Central Places and the Environment

Investigations of an Interdependent Relationship

Dissertation

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Überall geht ein frühes Ahnen dem späteren Wissen voraus.

A. v. Humboldt

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Abstract

This thesis, written within the *Cluster of Excellence Exc264 Topoi*, applies central place theory in archaeological context in order to investigate the influence of natural environmental characteristics on the formation, development, and persistence of central places. To allow an application of central place theory in archaeological context the definition of centrality is generalized. In this regard, centrality is understood as relative concentration of interaction. Applying this definition and a semi-quantitative approach to measure centrality, the intertwined influence of social and natural phenomena on the shaping and persistence of central place gets obvious: The centrality of a place can be seen as the result of interdependent processes that characterize specific features on different spatial scales, ranging from the local to the supra-regional. Natural environmental features are herein of relative importance, depending on the location and history of a central place. Therefore, to be able to assess the influence of environmental characteristics on central places, the natural and societal history of a place, in terms of its local, regional, and supra-regional integration has to be investigated.

Zusammenfassung

Diese Promotion wurde im Rahmen des Topoi Excellenzclusters (Exc 264) verfasst. Die Theorie der zentralen Orte wird im archäologischen Kontext angewendet um den Einfluss von naturräumlichen Parametern auf die Entstehung, Entwicklung und Konstanz von zentralen Orten zu analysieren. Um dies zu erreichen bedarf es einer Erweiterung der zentralörtlichen Theorie, die eine Anwendung im archäologischen Kontext erlaubt: Zentralität wird dabei verallgemeinert und als relative Konzentration von Interaktion verstanden. Auf Basis dieser Definition, gepaart mit einer semi-quantitativen Analysemethode zur Messung der Interaktionskonzentration, kann die Verzahnung von gesellschaftlichen und natürlichen Phänomenen bei der Bildung und Entwicklung von zentralen Orten aufgezeigt werden. Die Zentralität eines Ortes kann somit als das Ergebnis interdependenter Prozesse verstanden werden, die auf unterschiedlichen Raumskalen, von lokal bis überregional, wirken. Der natürlichen Umwelt kommt dabei eine relative Bedeutung zu, die aus der spezifischen Lage und Geschichte eines Ortes resultiert. Es kann gezeigt werden, dass der Einfluss der Natur auf die Zentralität von Orten nur durch eine integrative, diachrone, unterschiedliche Raumskalen berücksichtigende Analyse möglich ist.

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Introduction

This thesis is written within the Research Group A-I *Central Places and Their Environment* of the *Cluster of Excellence Exc264 Topoi*. Based on a collaboration of researchers from the humanities and sciences, the goal of Topoi is to understand the formation and transformation of space and knowledge in ancient civilizations. Humans and their relation to the natural environment is covered in Topoi's Research Area A. The main aims are the reconstruction of the spatial environment, its shaping by human beings, as well as the assessment of human adaptation to their natural environment (Schütt and Meyer, 2011, 4). Research is focused on the Mediterranean region, the Near East, the Black Sea area and parts of the Eurasian steppe. The focus of the Research Group A-I lies on individual central places and their surrounding regions (Schütt and Meyer, 2011, 6). In this regard, the present study aims to develop a general approach to investigate central places and their surroundings. Surroundings are understood as the natural and social character of a central place on a local to supra-regional scale. This is a contribution to the questions of how humans shaped and adapted to their spatial environments and is one of Topoi Research Area A's primary interests (Schütt and Meyer, 2011, 4).

1.1. Objective and structure

This thesis aims (1) to compare different aspects of central places and (2) to answer the question, whether the natural environment has influenced or even determined their formation, development, persistence, or decline. The sites selected for the investigation need to offer a sufficient amount of relevant data regarding human *and* environmental conditions. According to this, Aleppo in Syria (Topoi Project A-I-6) as well as Selçuk and Bergama in Western Turkey (Topoi Project A-I-8) were chosen.

The different aspects of the objective are investigated within three papers:

- The relationship between a central place and its hinterland—regarding natural environmental characteristics and location—is determined in Knitter et al. (in press): *The Centrality of Aleppo and its environs* [own contribution 70%]. In this study, centrality is redefined to be applicable in an archaeological context. Furthermore, central functions as a measure for centrality are applied. The interdependent character of different spatial scales and time are shown: favourable environmental conditions have a positive influence on the centrality of a place. In this regard it is also possible to compare Aleppo with other central places of different epochs.

- Knitter et al. (in press) shows that environmental favourable conditions have a positive influence on the centrality of a place. Nevertheless, changes in the societal organization are able to surpass environmental favourability. In order to get a better understanding of these factors a comparative study between at least two central places is necessary. This was done in Knitter et al. (2013): *Integrated centrality analysis: A diachronic comparison of selected Western Anatolian locations* [own contribution 60%]. In this study, the concept of central functions is developed further to a semi-quantitative method that allows the direct comparison of central places. It is shown that both natural and societal factors influence the centrality of a place. Nevertheless, their influence is different in a diachronic perspective: favourable environmental conditions lead to a *generally* high centrality potential. By contrast, societal efforts seem to be important and influential throughout *specific* periods.

- On the local scale, environmental characteristics influence the ability of places to interact and hence to function as central places (Knitter et al., 2012). On the regional and supra-regional scale this interaction potential is further influenced by the location of the place in relation to other central places and its integration in exchange networks. These characteristics are determined in Knitter et al. (submitted): *The importance of location in terms of Early Bronze Age 1 obsidian exchange in Western Anatolia* [own contribution 70%]. It is shown that a high centrality potential which is based on natural environmental characteristics emerges from the interrelation of different spatial scales: the local scale influences the interaction potential of a place while the environmental characteristics on regional and supra-regional scale influence the integration of a place in human-made networks of exchange.

These publications allow to answer different aspects of the relationship between a central place and the environment. They are merged in chapter 5. The following sections describe the research object as well as the terms and general assumptions used throughout this work.

1.2. Research object

> "The geographer (. . .) considers the arrangement and relationships of the phenomena within a region; to think geographically is to think of phenomena not as individual objects in themselves, but as elements determining the differential characters of areas" (Hartshorne, 1939, 418).

According to the quote above, investigating locations—herein central places—and their relationship to the natural environment is a task that has to take into account not just the local, specific characteristics of a location and its natural environment, but also its connection to objects and processes of the regional and supra-regional scale. Additionally, the focused time period is important, because "(...) any landscape is a **palimpsest** in that it comprises the consequences of a series of different occupations" (Norton, 2000, 94, bold in the original).

This interdependent character of spatial phenomena can be sketched in a three-dimensional diagram (figure 1.1). It gets obvious that, to understand the characteristics of a location in a specific, focused epoch, one has to know the importance of (a) its general characteristics, i.e. its topology, (b) its development, i.e. its chronology, and (c) its relation to other places, i.e. its chorology (Hettner, 1905, 557).
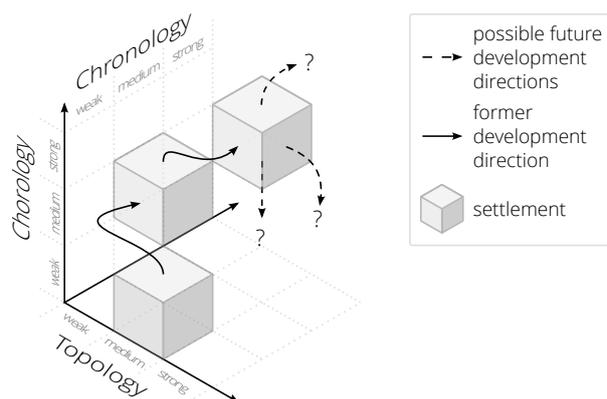
Figure 1.1: Three-dimensional representation of spatial phenomena. Settlements and their hinterland are characterized by interdependent topological and chorological relationships throughout the time.

1.3. Spatial interactions

The local, underlying areal conditions at a location correspond to its topological characteristics. Ullman terms this *site*, where relations between human and the environment are investigated (Ullman, 1980, 13). The site concept may be visualized as vertical relationship, e.g. the type of soil and the specific kind of agriculture on it. By contrast, the chorological characteristics of a settlement—what Ullman calls *situation*—refer to the effects of the phenomena in one area onto another. Accordingly, *situation* investigates the connections between areas, explores regional interdependences, diffusion or centralization processes (Ullman, 1980, 13). The situation concept

describes the horizontal relationship, e.g. the effect of markets in place A and its effect on the agriculture in place B.

To study these spatial interactions, one has to investigate a settlement's *situation*, whose prerequisites are:

- *Complementarity*: a function of areal differentiation, i.e. the differences in the topological characteristics of settlements, that promote spatial interactions (Ullman, 1980, 18). The latter are occurring when there is a demand in one and a supply in another area. Thus, a specific complementarity is needed before interactions take place. In this regard, complementarity makes the establishment of transport routes possible (Ullman, 1980, 15).

- *Intervening opportunities*: or intervening complementarity between two regions. Spatial interactions between two areas occur only if no intervening or complementary sources are available (Ullman, 1980, 16). Intervening opportunities result in a substitution of areas (Ullman, 1980, 18).

- *Distance*: measured in terms of time and cost. Interactions will not take place if the distances between market and supply are too large or too expensive to overcome— notwithstanding complementarity and lack of intervening opportunities (Ullman, 1980, 18). The factor of distance results in a substitution of products (Ullman, 1980, 18).

1.4. Relationship between human and environment

Spatial interactions are the result of the integration of topological and chorological dimensions throughout the time. The environmental conditions define these different dimensions to a certain degree and hence the occurrence and relation of spatial interactions. But to what degree? And how is this relation between interactions and the natural environment characterized? Researchers answered these questions from their specific scientific backgrounds. Starting from deterministic thinking, that was—at least implicitly— influenced by Darwinian thoughts (Stoddart, 1966) many different concepts were formulated, e.g. (see also figure 1.2):

- *Environmental Determinism*: where the characteristics of the natural environment determine human action and development. "Man is a product of the earth's surface. This means not merely that he is a child of the earth, dust of her dust; but that the earth has mothered him, fed him, set him tasks, directed his thoughts, confronted him with difficulties that have strengthened his body and sharpened his wits, given him his problems of navigation or irrigation, and at the same time whispered hints for their solution. She has entered into his bone and tissue, into his mind and soul" (Semple, 1911, 1).

- *Possibilism*: As the name suggests, in this view humans are free to select how they use their environment: "There are no necessities, only possibilities" (Fevbre in Jeans, 1974,

36).

- *Landscape School*: Humans are the creator of their landscape (cf. Sauer, 2008). They change the natural landscape (*Naturlandschaft*) to a cultural landscape (*Kulturlandschaft*).

- *Environmental Perception*: Human consciously perceive their natural environment—called perceptual or phenomenal environment— through a cultural filter, leading to the so-called behavioral environment: "(...) social and physical facts of the Phenomenal Environment are shown to constitute parts of the Behavioural Environment of a decision-taker (...) only after they have penetrated a highly selective cultural filter of values" (Kirk, 1963, 366).

- *Ecological Approach*: An approach, where humans, animals, plants, etc. are thought within a single framework to analyze the interactions of their different components. Humans, like other organisms, occupy defined ecological niches within the various communities (Jeans, 1974, 39–40).
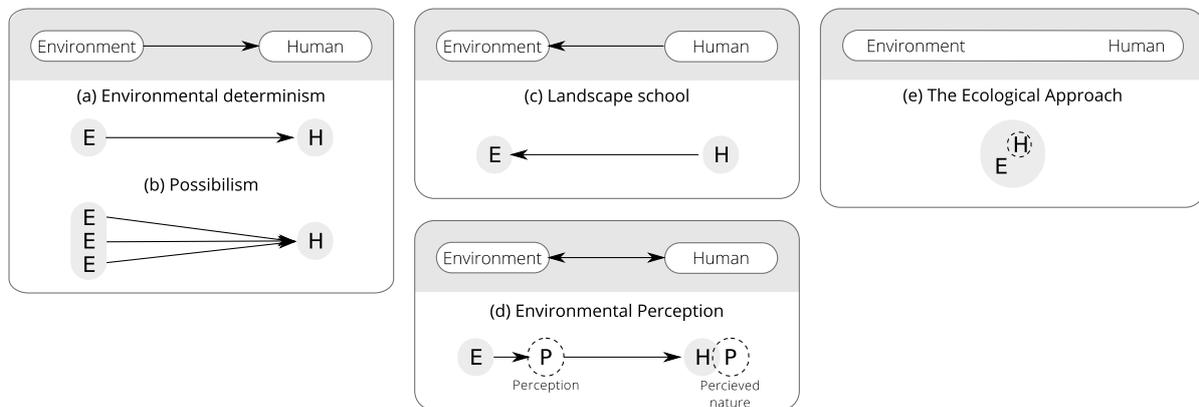
Figure 1.2.: Differences in the perception of the relationship between human and environment; representatives for the different schools of thought are e.g., (a) Herder, 1869; Semple, 1911; Huntington, 1915; (b) Febvre and Bataillon, 1950; (c) Marsh, 1867; Thomas, 1956; Sauer, 2008; (d) Kirk, 1963; Weichhart, 1978; (e) Stoddart, 1965 (based on Jeans, 1974; Norton, 2000).

This list is by far not exhaustive. A general overview is given, e.g. by Norton (2000); a detailed analysis of the scientific development of this theme throughout history can be found in Glacken (1967); a concise selection of papers regarding nature and culture is given by Oakes and Price (2008).

In essence, any of these approaches assign their specific elements to classes of human or environment. They integrate human/environment as another factor in their science-specific models. But these approaches that are based on a dichotomy are increasingly unsatisfactory: as Latour (2008) argues, the world consists largely of *hybrid elements* that cannot be assigned to one of these categories. Accordingly, to answer questions concerning human *and* environment one has to investigate them within a single holistic framework (Weichhart, 2006, 113).

An example of such a framework—that is adapted in a more general fashion in chapter 4.2 and 4.3—is the concept of societal metabolism (cf. Fischer-Kowalski et al., 1997). In this concept, society is defined as a closed system concerning communication and an open system concerning energy and matter: Society is a structural coupling of a cultural system with biophysical elements (Fischer-Kowalski et al., 2011, 98). The modification of the matter and energy metabolism between nature and society aims to utilize the space more efficient than under natural circumstances, e.g. due to tillage or livestock breeding. This is termed *colonization* of nature (Fischer-Kowalski et al., 2011, 99).

Generally, metabolism is a biological concept, referring to internal processes of a living organism: Organisms maintain a continuous flow of energy and matter with their environment to provide for their growth, reproduction, and survival. In an similar way, social systems convert raw materials via manufacturing into commodities, goods, services, and—in the end—into wastes (Fischer-Kowalski and Haberl, 1998, 573–574). This way of looking at the society-nature-interaction can be dated back to Marx and his description of labour:

> "Labour is, in the first place, a process in which both man and Nature participate, and in which man of his own accord starts, regulates, and controls the material re-actions between himself and Nature. He opposes himself to Nature as one of her own forces, setting in motion arms and legs, head and hands, the natural forces of his body, in order to appropriate Nature's productions in a form adapted to his own wants. By thus acting on the external world and changing it, he at the same time changes his own nature" (Marx, 1906, 197–198).

In a similar way, Godelier describes the interdependent relationship between human and nature:

> "The boundary between nature and culture (. . .) tend moreover to dissolve once we approach that part of nature which is directly subordinated to humanity—that is produced or reproduced by it (domestic animals and plants, tools, weapons, clothes). Although external to us this nature is not external to culture, society or history. It is that part of nature that is transformed by human action and thought. It is a reality that is simultaneously material and mental. It owes its existence to conscious human action on nature—action which can neither exist nor be reproduced without the intervention not simply of consciousness, but of every kind of thought, conscious and unconscious, individual and collective, historical and non-historical. This part of nature is appropriated, humanized, became society: it is history inscribed in nature" (Godelier, 1986, 4–5).

The higher the level of a society's complexity, the more it needs to organize its flows of energy and material. This is necessary not just for sustaining its population, but also to

sustain its intermediate biophysical structures influencing social reproduction, e.g. livestock, houses or infrastructure. "A notion of society as an open system that sustains itself on a continuous energetic and material exchange with its natural environment (and with other human societies) makes up the core of the socio-metabolic paradigm" (Fischer-Kowalski et al., 2004, 309). This shows the unity of human and environment in terms of societal development and spatial interactions.

According to this, the natural environmental characteristics of a central place can be seen as favourable when they facilitate a society's metabolism in terms of growth or sustainability. It follows that the natural environmental characteristics have no absolute but only a relative meaning. This is important when one aims to compare these characteristics between different central places.

1.5. Central place theory

Central place theory was developed by Christaller (1933) to understand the laws and principles that determine the number, size, and distribution of towns (Christaller, 1968, foreword). There were earlier attempts that aim to describe these aspects (see, e.g., Kohl 1841 or Reynaud 1841; for a critical discussion regarding the roots of central place theory see Istel 2002). Nevertheless, it was Christaller who first formalized it. A general overview about the theory, its development, applications, and criticism is given by e.g., Heinritz (1979), Beavon (1977), or King (1984). A discussion in terms of New Economic Geography can be found in Fujita et al. (1999). The application and development of the theory in archaeological context is best described in Nakoinz (2009).

With respect to Gradmann (1916, 427) and in analogy to natural phenomena, Christaller states that a town's major purpose is to be the center of an area (Christaller, 1968, 23). Such a *central place* has a surplus of meaning, because it provides its surrounding area—i.e. its complementary region—with goods and services (Christaller, 1968, 28-30). *Centrality* is the relative degree to which a place serves its complementary region with these commodities (Christaller, 1968, 27-28). Here, relative refers to a surplus of meaning above the level that would be expected with regard to the population density (Nakoinz, 2012c, 217; equation 1.1).

Christaller argues that it is not possible to understand the amount, distribution, or size of a city based on its natural location (Christaller, 1968, 13). Furthermore he argues, that it is not possible to derive the ordering principles of cities based on historical studies or statistical analyses alone (Christaller, 1968, 13). For Christaller these question can just be answered through a deductive, economic-geographical theory (Christaller, 1968, 14, 16). Hence, he developed a fundamentally economic, spatial-equilibrium theory, to predict how an optimal pattern of settlements will emerge—through competition for space (Pacione, 2009, 125). The

● central place

a market area defined by threshold population

b market area defined by range of good

area unserved by any market

overlapping market areas

compromise solution
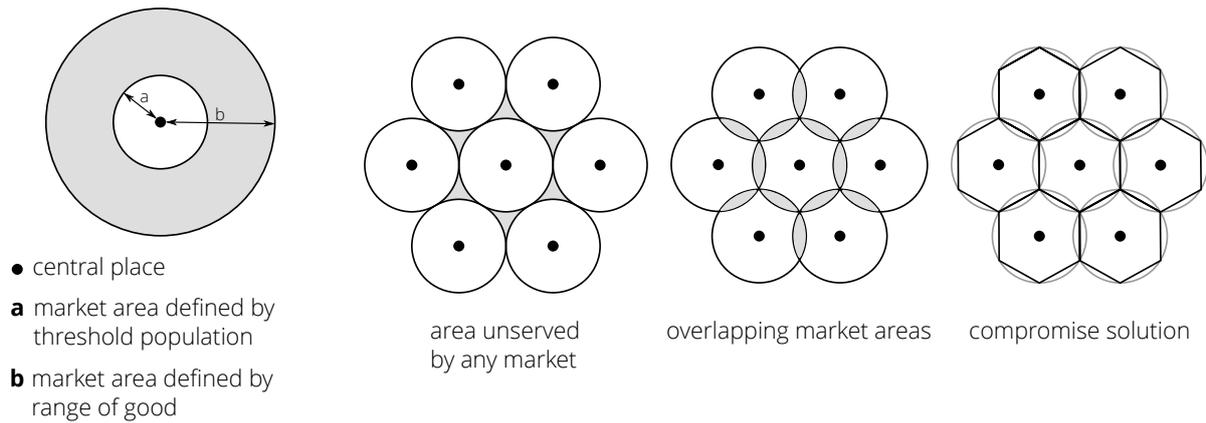
Figure 1.3.: Each good or service that is offered has an upper limit (determined by its range, i.e. the maximum distance people will travel to purchase it) and lower limit (determined by a threshold population, i.e. the minimum population required for a good or service to be produced viable). Based on this, every central place would have a circular trade area. But such a configuration would lead to areas that are served by more than one central place or areas that are not served at all. A hexagonal configuration of market areas is the most efficient way to ensure that every person on the plain is served (Christaller, 1968, 65–72).

theory has different assumptions (summarized in Pacione, 2009, 125): the world is an unbounded, uniform, isotropic plain where transport costs are proportional to distance. The population is evenly distributed and is equal regarding income and demand. On this plain there are central places that provide their surrounding areas with commodities, services and administrative functions. Humans are thought of as *homo oeconomici*, i.e. the consumers always visit the nearest place to minimize distance, the suppliers attempt to maximize their profits. Suppliers will locate as far away as possible from one another to maximize their market areas, since consumers visit the nearest center. This will be done to that extent where every consumer is still able to obtain the function—in the end, these assumptions lead to a hexagonal pattern of market areas (Christaller, 1968, 65–72; figure 1.3).

