al. 2014, 145.

[39] Barjamovic 2010, 18-20; Barjamovic 2011, 22–25.

These flows are summed to give the total incoming flow D_j to each site j:

$$D_j = \sum_i S_{ij} \qquad (2)$$

This incoming flow is used to calculate Z_j at the next time step, with ε used to control the speed of change and k a constant that can be used to scale Z_j, $Z_j^{(t+\delta t)}$, using:

$$Z_j^{t+\delta t} = Z_j^{t} + \varepsilon(D_j - kZ_j^{t}) \qquad (3)$$

Next, $X_i^{(t+\delta t)}$ for the following time step is determined by taking the corresponding $Z_i^{(t+\delta t)}$ value, normalized for the total of $Z_i^{(t+\delta t)}$ for all sites, and rescaling (n) so that sum of all $X_i^{(t+\delta t)}$ continue to have the same mean as the simulation start:

$$X_i^{t+\delta t} = n \frac{Z_i^{t+\delta t}}{\sum_k Z_k^{t+\delta t}} \qquad (4)$$

Then the model goes back to (1) for the next time step and continues until the end of the simulation.

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