Central places that offer many functions are called higher-order centers while places that provide fewer functions are lower-order centers (Christaller, 1968, 26). Centers of higher order offer all the functions that are provided by lower-order centers. Besides, they supply specific functions that are not offered by lower-order centers. This leads to spatial models for a hierarchy of centers that dominate their market areas in nested hexagons (Pumain, 2006, 188). These spatial models illustrate three types of urban hierarchies that correspond to different principles with a typical ratio (k-ratio) between market shares of two successive hierarchical levels of central places (figure 1.4):

- market principle ($k = 3$): maximizing the number of centers for the best accessibility of consumers (Christaller, 1968, 77–79)

- transportation principle ($k = 4$): reducing the transport distance of centers in the network
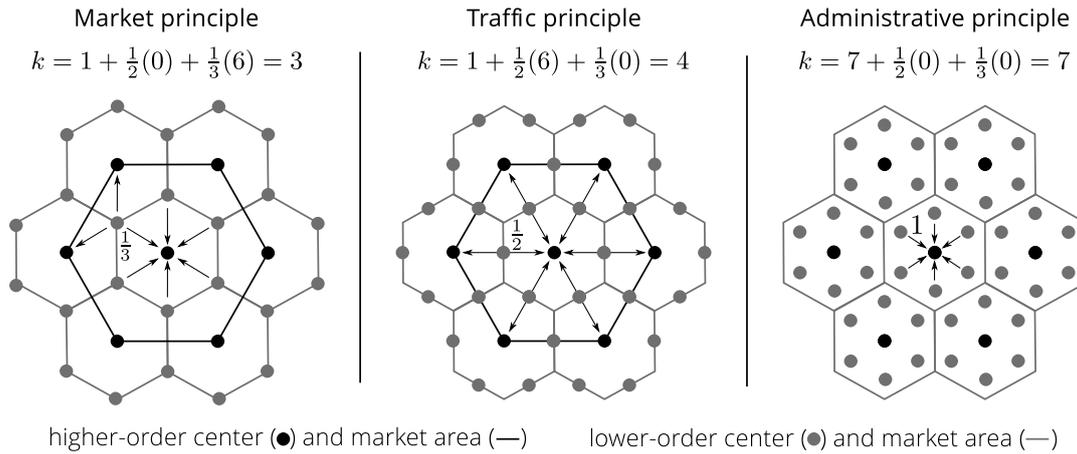
Figure 1.4.: The differences in the kind of goods or services offered by central places produce a hierarchy of places. The number of central places at each level of this hierarchy follows a fixed ratio (Christaller, 1968, 72), illustrated by different k-values (Schätzl, 2003, 79–80). In the basic case, the so-called market principle (left)— where the range of the lowest order central places (M places) was assumed to be between 4 and <6.9 km (Christaller, 1968, 69)—the distances between central places increase by a factor of $\sqrt{3}$ from one level of the hierarchy to the other (Christaller, 1968, 68). There are other k-values that aim to illustrate other forces that distort the general arrangement of central places. These are: the traffic principle ($k = 4$, middle), where as many places as possible are located on a route between two important towns (Christaller, 1968, 79–80); besides there is the separation or administrative principle ($k = 7$, right) where complete districts of equal area and population with the most important place in the center are constructed (Christaller, 1968, 82–83).

(Christaller, 1968, 79–81)

- administration principle ($k = 7$): no competition between centers by including all lower order centers inside the market area of the higher order center (Christaller, 1968, 82–83)

To assess the centrality of a central place and to describe the characteristics of places at different hierarchical levels, Christaller introduced a catalog of central institutions (Christaller, 1968, 139–140). For an empirical assessment of the theory this approach is problematic, since it is difficult to quantify the importance of the different institutions present in a central place. Therefore, Christaller introduced a "(. . .) perplexingly simple and sufficient exact method (. . .)" (Baskin, 1966, 143) that uses the amount of telephone connections as a proxy for the centrality of a place (Christaller, 1968, 146):

$$Z_Z = T_Z - E_Z \frac{T_G}{E_G} \tag{1.1}$$

where Z_Z is the centrality of a central place Z, T_Z is the number of telephone connections in the central place, E_Z is the population of the central place, T_G is the number of telephone connections in the region, and E_G is the region's population. The ratio of T_G and E_G is the expected number of telephone connections for the central place, assuming that the density of telephone connections per person is similar to the region (Christaller, 1968, 146). Using this

empirical method Christaller was able to define more precisely the different levels of the central place hierarchy and to verify his deductively developed theory (King, 1984, 49).

Based on the integration of central place theory and its empirical affirmation, Christaller derived law-like statements of the distribution of cities (Christaller, 1968, 252). The market principle, i.e. the distribution of settlements in a way that seeks a most cost efficient supply, is most common in low-dense settled, agricultural areas (Christaller, 1968, 252). By contrast, the traffic principle, i.e. the distribution of central places along a line from one central place of specific hierarchical level to another, is most common in well crossable areas. Furthermore, orographic obstacles may force the settlement to arrange in a layout that corresponds to this principle (Christaller, 1968, 252). In the latter case, Christaller calls this a *pseudo-traffic principle* because the settlement locations were determined by the natural characteristics and not by the advantages of a traffic oriented layout (Christaller, 1968, 253). The *real* traffic principle is common in rich, densely settled and craft-oriented areas, especially when these are located at the transition between two regions. Furthermore, the traffic principle is common in areas where supra-regional exchange is of prime importance, caused by the presence of a very large city (Christaller, 1968, 253). To detect a distribution that corresponds to the administrative principle is most difficult and might be just possible by historical studies. Only the presence of two lower order central places at the theoretical position of a higher order central place might give hints for the presence of this principle (Christaller, 1968, 254).

Based on the analysis of his study area in southern Germany, Christaller concludes that the market principle is the main law of settlement distribution. The traffic and the administrative principle are just secondary deviations, that are just effective under certain conditions (Christaller, 1968, 254–259). Regarding the principles of settlement distribution (see figure 1.4) studies suggest that neither in contemporary nor in archaeological context one distinct principle is present; it is mostly a complex combination of these three principles (e.g. Bernbeck, 1997, 171).

There are different regional and urban studies, generally in mid 20th century in context of the *quantitative revolution* (see, e.g., Haggett and Chorley, 1969), that corroborate Christaller's theory, e.g., Klöpper (1952), Berry and Garrison (1958), Carol (1960), or Skinner (1964). Furthermore, important enhancements to the theory were made, to overcome some of its limitations and to provide a more advanced analytical framework, e.g., Lösch (1954), Hudson (1969), von Böventer (1969), Parr (1978), Parr (1980), or Arlinghaus (1985). Nevertheless, central place theory and its descriptive value is criticized until today, generally because (selection after Pacione, 2009, 127–128):

- it is not applicable to all kind of settlements;

- it is economically deterministic;

- it oversimplifies human behavior;

- it does not integrate policy decisions;

- it is static;

Furthermore, Crumley (1979) criticizes the pyramidal form of hierarchy in the central place theory, because it is not the manner in which city development begins (Crumley, 1979, 153). Vance (1970) shows that central place theory just holds true for certain special conditions of local to regional scale that are only based on the internal demand for goods (Godfrey, 1999, 585). To explain settlements in terms of external influences, other models—like his mercantile model (Vance, 1978, 140)—are necessary to integrate supra-regional connections (Crumley, 1979, 152). This is mainly due to the fact that cities make a living from the wealth created by their *situation* (Pumain, 2006, 174). Hence, a city always belongs to a network or system of cities (cf. Berry 1964). In this regard Meijers (2007) even argues for a replacement of central place theory with network theory.

With regard to all these points it becomes clear that, to be applicable in archaeological context, central place theory requires abstractions (cf. Bernbeck, 1997, 171). Nakoinz (2009) and Nakoinz (2012c) give a general overview. In contrast to other studies that relate centrality to demographic factors based on Zipf's (1949) rank-size rule and indirect population measures, (e.g. Johnson, 1977; Wilkinson et al., 1994), the *functional* aspect of central places is in focus here. This can be referred to Christaller's definition of central places that are at first not settlements but spatial manifestations of central functions (Christaller, 1968, 25). In general, central places are agglomerations or clusters of institutions and functions that supply their market areas (Blotevogel, 2005, 1307). To assess functional aspects of central places in historical and archaeological context, Christaller's catalog of central institutions had to be simplified to correspond to the smaller and less reliable database. For historical epochs this was done by Denecke (1972). He classifies the functions and institutions that are able to define central places in historical context into ten categories (Denecke, 1972, 43):

- political and administrative functions and institutions

- institutions of law

- institutions of security

- cultic and spiritual institutions

- cultural institutions

- institutions of charity

- institutions of agricultural economy and administration

- institutions of craft

- institutions of trade

- institutions of traffic and transport

An assessment of the central functions within an area necessitates the collection of the central functions of all settlements within this area (Denecke, 1972, 43). Concerning earlier epochs Denecke (1972, 51) states that not all of these functions can be derived from archaeological sources and others are not or only indirectly accessible. Therefore, Gringmuth-Dallmer (1996, 8) further simplifies the concept of central functions. He defines five central functions characterizing central places from prehistory until Middle Ages:

- administration

- security

- craft and industry

- trade

- cult

The more of these functions are present at a site, the more complex it is. Hence, central functions are still able to reconstruct settlement hierarchies—presupposing that the settlement sample is complete (Gringmuth-Dallmer, 2011, 431).

Central functions are a tool to measure centrality. The abstraction of Christaller's and Denecke's central functions by Gringmuth-Dallmer (1996) allows the application in archaeological context. Nevertheless, these functions were not linked to Christaller's central place theory. This is done by Nakoinz (2012c) and throughout the different case studies of this thesis. In this regard, central place theory can be understood as a theory aiming to explain the spatial organization of interaction. Therefore, Nakoinz's definition focuses on interactions (after Nakoinz, 2012c, 219): *Centrality is the relative concentration of interaction*

This definition generalizes Christaller's term and allows to treat all kinds of human actions—spatial as well as non-spatial, economical as well as non-economical, etc. Furthermore, with regard to the critiques of Crumley (e.g. 1979), it integrates poly-centric and poly-hierarchic structures of settlements (Nakoinz, 2012c, 219–221). Throughout the different case studies of this thesis, centrality will be treated as relative concentration of interaction.

1.6. Gateways

Central place theory describes processes of the local dimension of a settlement's external relations (Taylor et al., 2010, 2811). To cover also the regional and supra-regional relations—i.e. to allow an explanation of the chorological characteristics of the investigated central places—the concept of gateway cities is considered. Gateways are already important in prehistoric times (Nakoinz, 2013; Hirth, 1978). A famous example are the Fürstensitze in Southern Germany (Nakoinz, 2013, 224).

The term *gateway city* was introduced in the context of the colonization of Northern America. Gateway cities developed at the margin of a production region. They function as collectors of basic products from the surrounding settlements and as distribution centres for manufactured goods that were produced outside of its territory. On the basis of railway transportation these gateway centers maintained contact with a tributary territory where hierarchical organized villages, towns, and cities developed (McKenzie, 1967, 4).

As in the case of Gradmann's function of a city (Gradmann, 1916, 427) gateways control and facilitate the connection between their tributary area and the outside world (Burghardt, 1971, 269); they function as focal points in the integration of their surrounding region into larger economic networks (McKenzie, 1967, 4). In general, gateway cites develop at (selection after Burghardt, 1971, 270 and Hirth, 1978, 37):

- the intersection between zones of differing types of production, along economic shear lines

- along natural communication corridors

- at critical passages between areas of high productivity (of mining, agriculture or craft) or dense population

- at locations where there is a high demand for scarce resources

- at the interface of different technological and socio-political complexity

Hence, gateway cities develop at locations that possess the potential of controlling fluxes of goods and/or people. At least in their initial stage gateway cities enjoy transportational advantages over potential competing cities (Burghardt, 1971, 282). "Gateway cities 'set up' the countryside; *and then*, the countryside 'set up' the central places" (Burghardt, 1971, 285, italics and quotation marks in the original).

The gateways' tendency to be located between different homogeneous regions, contrasts from central places that are located within an homogeneous production region and have generally local trading connections. Following this observation, gateway cities are characterized best by long-distance (trade) connections (Burghardt, 1971, 270; Nakoinz, 2013).

There are further differences to central places: While a central place is located in the centre, towards the locations of its tributary area, the gateway is located at one edge of its tributary

area (Burghardt, 1971, 269–270). Accordingly, the service areas are differently shaped. While the central place has a compact, circular, hexagonal or squared service area, the gateway city's service area is elongated and fanshaped (Burghardt, 1971, 270). "In more pictorial language one may envisage the central place as the center of a bowl, the gateway as a funnel or spout" (Burghardt, 1971, 270).

There are dynamic and static gateway cities. The former will develop along a moving frontier of settlements. The latter will develop on, or close to the boundary between regions of differing types of production (Burghardt, 1971, 272). In the dynamic case the importance of the gateway may change in correspondence with the competition and productiveness of the surrounding area, leading to the development of a central place of different level (Burghardt, 1971, 272–273). By contrast, in the static case the gateway will remain dominant. Changes in the economy, like decline or ascend will change the sphere of influence of the gateway (Burghardt, 1971, 273).

CHAPTER 2

Central place and hinterland

2.1. Introduction

Humans are—in one way or another—connected to their environment, e.g. due to different local conditions for subsistence and supply (see chapter 1.4). Therefore, also human interactions are influenced by the environment, because of its heterogeneous character that influences human actions. Archaeologically interactions are indirectly detectable e.g., by remains of exchanged goods, showing concentrated interactions and preferred routes of exchange. When the interactions are influenced by the natural environment than this may be true for the concentration of interaction as well. Hence, it can be hypothesized that central places are influenced by the conditions of the natural environment as it is used by humans.

The following case study investigates, whether this line of argumentation holds true or not. It focuses on the question, whether environmental characteristics influence the development of a central place or not. With regard to the interdependent character of spatial data (see chapter 1.2) this investigation is conducted on different spatial scales, throughout time.

2.2. Paper 1: The centrality of Aleppo and its environs

2.2.1. Abstract

This study analyses the relationship between Aleppo and settlements in the city's hinterland based on spatial statistics. Based on a theoretical extension of the term central place Aleppo's central character can be reconstructed. In this regard the city served as a local centre for trade, exchange, and cult. In a regional and supra-regional context advantages concerning the topographic location lead to different functions of trade, exchange, and craft. It is shown that

compared to other important cities in the Middle East the combination of different spatial scaled central functions fostered lasting importance of the city.

Keywords

central place; central functions; spatial scales; environmental determinsm; Middle East

2.2.2. Introduction

This study investigates the centrality of the city of Aleppo context of its environs. Recent investigations of the research group Central Places and Their Environment of the Excellence Cluster Topoi showed the need for an integrated, diachronic determination of a site's social, cultural and natural circumstances (Schütt and Meyer, 2011, 24–25). Thus, questions concerning centrality may not only focus on the interaction within or between cultures but also on the interaction between nature and culture.

In the 19th century, Kohl (1841) published a book concerning the location of settlements in dependence of the character of the earth's surface. The teleological character of Ritter's geography saw the unity of human and nature (Ritter, 1852). Marsh (1867) showed the destroying influence of man on the environment. Ratzel (1891) states the allegation that not just the specific human decision but also the natural environment leads to the heterogeneous pattern of human concentration on earth. Many other authors wrote thereafter on this topic covering questions concerning the dependency of cultural development from nature (e.g. Semple, 1911; Huntington, 1915). But the approaches of this natural deterministic school of thought were too general and simplistic to gain insights into the dynamic relationship of human and environment. Nevertheless, these studies try to identify the unity of human and nature and their complex interaction.[1] In the Excellence Cluster Topoi, researchers from geography and archaeology work together on different case studies to receive new insights into these questions on a site specific level. It is the aim of this paper to show first steps towards a theoretical framework that is able to synthesize these different case studies. To build a base for these first steps the centrality of a place with aspects of the local and regional human-environmental relationship. In contrast to the often mentioned assumptions of homogeneity (Heinritz, 1979, 23) in Walter Christaller's central place theory of 1968, the particularity of a location, in context of the natural and socio-economic environment is focussed. According to this, centrality is understood as relative concentration of interaction. The theoretical considerations are applied exemplarily to Aleppo and its environs in north-west Syria.

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[1]The mentioning of simple environmental determinism shall not disregard the other schools of thought, like possibilism, cultural relativism, the landscape school, cultural perception and the ecological approach (for further information see, e.g. Jeans, 1974 or Norton, 2000). The general character of all these approaches is important for the present study since their objective is always the relationship of human and environment. The wealth of approaches shows the complexity of this connection.

Centrality is the relative concentration of interaction. The places involved in an interaction are interaction nodes. A central place is a location of high density of interaction nodes (Nakoinz, 2012b, 218–221).

In this study centrality is assessed by a concept of different central functions and facilities, such as trade, justice or culture, first published by Denecke (1972). Denecke defines ten functions that can be ranked in context of their importance (Denecke, 1972, 46). This concept focusses on historical epochs, demanding different kinds of direct and indirect sources. In order to support also epochs with little cultural or human remains, Gringmuth-Dallmer generalizes this model by decreasing the number of central functions from ten to five (For an overview of the development of the central place concept in archaeology see e.g. Nakoinz, 2009). From prehistory to the Middle Ages these functions are reign, protection, trade, resources exploitation and craft, as well as cult (Gringmuth-Dallmer, 1996, 8). The more functions a location provides, the higher its complexity. The resulting hierarchy of this classification consists of four stages of centrality (after Gringmuth-Dallmer, 1996):

- the lowest rank are the autarchic, agricultural settlements

- the next rank comprises of craft and commerce settlements that produce seasonal goods and depend mostly on the supply by their surroundings

- the third rank consists of settlements that create a dependency of the surrounding settlements due to the offering of at least one central function, i.e. a function with a regional meaning or importance, such as reign or cult

- the highest rank equals complex centres that offer all or nearly all central functions, leading to the highest importance in the wider surrounding or region

The investigation of interaction is related to the different scales of the sphere of influence. As the parallel space concept of Nakoinz (2012a) shows, the socio-economic and environmental dynamics are different regarding to scale. Accordingly, an investigation of the location's centrality needs to use different spatial and temporal scales.

The case study focusses on Aleppo, its development through time and related to this its central functions on different spatial scales. Aleppo is one of the oldest cities known, occupied at least since the Early Bronze Age, around 2500 BC (Klengel, 1992; Del Fabbro, 2011; Two sites outside of the medieval city but within modern Aleppo date back to the Neolithic and Chalcolithic periods: 'Ain at-Tall and Tall as-Sawdā' (see Gonnella et al., 2005, 11; For a detailed description regarding the early history and further sources see Del Fabbro, 2011). Since the foundation of the city there were many pronounced changes of the political, religious, and socio-economic circumstances (Del Fabbro, 2011; Klengel, 1992; Wirth, 1971, 1966). Despite these changes Aleppo never vanished, as other important sites like Ebla (modern Tell Mardikh), Chalkis (modern Qinnasrin), and Antioch (modern Antakya) did. As it is shown in the following,
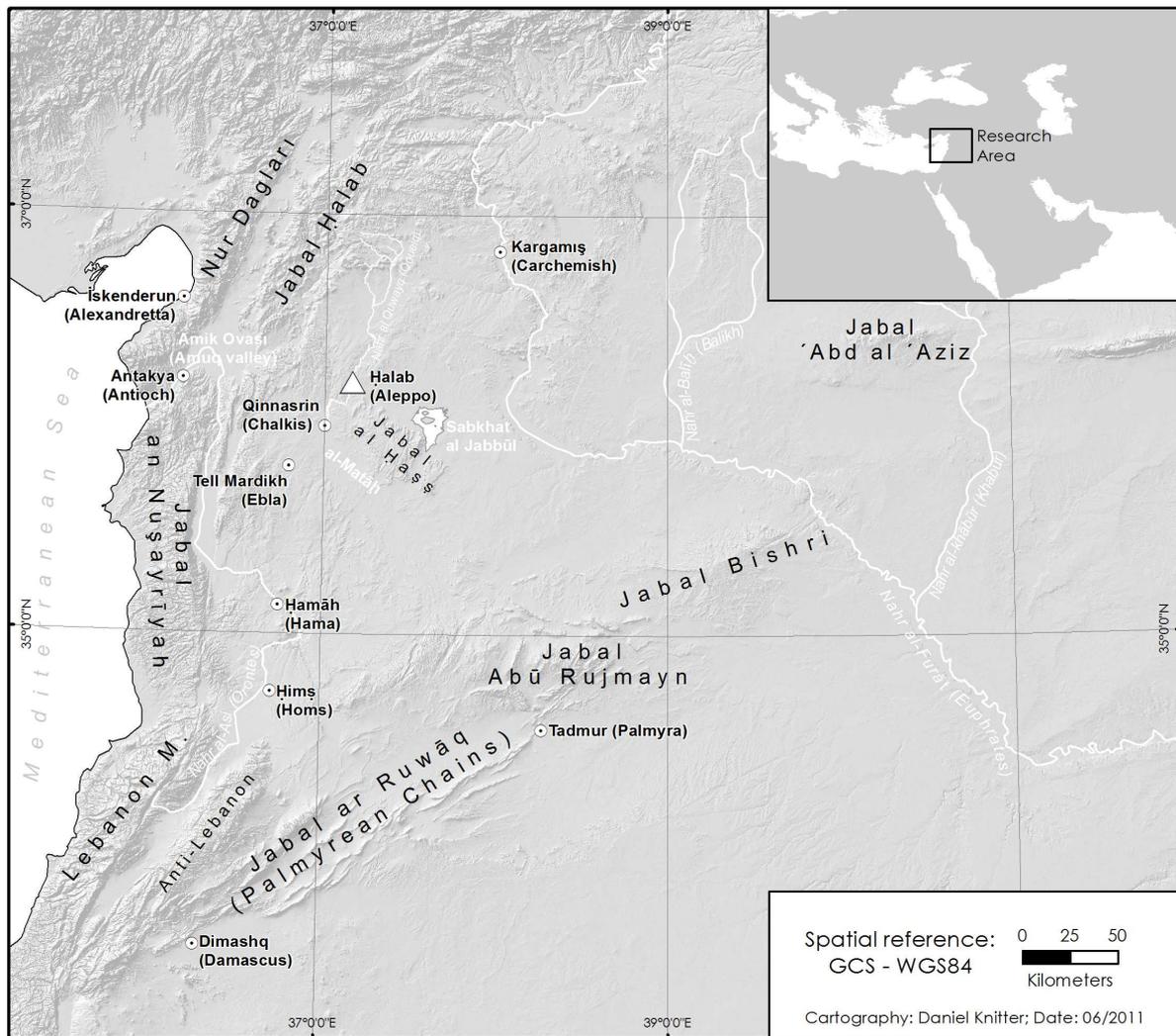
Figure 2.1.: Topography of the research area with important sites

this remarkable continuity can be evaluated as a result of a complex relationship between the natural and socio-economic circumstances.

2.2.3. Study site

The research area is located in modern day Syria between the Euphrates in the east and the coastal mountain range in the west. It is a slightly rolling sedimentary plain, intercalated by mesas of carbonaceous rocks and tectonic domes composed of magmatic rocks (Wirth, 1971, 378; figure 2.1).

Climate of Aleppo and its northern and western environs is warm-temperate with a dry and hot summer. It corresponds to a Csa climate (after Köppen-Geiger's classification) with an annual mean temperature of 17.3 °C and an annual mean precipitation of 340,8 mm at
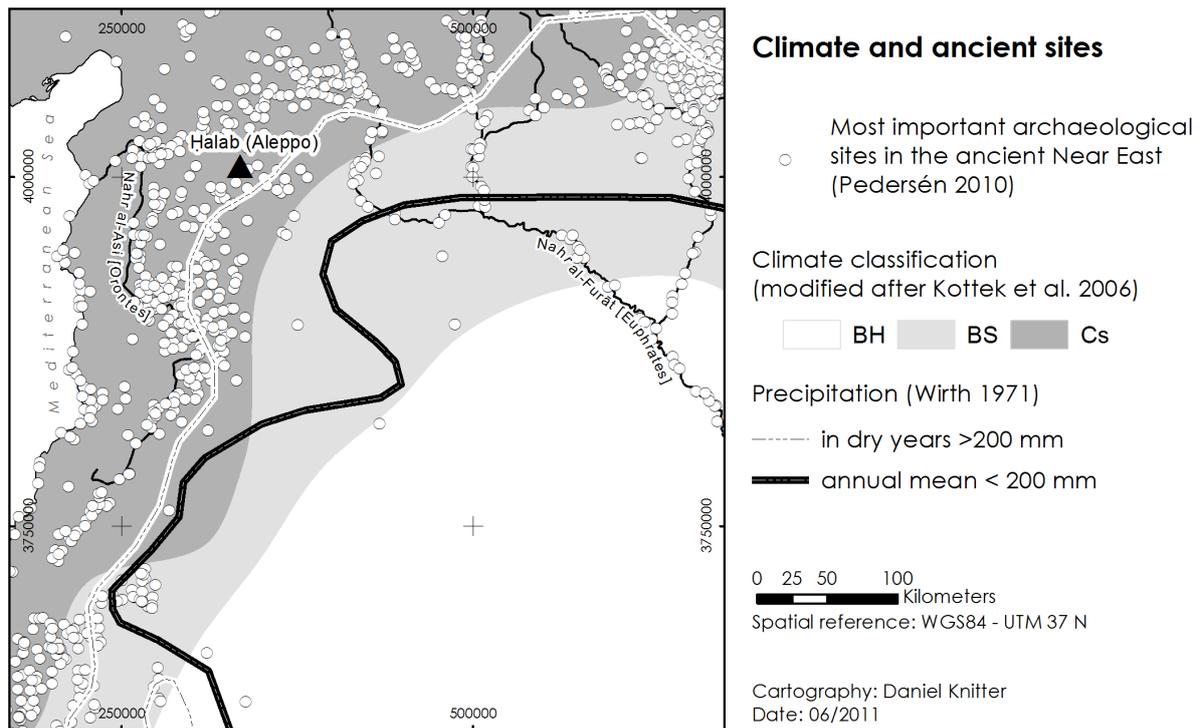
Figure 2.2.: Climatic characteristics and thresholds of precipitation in the research area; note the climate related regional settlement pattern of the dataset compiled by Pedersén, 2010

Aleppo (Rösner, 1995, 25). To the east and south a narrow, undulating band of an arid steppe climate (BSh climate after Köppen-Geiger classification) occurs that is continued by a hot, arid desert climate (BWh climate after Köppen-Geiger classification) (Kottek et al., 2006). The agriculturally important 200 mm precipitation isohyet crosses the study area during dry years in the south and west, leading to problems in rainfed agriculture (Wirth, 1971, figure 2.2).

Due to the geology and corresponding relief character there are no navigable streams connecting the west and the east (Ruppin, 1920, 7–8). The only perennial stream of the research area is the Nahr al-Quwayq (Qoueiq). From its sources in the mountains north of Aleppo, it crosses the city and drains into the steppe-swamp of al-Matāḫ. Besides precipitation and the Qoueiq as water resources, the groundwater resources are very important for the regional water supply. Well exploitable groundwater with low salt content is only present around the Nahr al-Quwayq as well as in the eastern and western environs of Aleppo (Wolfart, 1966, 11–15; Wolfart, 1967, 247).

The soils of the study area correspond to clayey, rich to medium deep developed, calcareous Grumusols (Vertic Inceptisols; Rösner, 1995, 23) with a thick dark-red to dark-brown humic horizon (Strebel, 1967, 273). These are the most fertile soils of present day Syria covering the environs of Ḥimṣ (Homs) and Ḥamāh, (Hama) as well as the plains around Aleppo (van Liere, 1963, 116; Wirth, 1971, 171).
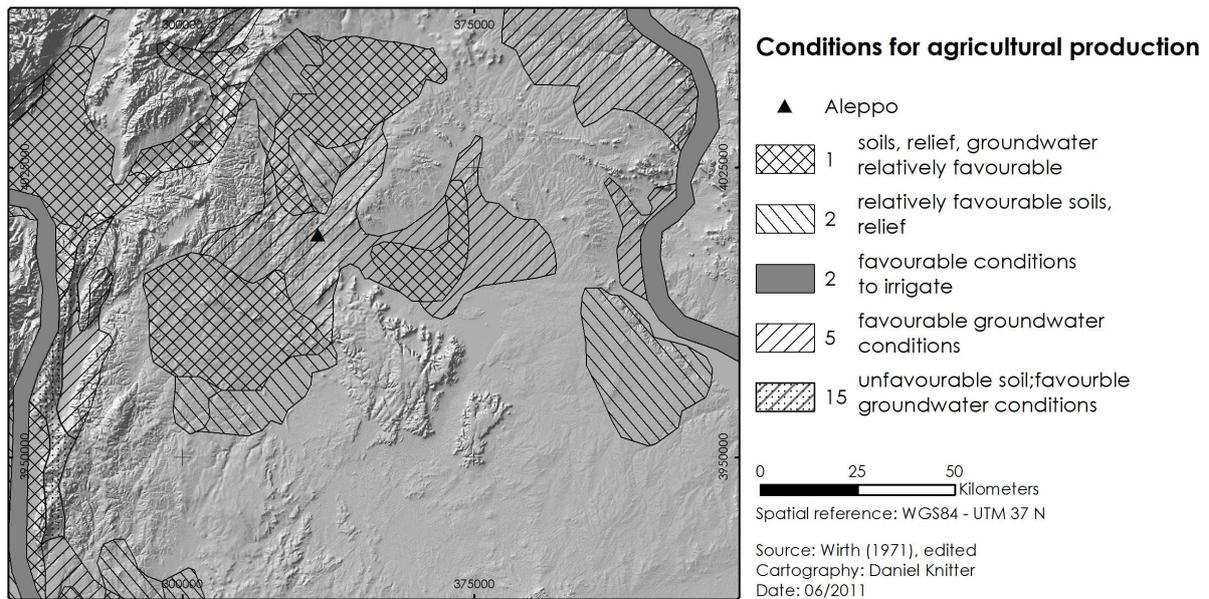
Figure 2.3.: Areas of suitable conditions for agricultural production. They are based on the combination of the factors soil type, relief, groundwater and irrigation capabilities (edited after Wirth, 1971)

Based on climate, relief, groundwater resources, and soil type the general suitability for agricultural production can be assessed (Wirth, 1971, 116). According to this, only the direct environs of the rivers Nahr al-Furāt (Euphrates) and Nahr al-Asi (Orontes), the Amik Ovası (Amuq valley) as well as the plains and lowlands around Aleppo are highly favourable areas for agriculture (figure 2.3).

2.2.4. Methods

The investigation of location's centrality needs integrate information about its complementary region (Christaller, 1968, 27; Carr, 1993, 40). Accordingly, besides the city of Aleppo, 293 settlement locations documented by tells from different prehistoric and historic epochs are integrated into this study (figure 2.4).

To identify potential patterns in the spatial distribution of the tells objectively, spatial statistics are applied. The method used in this study is the point process statistic. It aims to describe the short-range interaction among points that explain their common location (Illian et al., 2008, 3). To achieve this, tests of Complete Spatial Randomness (CSR) are applied. In the case of CSR, the points are randomly distributed and independent throughout the research area (Bivand et al., 2008, 160). There is a large and still growing amount of tests of the CSR hypothesis. Each test is only capable of assessing particular aspects of the CSR behaviour. Accordingly, it is not possible to derive the best performing test only based on a single criterion (Illian et al., 2008, 83). Therefore, the present analysis uses different standard test approaches to identify the structure inherent in the data. With regard to Illian et al.
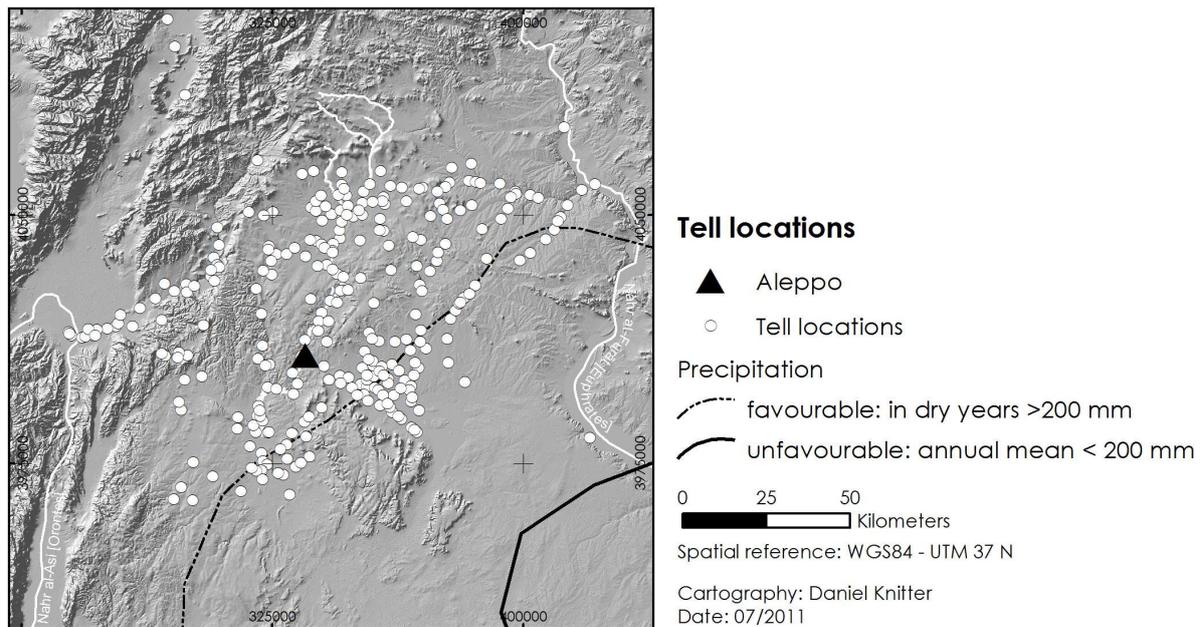
Figure 2.4.: Settlement locations as documented by tells around Aleppo (data kindly provided by Roswitha del Fabbro and the Topoi Project A-I-6; for further information see Del Fabbro, 2011)

(2008) a final rejection of the CSR hypothesis is possible if any of the standard tests reject the CSR hypothesis. The first utilized approach is the G-function, based on the nearest neighbour distances (figure 2.5a). It compares the cumulative frequency distribution of the empirical nearest neighbour distances with the measures of the distribution of the distances from an arbitrary point to its nearest neighbour (Bivand et al., 2008, 162). The second approach, the F-function (figure 2.5b), measures the distribution of all distances from an arbitrary non-point of the research area to its nearest neighbour. This function is occasionally called empty space function because it is a measure of the average space left between points (Bivand et al., 2008, 162–163). In order to perform the F-function and to avoid arbitrary empty space, the research area is defined by a convex hull surrounding all sites (Schabenberger and Gotway, 2005, 89). While G- and F-functions are based on the nearest neighbour for each event, the third test approach, the K-function (figure 2.5c), uses distances between all events in the study area (Lloyd, 2011, 251). It takes a range of distances within the area and compares the calculated number of points within the range with that of the observed number of points (Crawley, 2007, 754).

These methods describe the general distribution of the ancient settlements as documented by the tells. To receive information concerning the spatial density, hence the spatial distribution of tells, a simple Gaussian kernel density estimation (KDE) is conducted. A KDE calculates a two-dimensional kernel estimate of the intensity function (Duller, 2008, 278–285). Accordingly, a continuous surface is produced that allows to distinguish high and low density areas of tell
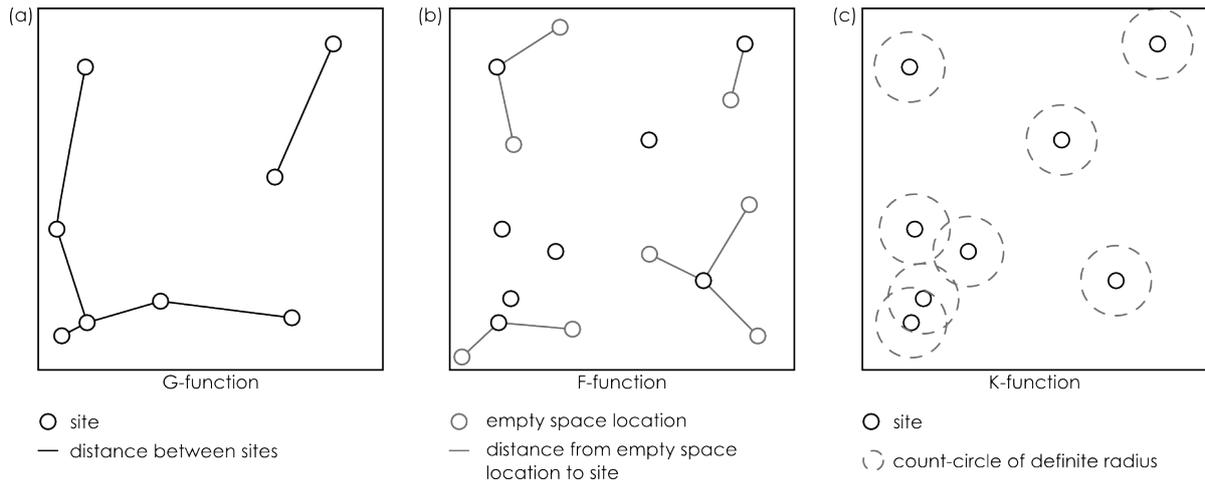
Figure 2.5.: Sketches of the different CSR test principles

locations (Bivand et al., 2008, 165–169). Methods to calculate the bandwidth can be found in Duller (2008, 287–289), though there is no general rule for the selection of the optimal value of the bandwidth. "It seems reasonable to use several values depending on the process under consideration, and choose a value that seems plausible" (Bivand et al., 2008, 166). In this regard, the kernel bandwidth is chosen based on expert knowledge, using two times the mean nearest neighbour distance.

2.2.5. Results

The general characteristics of the nearest neighbour distances show that besides a scattering of the data, the majority of tells is less than four kilometres apart from its nearest neighbour (figure 2.6).

Min.	392.2 m
1st Qu.	1506.0 m
Median	2341.0 m
Mean	2908.0 m
3rd Qu.	3472.0 m
Max.	40970.0 m
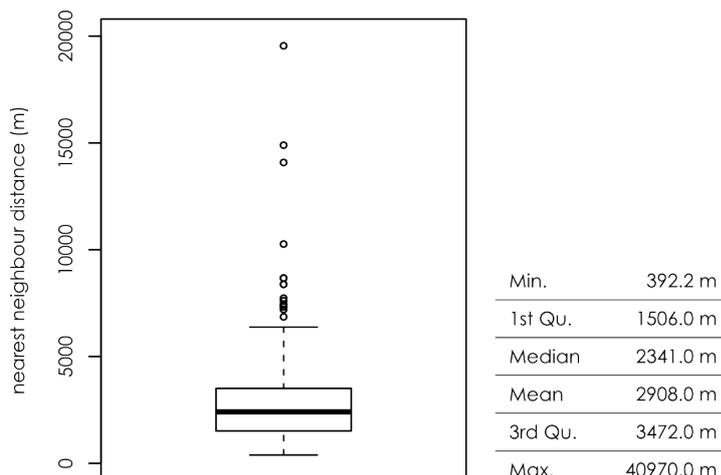
Figure 2.6: Descriptive statistics of the nearest neighbour distance calculation. The data is concentrated between 1.5 and 3.5 km (1st and 3rd quartile). Due to outliers (see max. distance of 40 km; omitted in boxplot) the data is skewed to the right, weakening the mean. Hence, the median is taken into account as well.

The tests for CSR document that the tells are not randomly distributed (figure 2.7a–c). The cumulative empirical nearest neighbour distances are larger than the theoretical ones. Thus,
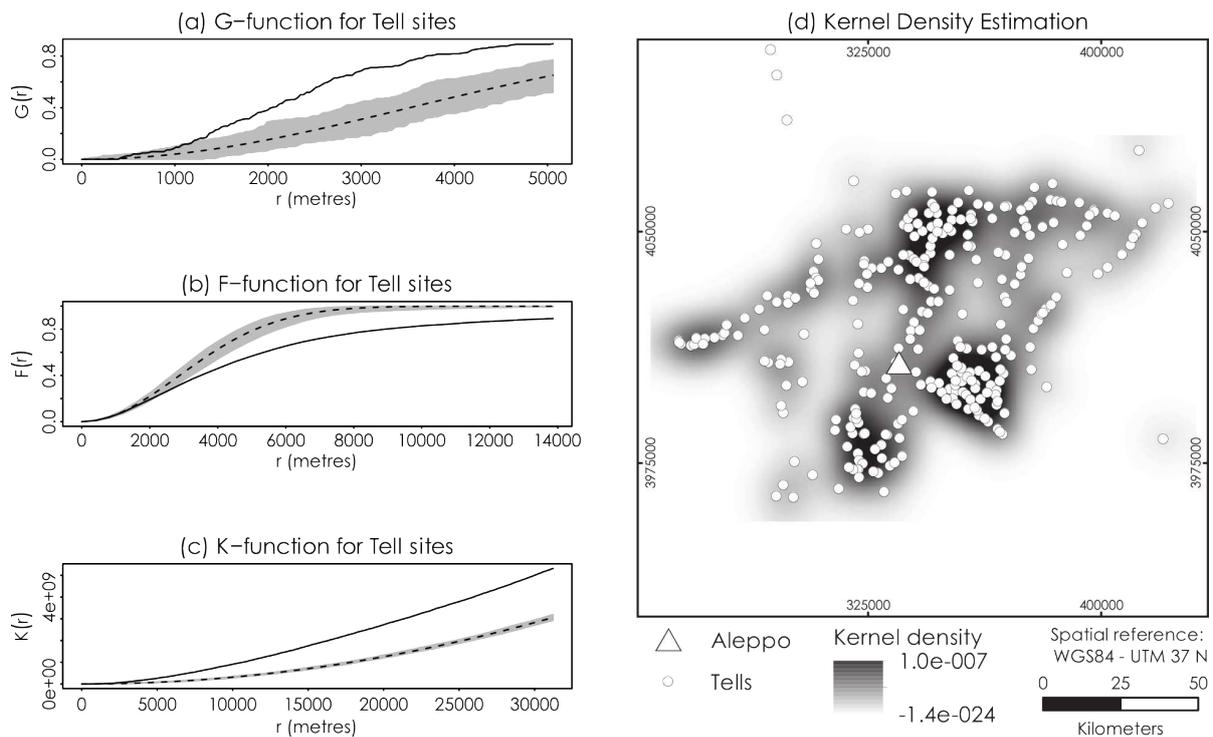
Figure 2.7.: Results of the CSR test (a-c); the solid lines represent the cumulative empirical distribution, while the dotted lines correspond to the theoretical. The grey area around the dotted graphs shows the uncertainty based on Monte Carlo experiments. For the G- and F-function 999 experiments and for the K-function 99 experiments were conducted. (d) shows the result of the KDE.

the distances to the nearest events are smaller than under random conditions (figure 2.7a). The F-function results in larger theoretical than empirical distances. The empirical curve shows less short distant nearest neighbours in contrast to the theoretical curve, hence the distances are larger than expected (figure 2.7b). The K-function results in tells at smaller distances than expected (figure 2.7c). All test approaches rejected the CSR-hypotheses. Besides this, the resulting graphs let assume a clustered distribution of the tells.

The KDE revealed high density areas of tells north, south-west, and east of Aleppo. The city itself is not in an area of high settling activity (figure 2.7d).

The intersection of the most favourable areas for agricultural purposes and the tell locations show a strong relationship (figure 2.8a). The majority of the tells (figure 2.8c) and nearly the whole area of the tells' high density clusters (figure 2.8d) focus on areas of the most favourable agricultural conditions.

2.2.6. Discussion

The nearest neighbour distances of the utilized tells are comparable to those of settlements with a subsistence agricultural economy (Chisholm, 2007, 125). Chisholm (2007, 148) points out that in subsistence economies, independently from the region, the location from the cultivated

Conditions for agricultural production

▲ Aleppo
○ Tell locations
⌒ High density cluster
⋮⋮ Favourable areas for agriculture

0   25   50
━━━━━━━━━━━━━ Kilometers
Spatial reference: WGS84 - UTM 37 N
Source: Wirth (1971), edited
Cartography: Daniel Knitter
Date: 07/2011

Relative frequencies of different favourable areas for agriculture production (categories see caption)

(b) Study area   (c) Tells   (d) Cluster

Figure 2.8.: Comparison of the areas of the most favourable conditions for agricultural production, tell locations, and high density tell clusters (a). The relative frequency of the different categories shows a strong concentration of class 1 at tell locations and within tell clusters. Category numbers correspond to (see also figure 2.3): 1 – soil, relief and groundwater are relatively favourable; 2 – soil and relief are relatively favourable; 5 – groundwater is relatively favourable; 15 – unfavourable soil and favourable groundwater conditions (based on Wirth, 1971)

land is less than two kilometres away from the farmstead (These empirical results confirm to the theoretical model of Chisholm (2007) that defines the location of a settlement in relation to its local resources (water, arable land, grazing land, fuel, building material) based on the cost-distance relationships investigated by Thünen (1910). Hence, by assigning different weights to elementary resources, the settlement's location can be explained – though this holds true only for a simple environmental deterministic viewpoint). Accordingly, settlements reliant on subsistence agriculture should be located in distances of two to four kilometres apart to each other. This holds true for the nearest neighbour distances of the examined tells. Thus, the tells around Aleppo correspond to rural, subsistence based settlements. The research of Wilkinson et al. (1994) on Bronze Age tells in Upper Mesopotamia corroborates this observation (Wilkinson et al., 1994, 492).

The tendency of the tell locations to be located in areas of most favourable agricultural conditions underline the general character of a subsistence based economy at least during the Bronze Age throughout the research area. For further interpretations a temporal, spatial, or even functional separation of the tell dataset is required.

Aleppo is neither part of the high density tell clusters nor is it located on most favourable soils: it is not integrated in the local networks of tells according to natural favourable positions. However, Aleppo is located in the centre between the different clusters of tells. For Gradmann (1916) central location is the main function and profession of a city, connecting the local traffic of its rural hinterland with the outside world (Gradmann, 1916, 427). In this regard Aleppo offers the central functions trade and craft to the rural settlement of its hinterland (Ruppin, 1920, 28; David, 2008, 329).

The advantage of this central position is also illustrated by the fact that the centre of worshipping the storm god (First venerated as Hadda, later as Addu, Teššub, Tarhunta, and Hadad, see Schwemer, 2001; Schwemer, 2008; Kohlmeyer, 2000; Kohlmeyer, 2009) was located in Aleppo. The need of sufficient precipitation for rainfed agriculture in an area of high variability of annual precipitation forms the basis of the cult (Klengel, 1965, 92). With respect to the subsistence based economy throughout the hinterland of Aleppo, the storm god's blessing was important for living and survival in the people's faith. Accordingly, Aleppo offers the central function cult, due to its location between the different tell clusters of the subsistence based hinterland. Furthermore, administrative functions seem to be important since the Bronze Age according to van Liere's statement that Aleppo was not a major centre of population, but one of the most important citadels of the region (van Liere, 1963, 116).

There seems to be a strong connection of the settlement structure of Aleppo and its hinterland to Christaller's central place concept because a central place serves as a supply centre for its complementary region (Beavon, 1977, 18; Christaller, 1968, 63; Heinritz, 1979, 26–28). However, Christaller defined centrality not in context of settlement clusters and centred city. The results show no centralization of the tells onto Aleppo. Therefore, Aleppo does not show a centrality

as defined by Christaller but a network centrality. Nevertheless extending the definition of centrality it is possible to assess the advantages of Aleppo's central position. In this regard the city is similar to an interaction node, whose degree of interaction is assessed by the identified central functions.

2.2.7. Synthesis – The centrality of Aleppo

During the Bronze Age Aleppo was the centre of cult, local trade and administrative functions for a subsistence based hinterland. Politically, the city was important only during the Middle Bronze Age as capital of the kingdom of Yamhad (Klengel, 1992, 52, 197 197; Kohlmeyer, 2000, 5–10; The question of the relation between Aleppo and Ebla (modern Tell Mardikh) with its important remains of the Middle Bronze II period has still to be solved). After this period it lost its political significance until the Hellenistic era but was still important as cult centre (Klengel, 1992, 197; Bryce, 2009, 28). Besides this, there are no remarkable amounts of exploitable resources in the environs of Aleppo (Gypsum is present in the El Bab (north-east of Aleppo) and the Jabboul basin. Large amounts of evaporative salt are present at the Sabkha Jabboul (Wolfart, 1967, 253–254). Today, a larger source of limonitic iron in the Kurd-Dagh mountains is known that contains approximately 12–16 million tons of iron (Wolfart, 1967, 249–250). Therefore, the continuing importance of the city in the regional and supra-regional context must be regarded to an advantage of the spatial location.

The advantageous position of Aleppo on a local scale between fertile agricultural plains was already described. In a more regional perspective the climatic forced environmental differences became important. Due to the lack of perennial streams and decent groundwater, the 200 mm precipitation isohyet is not just a physical but also a cultural boundary, marking the fringe between areas where rainfed agriculture is possible and where agriculture is only possible by irrigation. In areas where the precipitation is sufficient for rainfed agriculture, even in dry years resident farmers dominate. In the intermediate zone, where the variability of rainfall leads to frequent crop failures, they are mixed with semi-nomads and nomads. The sphere of influence or, as it is stated by Sachau (1883, 112), the realm of the nomads (Bedouin) begins south of Jabal al Ḥaṣṣ (Djebel Elḥaṣṣ in Sachau, 1883, 112; Jebel Hass in Wirth, 1971, 390), where rainfed agriculture is mostly impracticable. Aleppo benefits from this location at a cultural frontier. North and west of the city cotton, wheat, almonds, watermelons, figs and wine are cultivated. South and east of the city over large areas that extend until the Euphrates, wheat, barley, and millet are cultivated. Aleppo is the most important marketplace for the exchange of goods from these different areas of cultivation (Wirth, 1966, 106–108). This exchange also facilitated the establishment of a local craft industry (Wirth, 1971, 389). Thus, on regional scale Aleppo offers the central functions craft and trade as well. The city has a gateway function (Nakoinz, 2012a) that connects different cultural spaces and lead to its importance. This is based on the strong relationship between the environmental conditions and the different human

adaptations to it (Nevertheless, changes in the location of the frontier between nomads and farmers since the last six thousand years correspond to socio-economic changes and are not naturally determined; see Rösner, 1995, 52).

Focussing on a supra-regional scale, Aleppo's geographical location is excellent (Banse, 1919, 331; Wirth, 1966, 105)[2]. It is well located at the intersection of transcontinental trading routes between Europe, Asia, and Africa since these emerge (Sherrat, 2010). Aleppo's location at the point of contact between the maritime traffic towards Europe in the West and the caravan land commerce towards the East is especially important (Raymond, 2008, 736) because the shortest caravan route from the Mediterranean to Mesopotamia crossed the city, underlining its function as a trade centre (Beek, 1962). This favourable location, connecting the trade of Mediterranean Sea and Mesopotamia is for Banse (1919, 326) the reason for the development of Aleppo as the greatest commercial centre of the southern Middle East. Raymond (2008) verifies this evaluation. For him, the dimension and number of city's khans (also known as caravanserais; supported the flow of commerce, information, and people across trade routes) reflect the scope, importance and its role as a commercial centre. From cities of the Ottoman period, the most monumental and most finely decorated khans are those found in Aleppo (Raymond, 2008, 738). Furthermore, their number exceeds those of the most prominent cities of that time and is just topped by Cairo (Raymond, 2008, 739)[3]. On this large-scale it is not only Aleppo having a supra-regional importance. The most prominent example is Antioch (modern Antakya), the metropolis during Hellenistic and Roman periods (figure 2.2). During that time Aleppo prospered (Gaube and Wirth, 1994, 76; Bryce, 2009, 28) but was, as mentioned by Strabo, just a small city east of the metropolis Antioch: "To the east of Antioch are the Euphrates, Bambyce, Berœa, and Heracleia, small towns formerly under the government of Dionysius, the son of Heracleon" (see Hamilton and Falconer, 1857, 3: 163). The importance of Antioch relied on the Roman world economy and supra-regional trade (Yener et al., 2000, 192). Due to its location outside the Amik Ovası (figure 2.2), it has no local subsistence base. The foundation of Antioch, south-west of the Amik Ovası was not at random. Since the Neolithic there was a shift of major settlements first southwards and in the end entirely out of the plain of the Amik Ovası onto nodal points in the route network (Yener et al., 2000, 191; The most important routes cross the plain of the Amik Ovası in the south, connecting the Mediterranean in the west with Aleppo in the east as well as the Orontes in the south; see Yener et al., 2000, 189, 191). This suggests an increasing value of trade and exchange in the development of important settlements. With respect to the above mentioned, Antioch lost important central functions in context of the local and regional scale. Due to earthquakes (Sbeinati et al., 2009, 355–359),

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[2]„Die geographische Lage (. . .) ist für einen Handels- und Verkehrsknotenpunkt schlechthin hervorragend; das gilt sowohl für die Lagegunst innerhalb der Region Nordsyrien als auch für die im Rahmen der Großregion Vorderasien, und schließlich nicht zuletzt für die Lage zwischen den großen Kontinenten und Kulturerdteilen der Alten Welt" (Gaube and Wirth, 1994, 10)

[3]Number of khans in cities of the Ottoman period; sorted in ascending order (after Raymond, 2008, 739): Algiers (34), Mosul (35), Baghdad (44), Damascus (57), Aleppo (around 100), Cairo (360)

wars (Holmes, 1988; Greatrex and Lieu, 2005), and the demise of the antique world Antioch lost and never regained its former importance. Aleppo experienced the same catastrophes but resisted. Thus, while Antioch vanished, Aleppo flourished because it could benefit from its locational advantages on the local, regional, and supra-regional scale.

2.2.8. Conclusion and outlook

The case study of Aleppo's location shows the strength of an interaction based approach of centrality. The determination and integration of different spatial and temporal scales allows the description and separation of the important natural and social parameters. On this base parameters are assessed that produced or destructed the importance of a city. It is a holistic approach that benefits from archaeological, geoarchaeological, and geographical research concerning the relationship of human and environment. Based on the interaction definition of centrality it is possible to synthesize the specific results of different case studies and to combine them on the meta-layer of centrality. Further research regarding interaction in other case studies throughout the Mediterranean and Near East as well as in Europe will give new important insights to the old question of the relationship between human and environment at different epochs in time.

2.2.9. Acknowledgements

CHAPTER 3

Central place and time

3.1. Introduction

The environmental characteristics of a settlement's location influence its centrality on different spatial scales (Knitter et al., in press; see chapter 2.2): (a) locally due to the suitability of subsistence purposes, (b) regionally due to the connection of different cultural spheres, and (c) supra-regionally due to the integration in small-scaled exchange networks. Changes of the centrality throughout time are present but cannot be related to a change in the characteristics of the city's environs—as it got obvious in Aleppo's decline in centrality during the heyday of Antioch. This is important, since it points to a more complex interaction between the location's ability to concentrate interactions and its level of centrality at different points in time.

To investigate this features in more detail, another case study was conducted. In this study, the development of centrality throughout time was investigated at two sites, whose environmental characteristics are similar. Hence, differences in the centrality may be related to societal or non-natural factors. Furthermore, the method to assess centrality using central functions was advanced due to a systematic collection of central functions at different spatial scales to allow an objective comparison of the selected locations.

3.2. Paper 2: Integrated centrality analysis: A diachronic comparison of selected Western Anatolian locations

3.2.1. Abstract

The importance of an archaeological site is determined by its centrality, a measure of the interaction at the site. Interactions are assessed by different central functions that are important

on different spatial scales. With this integrated approach, applying the knowledge of geography, prehistoric archaeology and classical archaeology, the surroundings of present-day Bergama and Selçuk in Western Anatolia are analysed with regard to their centrality. The diachronic approach shows the different developments of both areas throughout time, indicating the importance of different environmental and social factors that create the level of centrality. Two kinds of centrality can be distinguished: (1) a natural centrality that is mainly based on the location of a site in relation to its local hinterland as well as supra-regional landscape characteristics and (2) a politically controlled centrality that is caused by human efforts to assemble central functions. While in the second case deterioration starts when the required effort can no longer be afforded, deterioration in the first type of centrality is caused by the natural landscape dynamics. This interdisciplinary, diachronic analysis allows a holistic assessment of centrality. Furthermore it shows that (1) local, natural or social factors alone are not able to give a full and sufficient explanation of the differences in a location's centrality as well as (2) the evident need for integrated research frameworks in the analysis of human-environmental relationships throughout time.

Keywords

Central place; central function; gateway; Pergamon; Ephesos; human-environmental relationship;

3.2.2. Introduction

During antiquity, Western Anatolia was a major area of cultural development. Two of the most prominent sites of that time were Ephesos, near present-day Selçuk, and Pergamon, modern Bergama (figure 3.1). Archaeologists have indicated that the importance of both sites varied during prehistory, even depicting the region around Bergama as marginal (Horejs, 2010, 64), whereas the vicinity of Selçuk was more central and better integrated into supra-regional communication and trade networks (Horejs et al., 2011, 47–48, 50; Şahoğlu, 2005, 352). We aim to sketch the history of both areas, to explore the environmental and socio-economic factors that caused their importance based on a concept of centrality for selected time slices.

3.2.3. Conceptual framework

A location is characterized by its topology, its chorology and its chronology (Hettner, 1905, 557). The topological characteristics are covered by the term site. It refers to the study of the relationship between human and environment on the local level (Ullman, 1980, 13). The chorological perspective is termed situation, what refers to the connections between areas, leading to interdependencies, diffusion or centralization (Ullman, 1980, 13). Our attempt is similar to Ullman's in that we "(. . .) try to make explicit that which has only been implicit (. . .)" (Ullman, 1980, 27). Using selected time slices we analyse the locations' site and situation
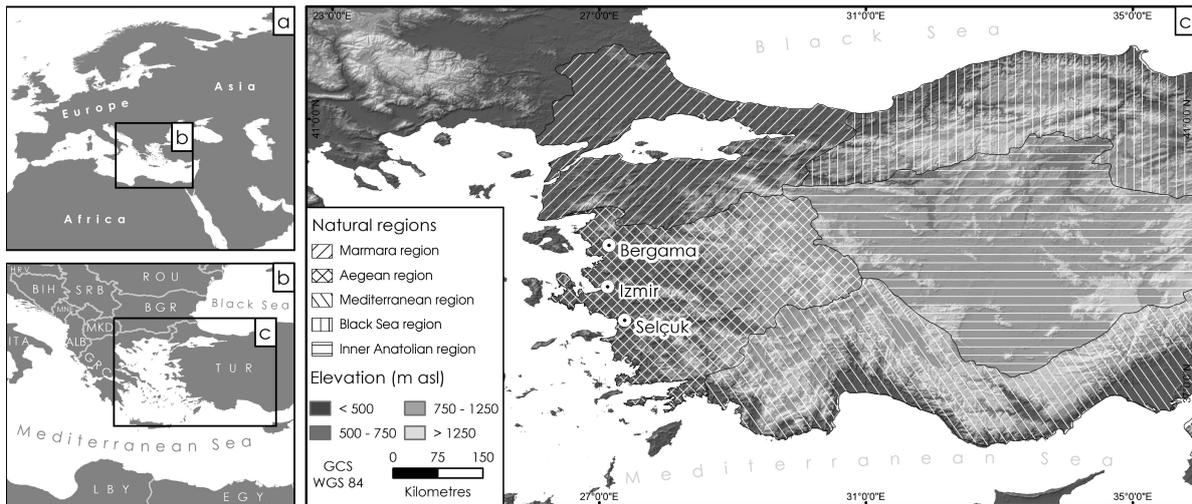
Figure 3.1.: Geographical overview of the research area. (c) Natural regions of Western and Central Anatolia. The focused sites, Bergama and Selçuk, belong to the Aegean natural region, whose characteristics are stated in the text (Natural regions Erol (1982a), Erol (1982b); Base map Natural Earth Data (2011); elevation Jarvis et al. (2008).

based on a concept of interaction, because it is interactions – as driver of cultural and historical processes – that lead to the formation of prominent – central places. Following Taylor et al. (2010) two theoretical models are necessary: a) central place theory, to describe relations between a location and its corresponding hinterland, i.e. site as well as b) central flow theory to describe the horizontal spatial structures of non-local interactions, i.e. situation.

It was Walter Christaller who developed the term central place and the relating concept of centrality. He discovered the underlying "laws" of the number, size and distribution of central places (Christaller, 1968, 252). In this regard, the main law of settlements distribution is a perfect, transport cost optimized, supply of its participating elements with central functions (Christaller, 1968, 77, 138–140, 254). A central place is a location that has a surplus of meaning, due to the central functions offered for its hinterland (Christaller, 1968, 31; Beavon, 1977, 18; Heinritz, 1979, 14). A central place does not need to be a settlement. It can be understood as a cluster of institutions that offers goods, commodities or services to a limited market area (Blotevogel, 2005, 1307). To understand changes in the importance of a location, central place theory is not enough, since it covers just the local affairs; hence it is inherently non-dynamic as an economic process. "(...) [E]conomic expansion [, i.e. an increasing importance due to more interactions,] does not occur as a result of servicing a hinterland, however, large. Therefore no small central place ever grew to become a metropolitan economy through external relations limited to its own hinterland" (Taylor et al., 2010, 2811–2812). Understanding a location's situation needs to focus on the sub-nodal points of a regional or supra-regional network, since it is the specific functions and not the locations that produce the network steering different interactions.

Table 3.1.: Central functions with exemplary institutions (Denecke, 1972; Gringmuth-Dallmer, 1996)

Central function	Exemplary institutions
Trade	Market, harbor
Security	Refuge castles; institutions that offer asylum; strategic/military institutions to shelter the central place and its hinterland
Administration	Institutions of state; institutions of law, e.g. tribunal
Craft/industry	Institutions of craftsmen such as carpenters, sculptors, blacksmiths, miners; institutions of culture, such as theatres; institutions of science such as academies, gymnasiums
Cult	Cultic institutions such as temples or shrines

Both, central place and central flow theory, are complementary concepts (Taylor et al., 2010; Taylor, 2012). They are applied in this study within a framework of interaction, allowing application of these theories in an archaeological context. People almost always interact. They do it in very different ways, e.g. the exchange of goods equals an interaction between individuals. Where the concentration of interaction is higher than indicated by the population density, centrality emerges. The degree of centrality is the relative concentration of interactions. Thus, a central place is an interaction node, a place of concentrated interaction in a spatial network – on local and regional scale based on central place theory and on supra-regional scale based on central flow theory. The universal nature of interaction enables the analysis of any human occupation regardless of any other premises about the behavior. Owing to this ubiquitous style of centrality, spatial and chronological comparisons are possible.

To identify interactions that generate central places, the occurrence of central functions as indicating parameters is analysed (Christaller, 1968, 27; Denecke, 1972, 43–47; Gringmuth-Dallmer, 1996, 12–22). Since every archaeological evidence is fragmented, central functions are simplified to allow the assessment of a site's importance from prehistory until the Middle Ages (Gringmuth-Dallmer, 1996, 8; table 3.1). The more central functions are present at a certain location, the more complex is the structure, and thus the higher is the level of centrality (Gringmuth-Dallmer, 1996, 9–11). Furthermore, the central functions do not need to be onsite, but can also be present in the near vicinity, creating a central space around the site (Gringmuth-Dallmer, 2011, 432–436).

Central functions create a hierarchy of sites; regarding their sphere of influence, they are themselves hierarchical, such as markets for everyday goods vs. a special market for rare spices. The maximum extent of the influential sphere constitutes the spatial scale of a central function: local (supplying the vicinity), regional (the wider hinterland, supplied with not everyday goods), and supra-regional scale (supplying a large region with scarce goods).

According to this theoretical framework, the indicating measures of interaction are diachroni-

cally assessed on different spatial scales to discover those factors that caused the centrality of the two focal regions and to show, whether these have changed throughout time.

3.2.4. Research area

Environmental characteristics

The area (figure 3.1c) is characterized by a temperate climate, classified as Cs after Köppen & Geiger (Kottek et al., 2006, 261). The winters are humid and temperate due to moist western winds. Summers are hot and dry and characterized by the Etesians (figure 3.2). These general climatic characteristics already occurred during prehistory as the modern atmospheric circulation mode was established during the mid-Holocene (Schulz and Paul, 2002, 46; Dusar et al., 2011, 142). From 4000 BC at the latest, the climate became similar to the present-day climate. Temporary aridization appeared around 100 BC to 0 AD (Finné et al., 2011, 3164).

The relief of Western Anatolia is highly influenced by tectonic and volcanic activities. Neogene structural movements caused east-west stretching mountain and graben systems to develop (Hütteroth and Höhfeld, 2002, 37–39). The graben structures are filled with alluvial sediments and are presently drained by large river systems. Along the Aegean Sea littoral zone the graben systems are drowned, while the mountains create isles and peninsulas. The result is a coastline with numerous gulfs that extend far inland, creating good harbour locations (Philippson, 1914a, 66; Hütteroth and Höhfeld, 2002, 60; Brückner, 2005; Brückner et al., 2005; Brückner et al., 2006). Best access to the hinterland is granted at the mouths of the large river systems. However, owing to their high sediment load, they very actively prograde their deltas. In combination with the strong seasonal river regime with high flow during winter and early spring and a low flow during summer and autumn, the rivers are not navigable (Hütteroth and Höhfeld, 2002, 91–92). Furthermore, the graben structures channel the moist western winds, causing relatively greater humidity further inland of the altogether arid central Anatolian plain (Erol, 1983, 81–83).

The common soils in the area are Rubefacient or Chromic Cambisols and Luvisols, mostly relictic soils of the Tertiary (Walter and Breckle, 1991, 12–14). In the alluvial plains and valleys, fertile Fluvisols occur, whereas the mountainous areas are dominated by Leptosols on the crystalline and magmatic rocks (Erol, 1983, 84–85; European Soil Bureau Network, 2005, 87, plate 16).

Owing to the winter rainy season without frost and the summer drought, the region belongs to the Mediterraneis (Frey and Lösch, 2010, 28). It is characterized by evergreen, micro- and sclerophyllous plants and pine and oak in the mountainous regions (Pott, 2005, 471–472). The widespread dominance of Maquis and Garrigue documents the long-lasting degradation processes due to human exploitation and land use (Chesworth, 2008, 67; Frey and Lösch, 2010, 424–427).
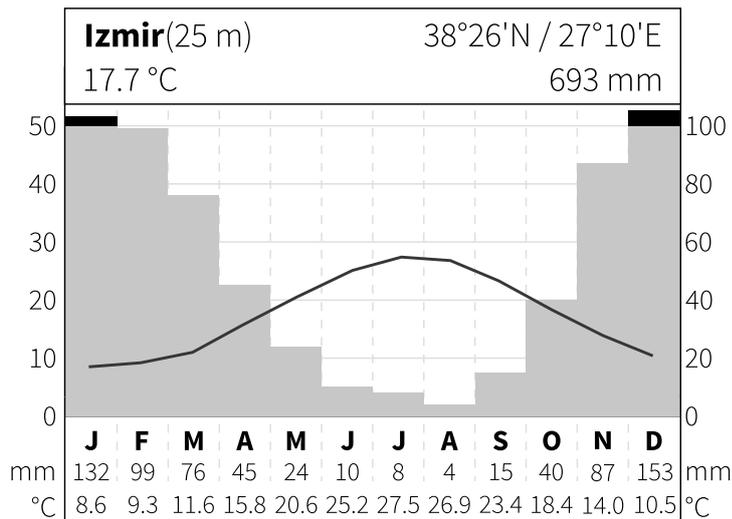
Figure 3.2: Climate diagram of Izmir for the period 1961-1990 (based on Sträßer, 1999, 146); during winter humid conditions prevail, while the summer is characterized by arid conditions.

Settlement locations

In western Anatolia five main factors control the location of settlements: the availability of water, arable and grazing land, fuel and building material (Chisholm, 2007, 115). Nagle (2004, 6) added freedom from flooding, level sites to build on, sunny south facing slopes, potential for trade and commerce, and defensibility to this list.

Considering these parameters, well-drained, gently inclined areas are preferable settlement areas and can be found in the ovas of western Anatolia. These basins have emerged as tectonic depressions since the Miocene (Erol, 1983, 33). The western Anatolian ovas are related to graben structures and are drained by large rivers such as Bakırçay, Gediz, Küçük Menderes and Büyük Menderes (Figure 10). They are filled with alluvial sediments (Kayan, 1999, 542–543). The edges of the ovas occasionally correspond to Neogene terraces and are covered by alluvial fans (Uzel and Sözbilir, 2008, 565, 569). These locations at the transition between the alluvial plains and the mountains are mostly well drained and rarely affected by seasonal flooding, and they connect different ecological zones (Weichhart, 1978, 184). Thus, ovas are preferred settlement areas, resulting in a concentration of villages, markets and towns along this geomorphological unit since early history (Erdoğu, 2003, 13; Meriç, 2009, plan 3).

The surroundings of Bergama and Selçuk offer these favourable settling conditions (figure 3.3). Comparable conditions are given by their location in the same natural supra-region (figure 3.1c). It is assumed that climatic shifts and environmental dynamics during the Holocene affected both areas similarly. Overall environmental conditions differed strongly from those today because during early cultural history the river alluvia had not entirely filled up the graben with their sediments, allowing the sea to intrude into the valleys. The soils were not yet degraded and eroded by burning or wood cutting (general overview, e.g. Roberts, 2008; more specific, e.g. Hughes, 2005). Evergreen broad-leaved and needle-leaved forest and, at higher elevations, predominantly deciduous closed forest covered up to 100% of the ground (Bottema and van
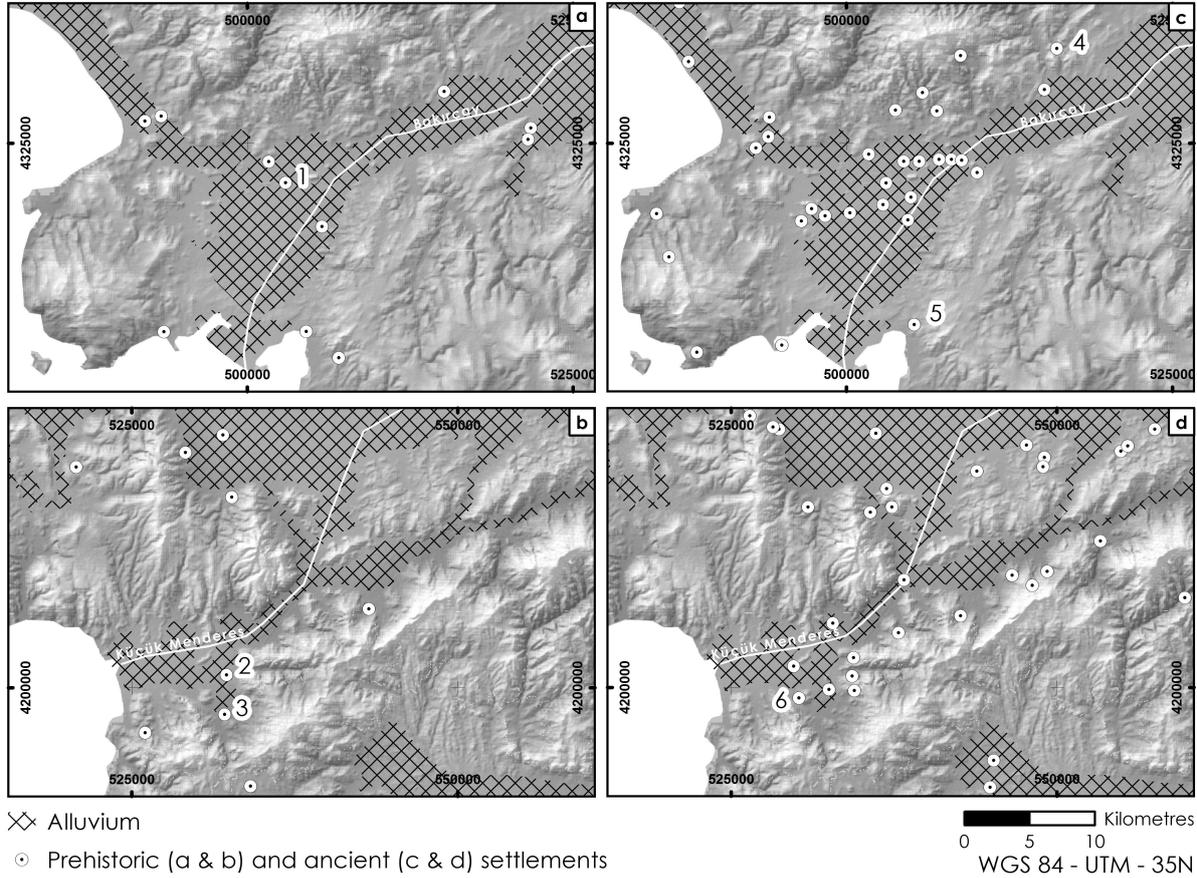
Figure 3.3.: Actually known prehistoric (Late Chalcoithic to Late Bronze Age period) and ancient (Archaic to Byzantine period) settlement locations in the surroundings of Bergama (a, c) and Selçuk (b, d). The majority of sites are located at the transition between the mountainous areas and the alluvial plains. The maps show the present-day coastline, which was different in prehistory and antiquity as Ephesos and Çukuriçi Höyük were harbour locations (Kraft et al., 2003, 2007; Brückner, 2005). Sites according to the numbers: 1) Yeni Yeldeğirmentepe 2) Ajasoluk/ Apaşa 3) Çukuriçi Höyük 4) Pergamon 5) Elaia 6) Ephesos (sites in (a) Horejs, 2010; sites in (b) Horejs et al., 2011; sites in (c) Pirson, 2007, 43; sites in (d) Meriç, 2009; alluvium in the surroundings of Bergama Philippson, 1910; alluvium in the surroundings of Selçuk Philippson, 1914b; streams Harita Genel Komutanliğinica Sayısal Olarak Hazırlanmış ve Basılmıştır, 2002. Tükiye Fiziki Haritası. Her Hakkı Saklıdır.; base map Jarvis et al., 2008).

Table 3.2.: Name of the research sites during the different cultural epochs

	Cultural period		
Study Site	Bronze Age	Antiquity	Today
Bergama	Yeni Yeldeğirmentepe	Pergamon	Bergama
Selçuk	Çukuriçi Höyük	Ephesos	Selçuk

Zeist, 1990). As a result of burning and wood cutting, the rivers' sediment loads increased and alluvial deposition was accelerated.

It is hypothesized that the naturally determined settlement activity and centrality is comparable in the surroundings of present-day Bergama and Selçuk. Differences are not the result of different environmental prerequisites but of different socio-cultural conditions during the establishment of the settlement system.

3.2.5. Centrality assessment using central functions

In the following, the centrality of Bergama and Selçuk is documented illustrating their socio-economic utilization of and development within their surroundings. With respect to the diachronic approach different cultural epochs are considered as examples sketching the development of centrality (table 3.2). Obviously many cultural epochs, important for technical or societal innovation and cultural changes, had to be omitted. Nevertheless, it is the general picture of the development of centrality and people familiar with other periods may notice that integrating periods omitted here will still lead to the same general picture.

Bronze Age (3000 - 1150 BC)

First settlements in the upper Küçük Menderes valley date back to the Neolithic period in the 7th millennium BC (Lichter, 2006; Galik and Horejs, 2011). So far no clear Neolithic or Chalcolithic remains have been detected in the Bakırçay valley.

In Early Bronze Age 1 the tell site Çukuriçi Höyük, close to present-day Selçuk, offered the central function of craft with local importance indicated by various metal workshops integrated in settlements (Horejs, 2011b, 161). Additional obsidian findings underline the importance of the local craft centre (Horejs et al., 2011, 48–49). The obsidian originates predominantly from the Aegean island of Melos approximately 300 km away. Other obsidian sources in Central Anatolia are at a distance of more than 700 km (Bergner et al., 2009, 251–252). Accordingly, these relations point to a supra-regional network of trade.

Information on administrative functions of Late Bronze Age Hittite texts for the developed 2nd millennium BC indicates that the surroundings of Bergama belonged to the Seha river land, whereas Selçuk's surroundings were part of the kingdom of Arzawa (Seeher, 2005, 35).

Apaša, the kingdom's capital, is assumed to correspond to Ayasoluk – modern Selçuk (Heinhold-Kramer, 1977; Seeher, 2005, 23–24; Niemeier, 2007, 65; Horejs, 2008). The kingdom of Arzawa is considered to have occupied the area from the Karabel pass south of modern Izmir in the north to the Beşparmak Dağları, the Latmus Mountains of antiquity, in the south (Heinhold-Kramer, 1977; Schachner and Meriç, 2000; Niemeier, 2007, 62). Besides this regional importance, Arzawa's ruler is called "King of Kings" and brother by Egyptian pharaoh Amenophis III (1390–1352 BC), indicating the supra-regional importance of this kingdom (Haider, 1999; Klinger, 2007, 53; Breyer, 2010, 315–318). From the region around Bergama no comparable administrative functions are known. If Arzawa is assessed as a supra-regional power, hierarchically below those of Egypt and the Hittites, Seha can be seen on a possibly lower hierarchical level with regional significance (figure 3.4). Archaeological remains of the Late Bronze Age are rare in both regions and do not offer any further information (Mountjoy, 1998; Niemeier, 2007).

At the current state of the art it is not possible to define cult and security central functions in the vicinity of the studied sites for the prehistoric periods.
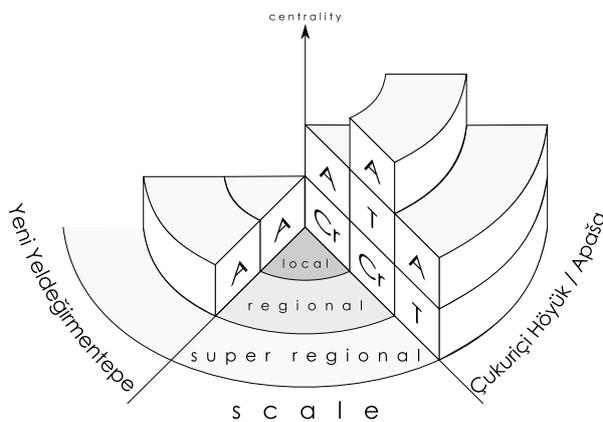
Figure 3.4: Centrality assessment using central functions for the Early Bronze Age around Yeni Yeldeğirmentepe and neighbouring sites and Çukuriçi Höyük and Late Bronze Age Apaša. Capital letters correspond to central functions: A: Administration; Cr: Craft/Industry; T: Trade.

Archaic and classical period

Whereas not much is known about Pergamon in the pre-Hellenistic era other than the fact that it was a fortified town of local political importance, it is quite clear from the earliest written records onward that Ephesos was one of the most important cities in western Asia Minor (Hertel, 2011; Kerschner et al., 2008; Radt et al., 2000, 543–544, 554; Radt, 1999, 23–25; Knibbe, 1998, 72ff.; Scherrer et al., 1997, 1078–1081). During the Archaic and Classical periods, however, Ephesos always seemed to be somewhat overshadowed by Miletus (Magie, 1950, 73–74; Greaves, 2010, 95ff., especially 101–102 and 105–107). From the 7th century BC onward, Miletus served as the base of Ionian colonization of the Black Sea shore (Boardman, 1981, 281ff.; Ehrhardt, 1983; Tsetskhladze, 1998; Greaves, 2010, 120ff.), it was the centre of Ionian early philosophy in the 6th century BC (Huxley, 1966, 93ff.), and at the beginning of the 5th century BC, it spearheaded the Ionian revolt against the Persians (Murray, 1988).

Over the course of the 5th and 4th centuries BC, most of the cities in Asia Minor faded into the background as first Athens, Sparta, Corinth, and Thebes took centre stage, and then later Philip II of Macedon and his son Alexander who conquered the Persian Empire (334–323 BC). After Alexander's death, the Greek world had to reorganize itself and, correspondingly, the map was redrawn in western Asia Minor as well. At this point, Pergamon and Ephesos went through a phase much like a rebirth. Ephesos was re-established on the shore by Lysimachos, one of Alexander's former generals, in 294 BC (Knibbe, 1970, 255–256). Somewhat by chance, Pergamon became the ruling seat of a dynasty with potential when Philetairos, who had been named by Lysimachos as commander of the city, took advantage of Lysimachos' death (281 BC), seized the leader's war treasury for himself and established himself as an independent ruler (Zimmermann, 2011, 19ff.).

Hellenistic World (280 – 133/30 BC)

During the Hellenistic era Pergamon and Ephesos seemed to function as complementary opposites (figure 3.5). Geography favoured Ephesos, while politics graced Pergamon. In those areas in which one city took the lead, the other receded and vice versa (Ladstätter and Pütz, 2007; Pirson, 2011; Pirson and Zimmermann, 2011).

Security   Around 290/280 BC Pergamon and newly founded Ephesos were fortified with strong walls. Under Eumenes II (180 BC onward) Pergamon was further strengthened with a larger ring wall (Halfmann, 2001, 7). Ephesos enjoyed geo-strategic importance as a port connected with far-reaching inland routes. Around 200 BC Ephesos was considered to be the most important stronghold for both naval and inland military operations in western Asia Minor. Possession of the city was a prerequisite for being able to control and defend the coastal cities of western Asia Minor (Polyb. 18,40a in Paton, 1926, 174–175). Consequently, Ephesos was repeatedly a focal point of military conflicts.

Administration   Pergamon established itself as an independent political force in 281 BC under Philetairos, the founder of the Attalid dynasty. It emerged as a mid-sized power in western Anatolia under the first three Attalids until c. 200 BC, but its importance was heavily dependent on the strength of the Seleucid Empire and never extended beyond the regional context (Zimmermann, 2011, 19–33).

This changed fundamentally when the Romans appeared around 215 BC (Marek, 2010, 284ff.; Bleicken, 2004, 48ff., 164ff.). Through its alliance with the Romans, who defeated the most important Hellenistic kingdoms within just a few decades, Pergamon became the strongest power in Asia Minor, after the Seleucid king Antiochos III had to capitulate in 188 BC. As the Romans left wide areas of the Anatolian peninsula under the control of Pergamon, the city became a pivotal political and administrative centre with cross-regional influence (Zimmermann,

2011, 34ff.). However, the Roman senate had to be consulted on any political issue (Bleicken, 2004, 175–176). As warrantor of the "new order" established by Rome, Pergamon increasingly lost its political independence. By contrast, Ephesos was less important as a political and administrative centre. Although the city was repeatedly the seat of residence or headquarters of various kings, generals, or governors in the 3rd century and the beginning of the 2nd century BC, Ephesos became part of the kingdom of Pergamon as a kind of district capital (Marek, 2010, 318ff.).

Craft/industry As a result of the Attalid's ascension as a political power, Pergamon was transformed into one of the most beautiful cities in Asia Minor, especially under the reign of Eumenes II (197–158 BC). Eumenes II stretched the boundaries of the city, endowing these newly incorporated areas with many magnificent buildings (Zimmermann, 2011, 37ff.; Radt, 1999, 53ff., 79–81). In keeping with the self-image of Hellenistic monarchs, the Attalid kings also ensured that Pergamon became a centre of intellectual and artistic life. Pergamon became one of the primary centres of Greek culture during the Hellenistic era and—at this time—easily competed with the capitals of the great kingdoms and with Athens.

Comparatively little is known about Ephesos in this respect (Calapà, 2009). It is striking that hardly any stately buildings were constructed in Ephesos during the Hellenistic period (Knibbe and Alzinger, 1980, 759; Halfmann, 2001, 10), and prior to the 1st century BC, there is practically no evidence of any artists, scholars or literati (Knibbe, 1970, 291).

Trade The wealth so ostentatiously on display in Pergamon's impressive buildings came from tax money and the royal treasury and had little to do with a state of prosperity that had been achieved through business and trade. We must assume, of course, that there were at least regional trade activities in Pergamon because the city had purchasing power and could afford to import goods. Moreover, the resident artisans and craftsmen doubtlessly took advantage of the presence of traders and businessmen to produce goods in excess of local demand for export, for example the Pergamon fine ware (cf. Meyer-Schlichtmann, 1988).

This is supported by the fact that at this time the harbour of Pergamon, Elaia, was expanded (cf. Zimmermann, 2011, 114–115). But, it is not merely a matter of coincidence that we have no proof that Pergamon was truly a trading centre (Rostovtzeff, 1955, 442–444). After all, Pergamon was not centrally located and it appears to have been more a final destination for trade routes than a crossroads on the way to supply other markets located further in the interior of Asia Minor.

In Ephesos, the situation was basically the opposite: its geographic location was ideally suited to support strong flows of transit traffic. A variety of sources indicate that Ephesos' potential for trade increased during the Hellenistic era and that the city grew into a centre of business and trade. For example, Italian bankers and tradesmen were present in the city relatively early on (Knibbe and Alzinger, 1980, 751; see also Broughton, 1938, 623 on the export of the dyestuff

"Sinopia" through Ephesos, and, in general, see Magie, 1950, Rostovtzeff, 1955, 133ff., 532, 633ff., and Halfmann, 2001, 21). The most impressive evidence for the city's flourishing trade, however, is certainly Stabon's description of Ephesos on the eve of the Roman Imperial period as a city experiencing dynamic growth and as one of the largest trading centres in Asia Minor (Strabon 14,1,24 in Radt, 2005, 26–27).

Cult/Religion   During the 3rd and 2nd centuries BC the Attalids enlarged and richly decorated the temples of Pergamon (Radt, 1999, 159ff.; Zimmermann, 2011, 93ff.). However, most of the cults and temples in Pergamon were only important for the city and the surrounding countryside (Zimmermann, 2011, 45). The case might have been different for the Temple of Asklepios outside Pergamon, constructed around 350 BC and rebuilt by the Attalid kings (Radt, 1999, 220ff.), as during the Roman Imperial era at the latest many pilgrims and cure-seekers sought out this temple honouring the healing god.

By contrast, Ephesos has been an important religious centre since the Archaic and Classical periods (Bürchner, 1905, 2804–2805). The most important cult was the Cult of Artemis and her temple (Fleischer, 1981). The goddess was most likely worshipped here from the Bronze Age onwards; the oldest temple structure dates back to the 8th century BC (Scherrer et al., 1997, 1081). There is also evidence of foreign gifts for the Artemision dating to the 6th century BC. The late-classical building, which was erected after the catastrophic fire in 356 BC, was counted among the Seven Wonders of the Ancient World (Bammer and Muss, 1996, 10ff., 53ff.). Therefore, we can assume that visitors to the area made sure to see this attraction. Moreover, the right of sanctuary and asylum which it offered made this temple a treasury and bank (Bürchner, 1905, 2811–2812).
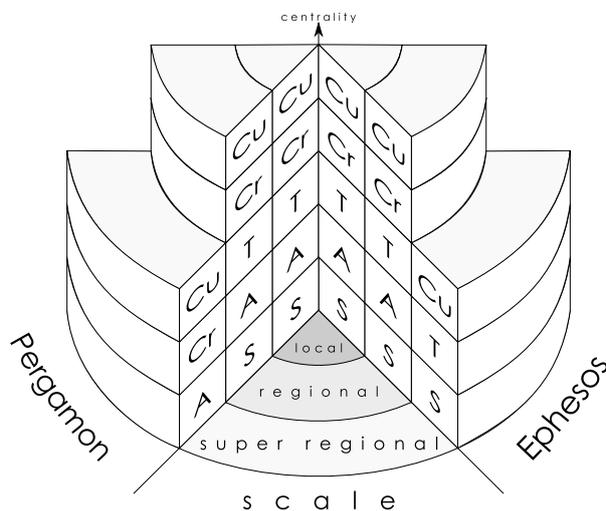

Figure 3.5: Centrality assessment using central functions for the Hellenistic era around Pergamon and Ephesos. Capital letters correspond to central functions: A: Administration; Cr: Craft/Industry; Cu: Cult; S: Security; T: Trade.

Roman Republic and High Empire (133/30 BC – 200/250 AD)

During the era of the Roman Empire, the differences between Ephesos and Pergamon disappeared. Both cities managed to catch up in those areas in which they had previously been inferior so that in the end, they basically stood on equal footing. Without a doubt, this was due to the fact that the central government in Rome more or less pushed the developments in this direction. Notwithstanding, however, Ephesos remained more important in terms of economy and demography, simply due to its more advantageous geographical position. Pergamon seemed to hold onto its position despite a rather disadvantageous starting point in terms of its "natural character" which, in turn, speaks to a level of momentum regarding centrality. In the end, however, Pergamon did lose some of its relative importance as the competition became stronger. For Ephesos, on the other hand, the Imperial era was marked by a continuous upswing (figure 3.6).

After the Romans took direct political control over western Asia Minor, the situation of the local population deteriorated when Roman businessmen exploited the new province. During the end of the civil war, after Caesar's assassination in 44 BC, Roman generals exacted large amounts of money from the cities of Greece and Asia Minor (Broughton, 1938, 535ff., 590; Magie, 1950, 232ff., 379ff.; Marek, 2010, 318ff.). Shortly afterwards, the situation calmed down when Emperor Augustus began to reorganize his empire after defeating Mark Antony and Cleopatra in 30 BC and established himself as the sole Roman ruler.

Security   The proverbial Pax Romana made strong fortresses dispensable (Marek, 2010, 389ff.). Accordingly, all over the empire settlements emerged on the unprotected plains, and Pergamon and Ephesos were no exception (Klose, 1999, 489–490; Radt et al., 2000, 551).

Administration   It remains unclear whether the capital of the Roman province of Asia, which was established as of 129 BC, was Ephesos or Pergamon (Haensch, 1997, 298ff.). There is evidence that from 50 BC at the latest Ephesos was the main administrative centre, especially as Roman tax collectors were based in the city (Haensch, 1997, 312ff.). The good transport connections of Ephesos made it a suitable administrative centre for the Roman empire, especially as the city was also the place where most of the new governors of Asia first set foot on the soil of Asia Minor (cf. Dig. 1.16.4.5 in Behrends, 1995, 155–156).

Both Ephesos and Pergamon became cities of virtually the same rank. Augustus had already divided the politically significant official imperial cults equally among Ephesos and Pergamon (Dio 51,20,6–7 in Cary, 1917, 56–57), and both cities were—together with Smyrna, the third most important city of Western Asia Minor—meeting sites for the provincial assembly (Magie, 1950, 447–448, 1295). Later Pergamon and Ephesos became home to additional temples for the provincial cults of the emperors (Haensch, 1997, 315–317). A fierce competition for privileges and titles arose between both cities. Pliny the Elder referred to Pergamon in the second half

of the 1st century AD as "by far the most famous city of Asia", whereas Ephesos was merely described as "alterum lumen", a polite way of saying that he appraised the city to be the number two only (Pliny, NH 5,120; 5,126 in Winkler and König, 1993, 86–87, 90–91). Not until the reign of Antoninus Pius (138–161 AD) did Ephesos become the "first Metropolis of Asia". The city held this honour only briefly and had ascended to this position because the emperor himself had a special connection to Ephesos that dated back to his time as governor of Asia (Knibbe, 1998, 158–159; Halfmann, 2001, 75–76).

Trade   The first two centuries AD were a period of prosperity and growth all over the Roman Empire (Pleket, 1990). This general affluence did not necessarily cause structural changes of the individual cities. Hence, for Pergamon there is no evidence of noteworthy cross-regional trading activities during the Imperial period (Broughton, 1938, 868ff.). Rather, the elites of Pergamon seemed to have primarily gained their wealth from land ownership (Halfmann, 2001, 20, 97ff.).

In Ephesos, businessmen and financiers were well represented in the elites (Halfmann, 2001, 97ff.). The technical measures which were repeatedly undertaken to combat the siltation of the harbour in Ephesos are a clear indicator for the importance of this waterway. Around 160 AD, the rhetorician Aelius Aristides praised the city as a crossroads of trade known through the entire Mediterranean area and as the "bank and treasury of Asia" (Aristides 23,24 in Dindorf, 1964, 775; Behr, 1981, 30; Knibbe, 1998, 136–137). After Alexandria, Ephesos was the second largest city in the eastern empire, one of the few cosmopolitan cities of the Imperium Romanum (Seneca, Epist. 102,21 in Gummere, 1925, 180–181). It had a population of about 100,000, compared to the estimated 40,000 inhabitants living in Pergamon (Kolb, 1984, 177, 191; Knibbe, 1998, 149; Halfmann, 2001, 61; Zimmermann, 2011, 86, 111).

Craft/industry   The development of Pergamon under the Attalids turned the city into a "synthesis of artworks" (Zimmermann, 2011, 78), and so construction during the Imperial period was at first limited to the maintenance and embellishment of the existing structures. This changed during the 2nd century AD when several citizens of Pergamon were appointed as Roman Senators and, in parallel, a temple dedicated to the Emperor Trajan (98–117 AD) was built on the Acropolis. New buildings such as several thermal baths appeared in the lower city, and the Temple of Asklepios was completely renovated (Radt, 1999, 230ff.).

In Ephesos the "building boom" of the Imperial era appeared earlier (Knibbe, 1998, 109ff.; Halfmann, 2001, 21ff., 36ff., 63ff.). All over the city new squares, halls, temples, and other monumental buildings were built (Knibbe and Alzinger, 1980, 811ff). The list of craft trades known for Ephesos is impressively long (Broughton, 1938, 842). Until the 2nd century AD, Ephesos was certainly equal to Pergamon as a cross-regional centre of art and crafts, and during this period, both cities regained their long-lost reputations in terms of culture. Together with Smyrna, Ephesos and Pergamon were at the heart of the so-called "second sophistic" literary

movement that shaped intellectual life throughout the entire Greek-speaking eastern regions of the empire (Bowie, 2002; Zimmermann, 2011, 66, 110–111).

Cult/Religion   In terms of cults and religious aspects, Pergamon and Ephesos also reached about the same level, but in this case, it was Pergamon that caught up with Ephesos. The imperial cults mentioned earlier were cults for the entire province and therefore enjoyed trans-regional importance (in the end, Pergamon had three imperial temple wardens (so-called neokoroi, see Burrell, 2004, 30ff.). More importantly, however, the 2nd century AD marked the heyday of the Asklepios Temple (Radt, 1999, 227ff.; Zimmermann, 2011, 66, 100ff.). The entire complex was remodelled under the Emperor Hadrian (117–138 AD) and we know for a fact that afterwards countless numbers of visitors from around the entire empire sought out the healing powers of this temple, including two emperors and many other high-ranking people. The famous Galen who later became the personal physician of Marcus Aurelius (161–180 AD) also studied and worked at the Asclepieion which, like the Artemision, was ultimately considered to be one of the Wonders of the World (Zimmermann, 2011, 102).
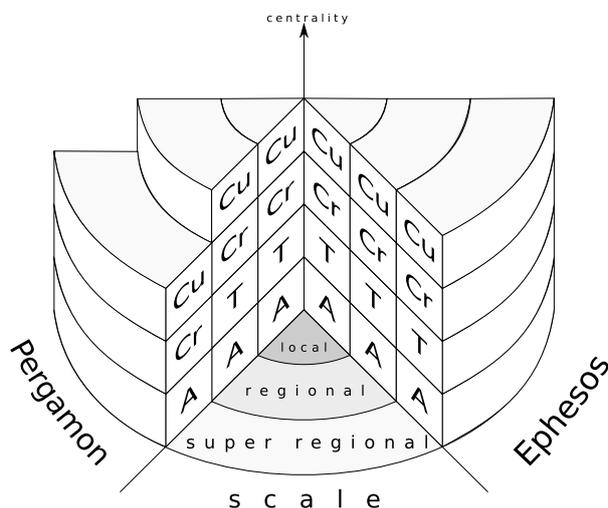
Figure 3.6: Centrality assessment using central functions for the Roman era around Pergamon and Ephesos. Capital letters correspond to central functions: A: Administration; Cr: Craft/Industry; Cu: Cult; T: Trade.

20th century

Today, Bergama and Selçuk belong to Izmir Province. They are local supplying centres for their hinterland, though Bergama is markedly bigger and grew faster during the 20th century (table 3.3). Both profit from their antique remains and the corresponding tourism that enables the cities to offer craft/industry on regional and supra-regional scale (figure 3.7).

3.2.6. Discussion

The gradual increase of centrality in the surroundings of Selçuk is related to its favourable location regarding supra-regional trade and communication—it shows the typical characteristics

Table 3.3.: Inhabitants of Bergama and Selçuk in the 20th century ([1]Philippson (1912, 56); [2]Banse (1919, 129); [3]Meyer (1902, 216); [4]Turkish Statistical Institute - Regional Statistics (2010))

| Year	Bergama	Selçuk
Early 20th century	20,000[1] or 15,000[2]	2793
2000[4]	total 106,536 city 52,173 village 54,363	total 33,594 city 25,414 village 8,180
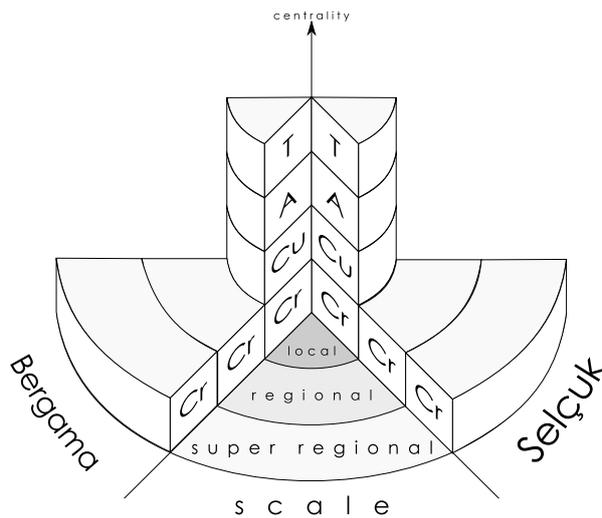
Figure 3.7: Centrality assessment using central functions for Bergama and Selçuk. Capital letters correspond to central functions: A: Administration; Cr: Craft/Industry; Cu: Cult; T:Trade.

of a static gateway location (Burghardt, 1971, 273). Different transport axes connected Inner Anatolia with the Aegean, granting access to the coast via the valleys that drain to the north and west. These guidelines of interaction created a transition zone between the Aegean and Anatolian cultural spheres, represented by the archaeological record (figure 3.9). Findings at Liman Tepe, Bakla Tepe or Çukuriçi Höyük suggest that from prehistory onward this area was not just the margin of cultural spaces but an important centre of production and trade with its own identity (Lichter, 2006, 30; Erkanal, 2008b, 181). The strong connections to the Aegean islands and to the hinterland of the sites as far as the central Anatolian sites are indicated by (a) obsidian trade and (b) the changing inventory of sites located at putative trade routes (Lichter, 2006, 31–32; Rahmstorf, 2006, 80–82; Thompson, 2007, 94–96). These are all features that show the influencing role of sub-nodal functions, related to specific trading agents, that are characteristics for the inter-city relations of central flow theory (Taylor et al., 2010, 2814).

Regarding these transport axes, the region around Bergama was and is located marginally. It caused most likely its low centrality in early epochs and its decline after the boom of ancient Pergamon. The marginality may be caused by the heterogeneous relief character of Bergama's surroundings that obstructs trade and cultural development (Philippson, 1912, 57; Banse, 1919, 126, 127; Radt, 1999, 17). Today, the region of Bergama profits from tourism and gold mining activities at Ovacik. The continuous economic growth of Izmir has led to the planning of an
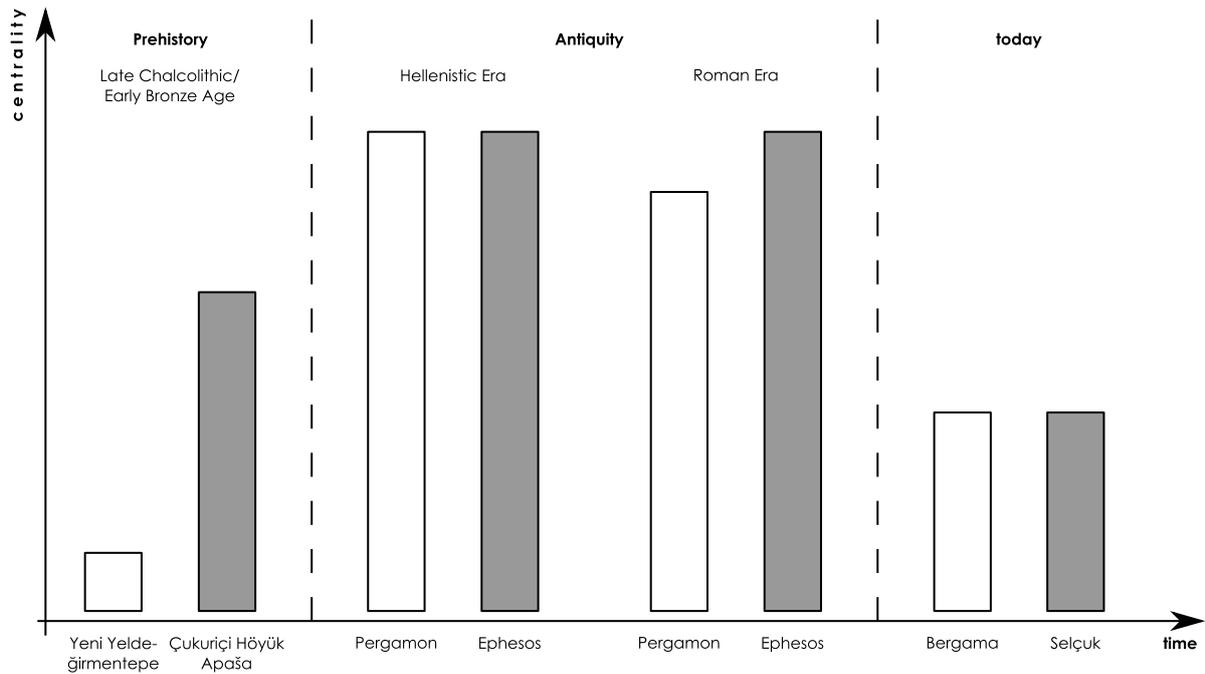
Figure 3.8.: Overview of the centrality of the studied areas throughout time. Centrality is indicated by the number and weighting of central functions regarding their scale: local 1x, regional 2x, supra-regional 3x

international harbour that will be built in the gulf of Çandarlı.

The decline of Selçuk has different reasons: siltation is a severe problem of all harbours in Western Anatolia which are located at the mouths of the big rivers. Historical examples are Troy (e.g. Kraft et al., 2003), Priene and Milet (Müllenhoff, 2005), and finally Ephesos (Kraft et al., 2007). By relocating the city, Lysimachos was the first who reacted to the siltation of the harbour (Thiele, 1907, 117). Afterwards the Romans repeatedly dug out the harbour (e.g. under the reigns of Nero (Tac.Ann. 16,23 in Church et al., 1942) and Hadrian (Börker et al., 1979, 71–72), and even in the 3rd century AD (Meriç et al., 1981, 72–73)) but finally the harbour silted up, eliminating the advantages of the city's dynamic economic agents. In consequence, its centrality has deteriorated to the present state – though modern tourism plays an important role and causes the 20th century upswing of the place.

The heterogeneous diachronic development of the sites (figure 3.8) highlights the different kinds of centrality: There is a high potential for centralization at Selçuk in prehistory and antiquity due to the environmentally favourable hinterland, the combination of transport connection, and the location in an area of exchanging cultural spheres. Hence the potential levels of central place and central flow theory are high. By contrast, the supra-regional exchange potential around Bergama is low. The locally favourable hinterland is too remote from supra-regional developments to participate as an independent core area of centrality. Owing to the enormous wealth of the Attalid dynasty and their political power, they were able to increase
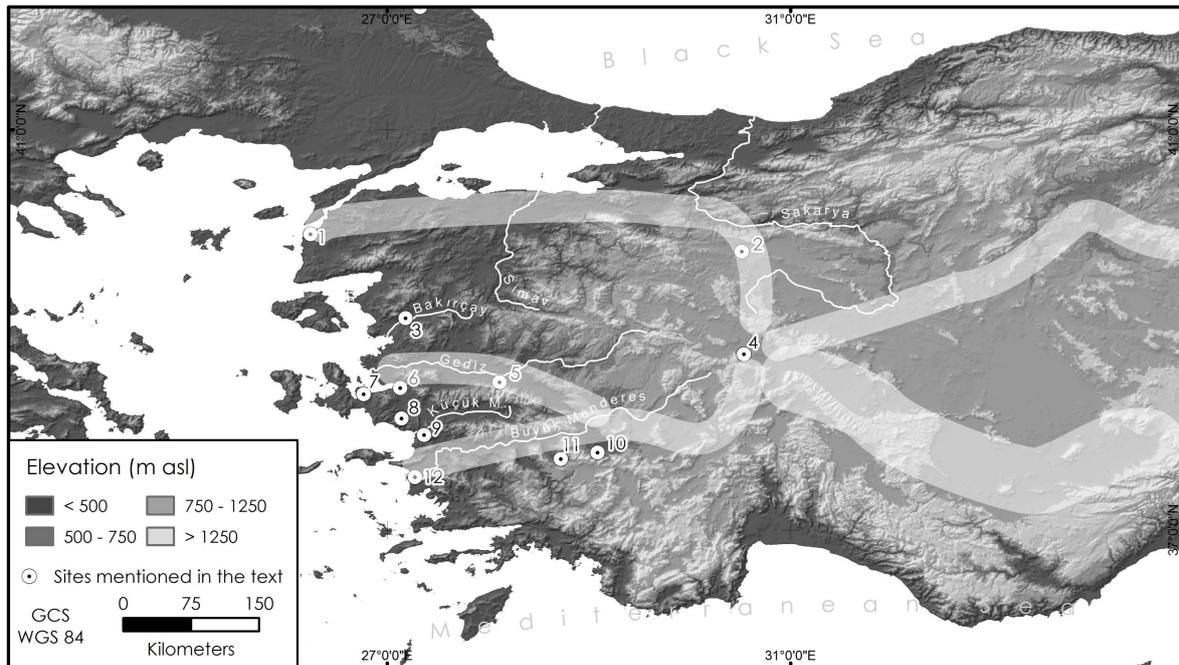
Figure 3.9.: Major routes of trade and cultural exchange in Western Anatolia; Sites according to numbers: 1–Troy, 2–Eskişehir, 3–Bergama, 4–Afyonkarahisar, 5–Sardes, 6–Izmir, 7–Liman Tepe, 8–Bakla Tepe, 9–Selçuk, 10–Denizli, 11–Aphrodisias, 12–Milet; (routes after Şahoğlu, 2005; Efe, 2007; Rahmstorf, 2006; streams Harita GenelKomutanliğinica Sayısal Olarak Hazırlanmış ve Basılmıştır, 2002. Tükiye Fiziki Haritası. Her Hakkı Saklıdır; base map Jarvis et al., 2008).

temporarily Pergamon's potential centrality by pulling different functions towards the location. Thus, politically triggered central functions such as craft/industry, administration, and security based on specific agents prevailed. Supra-regional functions, typical for gateway locations, were not sustainably integrated into the central functions offered by Pergamon. Thus, after political influence vanished in the Roman Empire, Pergamon's centrality deteriorated to a lower level. However, according to the established structures and the advanced traffic this level was higher than the natural centrality of prehistoric time.

3.2.7. Synthesis and conclusion

The centrality assessments show that the investigated areas differ regarding their central functions and their development. A general characteristic is the gradual increase of centrality in the area around Selçuk until the end of antiquity, followed by its decrease to only local importance (figure 3.4–3.7, 3.8). By contrast, the region around Bergama shows a sudden increase in centrality at the beginning of the Hellenistic Age. This centrality was maintained well into Roman times, before Bergama gradually lost its importance (figure 3.4–3.7, 3.8).

It becomes obvious that the reasons for the centrality of the places differ. According to trade and cult, Ephesos was the centre of Western Anatolia while Pergamon's importance was mainly

due to its role as residence seat of the Attalid dynasty and a resulting cultural importance. It is the combination of advantages regarding central flows and its effects on the local central place that caused centrality and, if this combination is not sustainable, leads to its decline.

This diachronic, comparative analysis documents that the centrality of a site is not only related to the favourability of its surroundings or location – as also indicated by theoretical considerations of Jacobs (1970), Soja (2003) and central flow theory (Taylor et al., 2010; Taylor, 2012). The example of Pergamon shows that it is possible to increase a low level of potential centralization, due to pulling supra-regional agents, to create a regional and supra-regional importance.

Furthermore, the high potential of centralization can also change over time. As the analysis around Selçuk shows, natural dynamics are able to diminish a location's importance. During prehistory and antiquity the potential of centralization was high, but it deteriorated owing to the gradual increase of unfavourable conditions at the site's harbour, causing a decrease of trade; hence unfavourable conditions for supra-regionally acting agents. These conditions, in conjunction with generally changing socio-economic circumstances and competition with other cities, decreased the potential of centralization to a level where the effort needed to dig out the harbour could no longer be afforded. Thus, a continuation of the city's supra-regional importance, based on its function as a gateway, was impossible. Consequently, the supra-regional importance was left to another city, whose supra-regional centrality has lasted until today – Izmir.

In summary, it can be stated that central functions on different spatial scales are able to assess the centrality of a place and offer the possibility for diachronic comparisons. Based on the analysed centrality pattern, it becomes obvious that local, natural or social factors alone are not able to give a full and sufficient explanation of the differences in a location's centrality. The integrated investigations of site and situation, deviated from considerations of central place and central flow theory, throughout time allows us to explain differences in the development of central places.

3.2.8. Acknowledgements

CHAPTER 4

Central place and interaction potential

4.1. Introduction

The level of centrality—at a certain time—depends on the local, regional, and supra-regional characteristics of the society and the natural-environment (Knitter et al., 2013; see chapter 3.2). A high level of centrality that is based on societal effort—as it was shown in the case of antique Pergamon—seems partly independent from a multi-scale environmental favourability. There are other examples for this kind of centrality that were studied throughout different Topoi projects, e.g.:

- Petra (Topoi project A-I-16), whose centrality was related to the Nabatean trade network (e.g. Schmid, 2008; Beckers et al., 2013);

- Resafa (Topoi project A-I-3), whose high relative concentration of interactions resulted from the martyrdom of Sergius and the city's subsequent role as ritual and political center (e.g. Fowden, 1999);

- Felix Romuliana (Topoi project A-I-4), whose centrality was the result of emperor Galerius' decision to build a palace at its place of birth (e.g. Škundrić, 2012).

By contrast, there are cities whose centrality is based on a high multi-scale environmental favourability—at least when no special efforts are conducted to pull the centrality to a different location. Examples for this kind of centrality are Ephesos (Knitter et al., 2013; see chapter 3.2) or Aleppo (Knitter et al., in press; see chapter 2.2). On regional to supra-regional scale the favourability of the environment mostly relates to the accessibility of the site and its relative location in small-scaled networks. On the local scale it is less definite what the main reasons

for the concentration of interactions are and how these influence the ability to be integrated in smaller-scaled networks. Antrop (2000, 260) states: "(. . .) each settlement tries to obtain a territory containing the largest diversity of natural resources as possible". Two questions arise: (1) How to detect such areas when no direct field evidence is present or possible? (2) How does a maximal diversity of natural resources at a location influences its ability to be connected to regional or supra-regional networks?

These questions are investigated in the following case study where the local characteristics of a site are linked to its *interaction potential* (see below). Obsidian, as a good of supra-regional importance, is used to indicate whether the interaction potential influences the integration of a site in small-scaled networks or not.

4.2. Paper 3: The importance of location in terms of Early Bronze Age 1 obsidian exchange in western Anatolia

4.2.1. Abstract

This paper studies the pattern of obsidian occurrence of selected settlements during Early Bronze Age 1 in western Anatolia. On the basis of theoretical assumptions of social ecology, we analysed the exchange potential of Yeni Yeldeğirmentepe and other sites in the Bakırçay valley and Çukuriçi Höyük in the Küçük Menderes valley using relief parameters integrated into a fuzzy analysis. Archaeological findings at both sites confirm that environmental characteristics favouring surplus production enhance the ability to facilitate exchange. Besides this local perspective, the importance of integration in supra-regional networks of communication is shown. Çukuriçi Höyük can be seen as a gateway location, whereas the sites within the Bakırçay valley may be too marginal to participate in this network. Furthermore, local obsidian occurrence or its absence at contemporaneous sites in western Anatolia and the eastern Aegean are integrated to gain a broader picture. Spatial analysis of environmental characters and archaeological findings give an initial understanding of the relationship between local environmental characteristics, exchange potential and location within supra-regional networks.

Keywords

4.2.2. Introduction

In the Mediterranean, the transition from the Late Chalcolithic (4000–3000 BC) to the Early Bronze Age 1 (3000–2700/600 BC) saw the occurrence of different developments that illustrate the emergence of more complex forms of society (Schoop, 2011, 31). Throughout this period,

dynamic changes occurred—indicated by higher population densities, beginning urbanism, societal stratification, specialised production, as well as the development of metallurgy (Yakar, 1985, 3–4)—and long-distance trade emerged (Düring, 2011, 257; Schoop, 2011). Obsidian is suitable for the detection of long-distance trade, owing to its rare sources in the Mediterranean and its unique chemical characteristics (cf. McCall, 2005; Renfrew, 2005, 24). The obsidian in western Anatolian sites originates from different sources, primarily the majority decends from the Cycladic island of Melos (figure 4.1, #39); additional known sources of obsidian are Yali in the Dodecanese (figure 4.1, #46) and central Anatolia (cf. Bergner et al., 2009; Georgiadis, 2008; Perlès et al., 2011). The compilation of presently known Early Bronze Age 1 sites with obsidian finds in western Anatolia shows the heterogeneous distribution of this resource (figure 4.1). Melian obsidian is found at most western Anatolian sites, with declining quantities further inland, for example in Liman Tepe (figure 4.1, #29), Bakla Tepe (figure 4.1, #8), Aphrodisias (figure 4.1, #4; Leurquin, 1986) or Beycesultan (figure 4.1, #12; Lloyd and Mellaart, 1962). Obsidian artefacts are rare in northwestern Anatolia, for instance in Troy (figure 4.1, #45; Gatsov, 1998) or Demircihüyük (figure 4.1, #14; Baykal-Seeher, 1996). A very large amount of Melian obsidian is present at Çukuriçi Höyük (figure 4.1, #13; Bergner et al., 2009, 253). With increasing distance from the coast, central Anatolian obsidian deposits became available. Çukuriçi Höyük also received some obsidian from that region in the Early Bronze Age (Bergner et al., 2009, 255), illustrating the wide-ranging exchange network.

The aim of this paper is to discuss reasons for the heterogeneous distribution of obsidian from different sources and whether natural environmental characteristics have influenced it. With regard to two exemplary sites in western Anatolia, the interaction potential is analysed to gain insights into the relationship between an area's environmental characteristics and its ability to be integrated into supra-regional networks.

4.2.3. State of the art

The exchange potential of a location can be assessed using theoretical assumptions that derive from social ecology (cf. Fischer-Kowalski et al., 1997; Sieferle, 1997). In this regard, a society at a certain location is understood as a social unit functioning to reproduce its population within a territory, guided by a specific culture (Fischer-Kowalski et al., 2004, 309). The societies considered here based their livelihood on agriculture, which can be understood as a system to control the area-specific solar energy fluxes (Sieferle, 1997, 79). Concerning societal practices, areas are used according to their suitability for society-related needs, i.e. water access, availability of tillage and grazing land, supply of wood and building material (Chisholm, 2007, 115). These modes of utilisation correspond to a reshaping of different forms of energy present in the location's hinterland. These are (according to Sieferle, 1997, 82): (a) metabolic energy, e.g. food, produced on agricultural land, (b) mechanical energy, i.e. labor, either by humans or by cattle that need pasture, and (c) caloric energy, e.g. heat/warmth, present

mainly in forests. It is assumed that settlements try to optimise the outcome of these energies, whose maximum level depends on the environmental characteristics. The better the societal organisation and the higher the environmental suitability, the easier is the societal livelihood owing to surplus production. Surplus production enables labour division and, depending on the available resources, the production of special goods, e.g. metal tools or jewelry, for exchange purposes. Hence, the larger the division of labour, the more potential interactions can arise owing to a complementarity of areas (Ullman, 1980, 15–18).

4.2.4. Study area

The interaction in terms of obsidian exchange is investigated at two different Early Bronze Age 1 sites in western Anatolia. The first, Çukuriçi Höyük (figure 4.1, #13), a settlement dating from the Neolithic to the Early Bronze Age, has been excavated since 2006. It is located in a tributary valley at the mouth of the Küçük Menderes river. The second is Yeni Yeldeğirmentepe (figure 4.1, #48) located within the alluvial plain of the Bakırçay river. The site was the subject of a field survey in 2008 and 2009 and shows clear traces of Early Bronze Age occupation (Horejs, 2010). Of course the different methods of investigation—survey and excavation—at the two sites offer different degrees of insight, but the results achieved are noteworthy and will be discussed. Moreover, the results from Yeni Yeldeğirmentepe are taken as a selected case study and should be understand as pars pro toto for all Early Bronze Age 1 sites in the Bakırçay valley analysed and published so far (Horejs, 2010).

The general environmental characteristics at both sites are comparable (Erol, 1983, 73–86). Both are characterised by a temperate climate, classified as Cs after Köppen & Geiger, with wet, mild winters and hot, dry summers (Kottek et al., 2006, 261). These present-day general climatic characteristics are considered to be similar to the climatic characteristics of the epoch in focus (Schulz and Paul, 2002, 46). In combination with fertile Fluvisols in the alluvial plains and valleys (Spaargaren, 2008, 281) and Rubefacient or Chromic Cambisols and Luvisols along the slopes (Walter and Breckle, 1991, 12–14), the area is favourable for agricultural production.

On the local scale, Yeni Yeldeğirmentepe is located in the midst of the flood-prone Bakırçay alluvial plain. Sedimentological investigations indicate a meandering river system in the vicinity of the settlement during its time of occupation (Schneider et al., 2010, 185; Seeliger et al., 2011, 61). Owing to the stream's high sediment load, low stream velocity, seasonal floods and channel shifts, highly dynamic geomorphological conditions prevailed (cf. Gordon et al., 2004, 184; Marsh, 1987, 423–427). This is confirmed by sedimentological investigations at Yeni Yeldeğirmentepe, where at least 3.5 m of alluvial sediments have been deposited since its colonisation (Seeliger et al., 2011, 61).

By contrast, Çukuriçi Höyük is located in a tributary valley of the Küçük Menderes. Its location on an alluvial fan (Grund, 1906, 8–9; Horejs et al., 2011, 37–38) makes the area suitable for agricultural use, with water from the hilly hinterland but without an excessive flood risk.
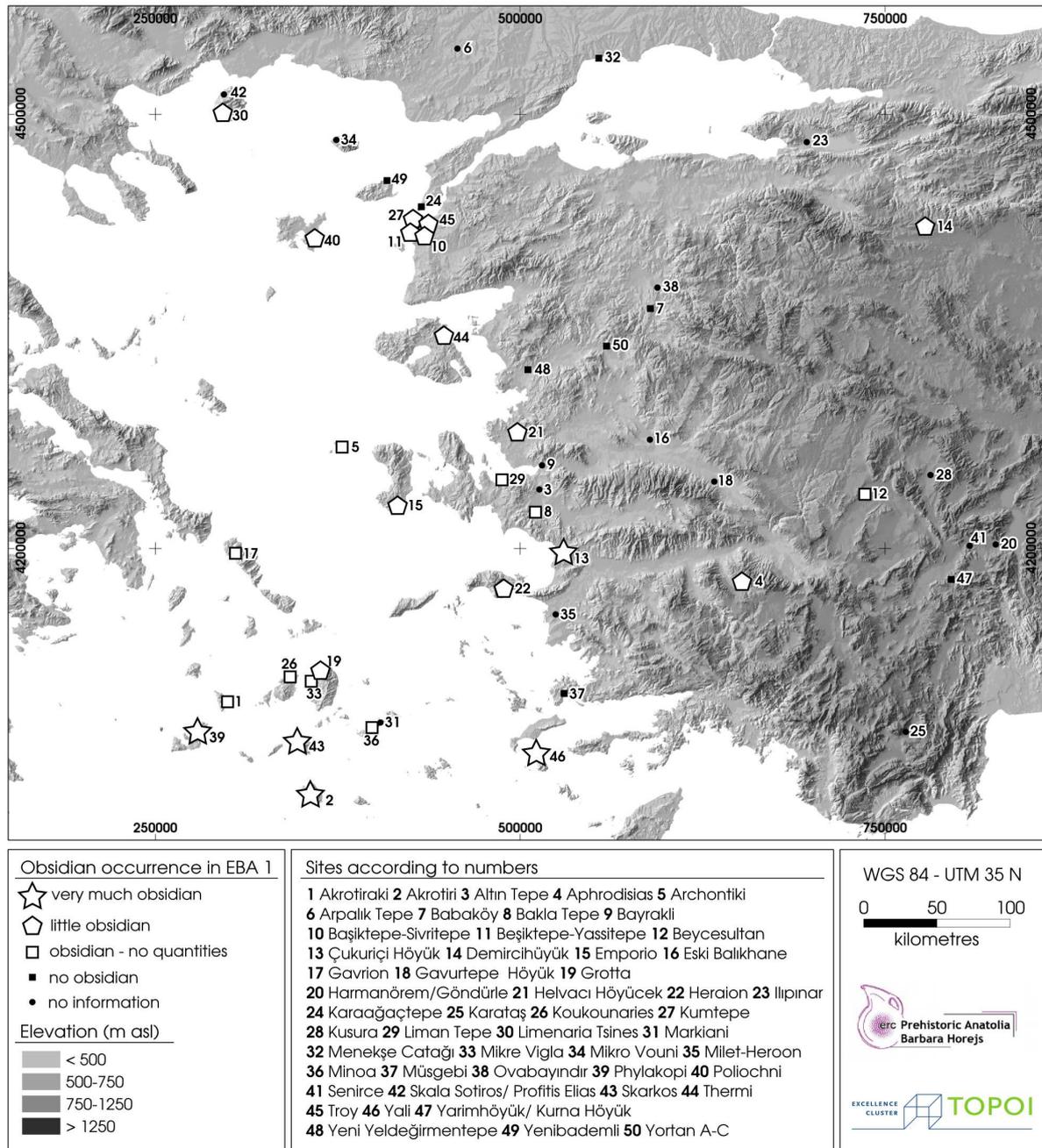
Figure 4.1.: Obsidian occurrence in Early Bronze Age 1 in West-Turkey (Based on Alram-Stern, 2004 (for Akrotiraki); Shelford et al., 1982 (for Akrotiri); Leurquin, 1986 (for Aphrodisias); Alram-Stern, 2004 (for Archontiki); Erkanal and Özkan, 1999 (for Bakla Tepe); Şahoğlu, 2008 (for Bakla Tepe); Pernicka et al., 1994 (for Başiktepe-Sivritepe); Korfmann, 1989 (for Beşiktepe-Yassitepe); Lloyd and Mellaart, 1962 (for Beycesultan); Bergner et al., 2009 (for Çukuriçi Höyük); Baykal-Seeher, 1996 (for Demircihüyük); Hood et al., 1981 (for Emporio); Alram-Stern, 2004 (for Gavrion); Renfrew, 1972 (for Grotta); Şenyürek et al., 1950 (for Helvacı Höyücek); Kouka, 2012 (for Heraion); Katsarou and Schilardi, 2004 (for Koukounaries); Sperling, 1979 (for Kumtepe); Kouka, 2009 (for Liman Tepe); Kourtessi-Philippakis, 2009 (for Limenaria Tsines); Barber and Hadjianastasiou, 1989 (for Mikre Vigla); Cherry and Torrence, 1984 (for Phylakopi); Kouka, 2002 (for Poliochni); Marthari, 1990 (for Skarkos); Lamb, 1936 (for Thermi); Gatsov, 1998 (for Troy), Gatsov, 2002 (for Troy); Georgiadis, 2008 (for Yali); Hüryılmaz, 2008 (for Yenibademli); Kamil, 1982 (for Yortan); elevation data based on Jarvis et al., 2008)

Furthermore, owing to the high sediment load of the Küçük Menderes, its delta prograded towards the sea during the Holocene. The settlement of Çukuriçi Höyük was founded in the direct vicinity of the sea, with local supplies from a hinterland several square kilometres in size (Horejs et al., 2011, 37; Kraft et al., 2003, 370–371 and their figure 8).

4.2.5. Assessment of interaction potential based on landscape features

Interactions imply a production surplus to facilitate the energy effort of exchange that is related to landscape features (Sieferle, 1997, 95). Owing to its universal accessibility, a digital elevation model (DEM), which is a continuous representation of the relief, is applied to derive these landscape features and the general landscape character. Relief is an expression of potential energy, reflecting and controlling environmental dynamics on human-relevant time scales (Ahnert, 2003, 12–14). With regard to the continuous character of relief and to avoid crisp logic classifications of the parameters, maps of landscape character are created using a fuzzy logic system (further general information regarding fuzzy logic in Demicco, 2004; Klir and Wierman, 1998). The fuzzy logic system utilises DEM-derived parameters (a) slope, as representative for relief character, and (b) modified topographic index (MTI) (based on Manfreda et al., 2011; MTI is an advancement of the Topographic Index developed by Beven and Kirkby, 1979), representing areas of converging water as well as liability to floods (figure 4.2; see appendix A.1 for further information). A combination of these parameters yields four different fuzzy classes that represent different landscape features. The landscape features are distinct regarding their most energy-efficient utilisation and hence their potential for surplus production.

4.2.6. Results

The occurrence and distribution of the different fuzzy classes, representing specific landscape features, are similar in both regions (figure 4.3, table 4.1): large areas are categorised as "flat, wet", representing the wetlands or floodplains. The areas surrounding the floodplains are categorised as "steep, dry", representing mountainous or hilly areas, sensitive to erosion. At the intersection of both, the landscape is categorised as "flat, dry" or "flat-gentle inclined, moist", representing footslopes as well as alluvial fans. The majority of Early Bronze Age settlements are typically located in this transition zone between floodplains and mountains (figure 4.3). On the basis of relief analysis, different forms of the most energy-efficient utilisation are delineated, leading to different potentials for surplus production (table 4.1).

Yeni Yeldeğirmentepe is located within the flat and wet area (figure 4.3a, #10). The potential for surplus production is medium. By contrast, Çukuriçi Höyük is located in a flat-gently inclined and moist area that is typical of an alluvial fan with a high potential for surplus production (figure 4.3b, #2).
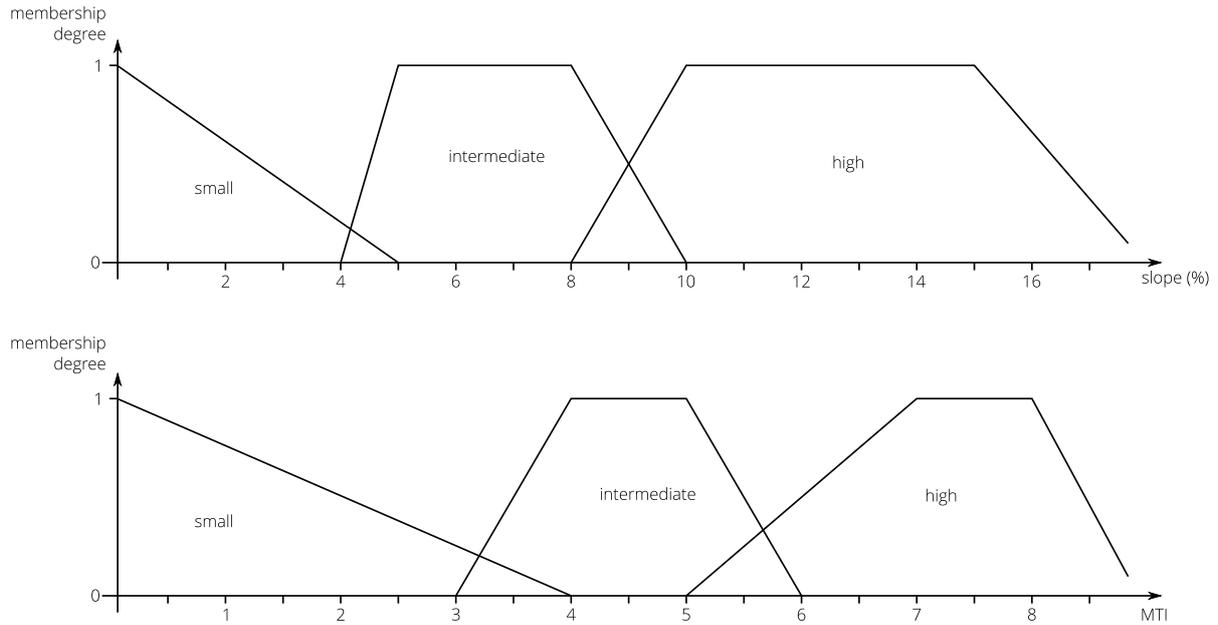
Figure 4.2.: Graphical representation of the three membership functions of the fuzzy sets small, intermediate, high, for DEM derived parameters slope (top) and MTI (bottom). Fuzzy sets for slope are defined on the basis of empirical studies showing that below 5% slope areas are suitable for agricultural purposes and erosion is a minor problem (fuzzy set small), 8% is the critical slope value to build houses and erosion significantly increases (fuzzy set intermediate), and above 10% erosion is a severe problem (fuzzy set high) (Leser, 1968, 38; Cooke and Doornkamp, 1974, 361; Pécsi, 1985); Fuzzy sets for MTI are based on expert knowledge representing mountains and areas of little water convergence in the small set; intermediate values, representative e.g. for alluvial fans in the intermediate set; and flood prone areas of strong water convergence in the high set

Table 4.1.: Fuzzy classes, their representative landscape features, their most energy-efficient utilisation, and their potential for surplus production, with regard to the needs of an agricultural settlement, i.e. in order of importance: water (not mentioned here), agricultural land, grazing land, fuel (i.e. wood), and building material (Chisholm, 2007, 115–116)

Fuzzy class	Landscape features	Most suitable, energy efficient utilisation	Potential for surplus production
Flat, wet	Wetlands; floodplain	Grazing land; fuel, agricultural land	medium
Steep, dry	Mountainous areas	Fuel; building material	low
Flat, dry	Footslopes	Agricultural land; housing; grazing land	high
Flat-gently inclined, moist	Alluvial fans and footslopes	Agricultural land; housing; grazing land	high
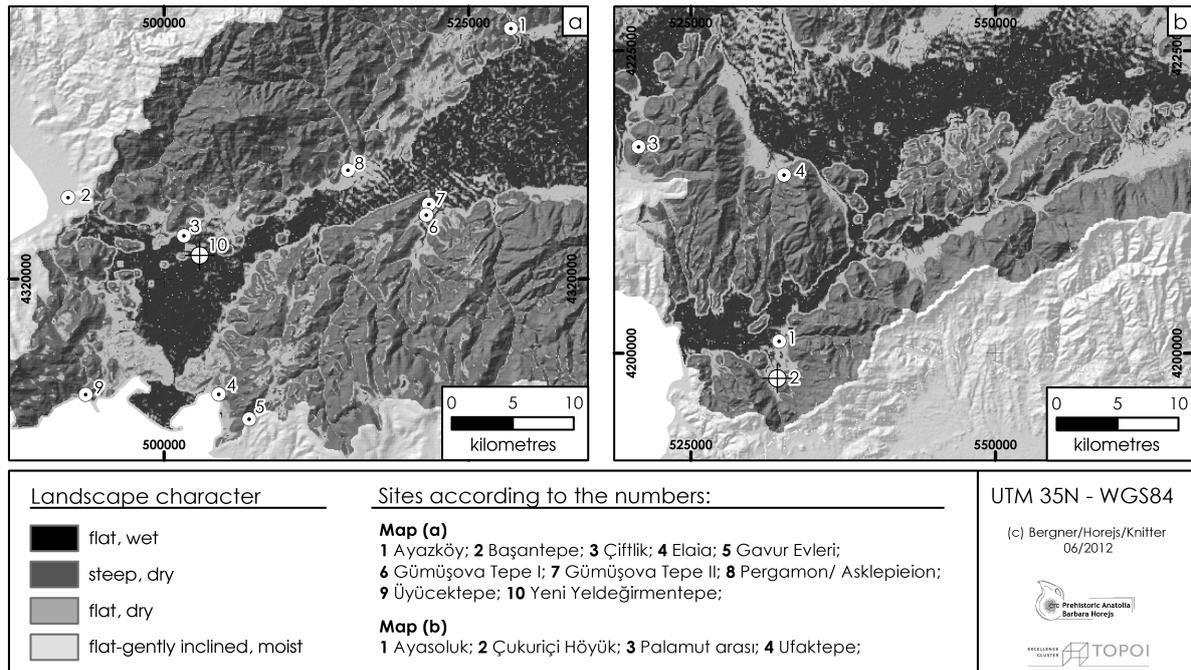
Figure 4.3.: Landscape character map of the two selected study sites showing the location of Yeni Yeldeğirmentepe within a flood-prone area (a). By contrast, Çukuriçi Höyük is located on an alluvial fan, showing well-drained and flat- to gently inclined slopes (b). (sites in (a) Horejs, 2010; sites in (b) Horejs et al., 2011; shaded relief based on elevation data from Jarvis et al., 2008; calculations using Grass GIS software, version 6.4.2 of GRASS Development Team 2011)

4.2.7. Discussion

As indicated by the natural environmental characteristics and the results of the fuzzy analysis, Yeni Yeldeğirmentepe has a low interaction potential due to its location in a flood-prone area of high fluvial dynamics. This is confirmed by the archaeological evidence, as Yeni Yeldeğirmentepe shows no signs of any imports. Its lithic assemblage indicates only production of chert tools out of local materials, mainly flakes. The raw material seems to originate from a local source as implied by some recovered raw nodules. Local obsidian sources cannot be confirmed (Horejs, 2010, 61).

By contrast, Çukuriçi Höyük has a high interaction potential as indicated by the results of the fuzzy analysis and the overall natural environmental characteristics. Hence, signs of regional or supra-regional interactions occur. The archaeological evidence indicates that the Early Bronze Age layers at Çukuriçi Höyük show multiple signs of copper metallurgy such as moulds, ovens, ingots and metal finds (Horejs et al., 2011, 48–49). Furthermore, some standardised weights point towards participation in a wider exchange network (Rahmstorf, 2006, 67–73, 81). Roughly two thirds of the chipped stone objects were made of obsidian with an allochthonous origin (Bergner et al., 2009, 251). Production waste and cortical specimens indicate that the raw material was delivered to the settlement as pre-shaped cores or raw nodules and was knapped on site. Production mainly consisted of regular blades and bladelettes. Chert is available in the vicinity of the settlement and was also used. Neutron Activating Analyses show that most of the obsidian came from the Cycladic island of Melos and only small quantities from central Anatolian sources (Bergner et al., 2009, 252–2533).

With regard to the regional characteristics, assessment of the interaction potential shows contemporary settlements in the Bakırçay valley with comparable characteristics to those of Çukuriçi Höyük. Nevertheless, obsidian as an exchange-indicating parameter is not found there (Horejs, 2010, 62). This indicates that not just the local interaction potential based on the natural environmental characteristics is important but also the location in the supra-regional networks. In this regard, the location of Çukuriçi Höyük at one of the main routes of interaction and communication between Inner Anatolia and the Aegean may be seen as advantageous (cf. Rahmstorf, 2006; Şahoğlu, 2005). Because of the high interaction potential, the settlement profited from its local locational advantages based on the intersection of seaward and landward traffic. Hence, a locally caused high exchange potential is supplemented by complementary supra-regional connections. Accordingly, Çukuriçi Höyük can be interpreted as a gateway location in the early third millennium BC (Burghardt, 1971) that allots goods from regional and supra regional networks (figure 4.5b). By contrast, Yeni Yeldeğirmentepe and the other Early Bronze Age settlements in the Bakırçay valley are not integrated in the network of obsidian exchange. This is surprising, because the modelled exchange potential at some locations in the valley, e.g. Elaia (figure 4.3a, #4), is comparable to Çukuriçi Höyük, and obsidian as an indicator of this exchange is present at Thermi on Lesbos (figure 4.1, #44) in the direct vicinity,
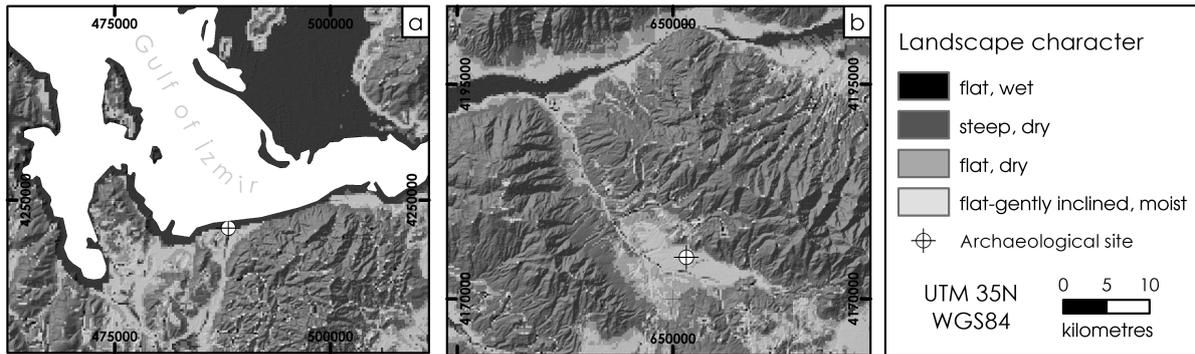
Figure 4.4.: The location of Early Bronze Age sites Liman Tepe (a) and Aphrodisias (b) with regard to their landscape character. Both sites are located in flat-gently inclined, moist areas, showing suitable conditions for local supply. Please note that (a) shows the modern coastline. Especially the north-eastern part of this area was markedly different throughout prehistory owing to the less developed delta of the Gediz river (shaded relief based on elevation data from Jarvis et al., 2008; Calculations using Grass GIS software, version 6.4.2 of GRASS Development Team 2011).

though in very small amounts. One reason might be the marginality of the Bakırçay valley in terms of general supra-regional exchange patterns that run farther north, via Demircihöyük, and south, via Beycesultan and Çukuriçi Höyük (cf. Rahmstorf, 2006; Şahoğlu, 2005). Even possible erratic findings of obsidian in the Bakırçay region may be seen as destination points in the exchange network of obsidian and not as an indicator for a gateway. Moreover, our analyses of general occurrence demonstrate that the whole northeast Aegean region including the Troad is integrated in this exchange network, where obsidian is present at almost all sites (figure 4.1).

An expansion of the approach presented here may lead to a better understanding of the processes that caused the pattern of obsidian findings. For example, it may be hypothesised that Liman Tepe (figure 4.1, 29; cf. Erkanal, 2008b; Şahoğlu, 2008), whose interaction potential is comparable to that of Çukuriçi Höyük (compare figure 4.3b and figure 4.4a), is also a gateway location. In this role, Liman Tepe might integrate settlements of its hinterland, such as Bakla Tepe (figure 4.1, #8; cf. Erkanal, 2008a; Şahoğlu, 2008), into the obsidian exchange network (figure 4.5b). Aphrodisias (figure 4.1, #4) is an example of locations lacking access to the sea: the landscape features show a high interaction potential of the settlement (figure 4.4b; Joukowsky, 1986, 19). The settlement's location at the intersection between the Aegean and Inner Anatolian cultural spheres may have constituted its integration into the supra-regional network. In combination, Aphrodisias may hypothetically have acted as a gateway location between these cultural spheres (figure 4.5b).

4.2.8. Conclusions

This study investigates the reasons for the differences in the distribution of allochthonous obsidian in western Anatolia during the Early Bronze Age 1 in the early third millennium BC. On the premise that specific landscape features have a different suitability for surplus
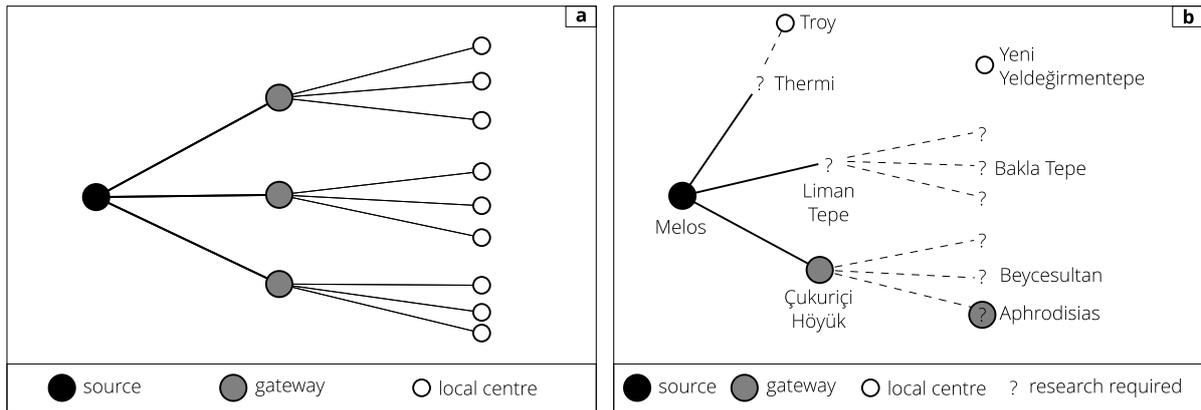
Figure 4.5.: (a) Theoretical concept of gateway locations that serve as focal points for their complementary region to connect them to larger scaled networks; (b) Sketch of Early Bronze Age 1 obsidian exchange network distinguishing between sites functioning as source, gateway and local centre. Confirmed connections are indicated by solid lines, putative connections by dotted lines.

production, we analysed the exchange potential of these locations. Comparative analysis of Yeni Yeldeğirmentepe and Çukuriçi Höyük shows that the more suitable an area was for surplus production, the larger was the settlement's ability to be involved in exchange networks. Nevertheless, this should also be linked to the embedding of the respective settlement in terms of supra-regional networks of communication and interaction. Together, these insights can be used to sketch the obsidian exchange network throughout the Early Bronze Age 1 in western Anatolia. Further archaeological research will lead to a more detailed knowledge regarding other sites epoch in focus (a) to prove the connection of exchange potential and participation in exchange networks and (b) to illustrate the importance of supra-regional location in terms of gateway functions and general integration of settlements.

4.2.9. Acknowledgements

4.3. Settlement location and interaction potential on the local scale – Short communication of investigations in the Gümüş catchment

As it was shown in Knitter et al. (2013), the Bakırçay valley appears to be located marginally in terms of regional to supra-regional exchange. Nevertheless, there are many traces of settlement activities that point to a local organization of settlements. An investigation of these might offer insights in the distribution and concentration of interactions. To assess the influence of environmental parameters on this scale, a small tributary valley of the Bakırçay was chosen to investigate the location and organization of settlements.

The study was conducted during a field trip in summer 2012 in collaboration with archaeologists of the Austrian Archaeological Institute. The investigations revealed traces of settling activity in the lower part of the catchment of the Gümüş stream. These date to the Late Chalcolithic period, the Early and Late Bronze Age, the Antique as well as Byzantine periods (cf. Horejs, 2011a). Two of these sites were subject to detailed archaeological surveys and named for now Güm1 and Güm4/GümX.

Today, the area is occupied by a few villages of mainly farmers and shepherds. Perlite, a natural volcanic glass with distinctive concentric cracks and relatively high water content, is exploited in the catchment (McCall, 2005). Perlitic sand, as weathering product of the bedrock, has a shiny greyish-white colour what may constitute the stream's name Gümüş, i.e. silver. More detailed information regarding the general environmental characteristics can be found in Knitter et al. (2013) and chapter 3.2.

4.3.1. General geomorphological characteristics of the lower Gümüş catchment

From the headwater area to the village Musacalı, the streams of the catchment are deeply incised, creating v-shaped floodplain valleys. North of Musacalı the valley widens to a through-shaped or basin valley. In this part the modern stream is fixed within a trapezoidal profile (figure 4.10). The floodplain shows remains of abandoned stream beds as well as slightly higher elevated areas characterized by fine sediments and clusters of boulders that are indicative of a former braided pattern (figure 4.6).

The hills are characterized by outcropping bedrock and commonly edge-rounded, egg-shaped boulders as weathering products due to block separation and hydrolysis (Strahler, 1975, 371, 398, 402). The piles of these edge-rounded blocks create colluvia at the base of the slopes. Piles in midslope positions are connected to changes in bedrock from basaltic-andesitic to underlain tuff or lapilli tuff, causing changes in inclination (Yılmaz et al., 2000, 356, 358, 361; Yılmaz et al., 2001, 252–253).

The transition from the hills to the stream's floodplain is characterized by straight or concave slopes that are overlain by colluvia. Fine-grained sediments dominating this area. The stream's
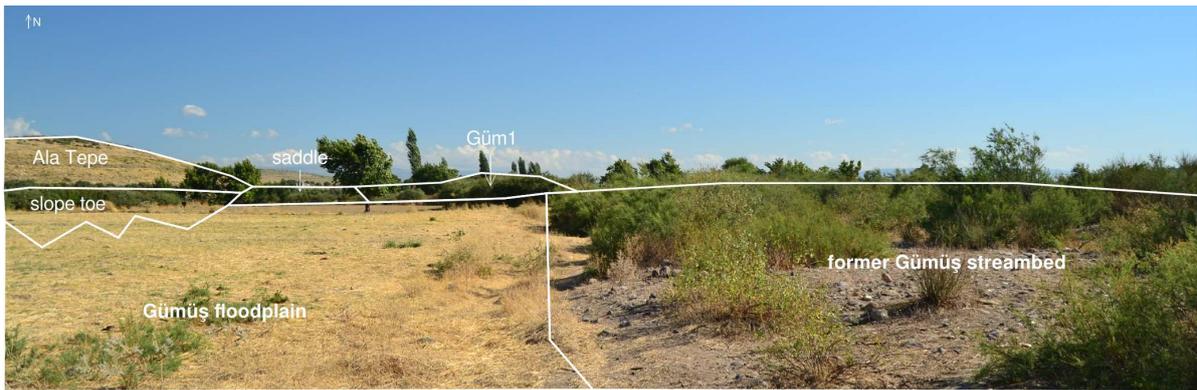
Figure 4.6.: Gümüş floodplain and remains of the braided river

floodplain varies in extent, depending on the width of the streambed as well as the extent of colluvia. North of settlement Güm4 the floodplain has its largest extent (figure 4.7).

4.3.2. Geomorphological situation of the prehistoric settlement locations

Settlement Güm 1

Güm1 is located on a limestone spur in the north-eastern extension of the Ala Tepe (figure 4.6, 4.8, and 4.9). The Gümüş stream flows in direct vicinity of the settlement. Due to the bedrock underlying the settlement and its elevated position it was sheltered from the stream's erosional forces. The surroundings of the settlement—except the saddle to the Ala Tepe—are flat and on the level of the stream's floodplain. Only the south-western hinterland shows a narrow slope toe, whose general concave profile is occasionally disturbed by colluvia (figure 4.6 and 4.10). With respect to fluvial dynamics, the northern, southern, and eastern surroundings of the site are prone to floods of the Gümüş stream, while the area southwest of the site is less liable due to its elevated position. The land's suitability for tillage is directly related to these fluvial dynamics: during the time of the settlement's occupation the stream was braided, not channeled, and hence floods were more pronounced. In combination with a frequently changing streambed a complex of intertwined erosion and accumulation develops, whose dynamics prohibit extensive agricultural cultivation.

Settlement Güm 4

Güm4 is located on the northern end of an undulating limestone ridge, which runs parallel to the Ala Tepe. At the southern end, the settlement is connected to the Ala Tepe via a saddle (figure 4.11 and 4.12). The Gümüş stream flows in direct vicinity east of the site. Protected by the limestone ridge, this area was not affected by the stream's erosional forces. West of the settlement is a small sub-catchment, whose watershed is formed by the limestone ridge, the saddle, and the Ala Tepe (figure 4.11). This configuration leads to a higher elevation of Güm4's
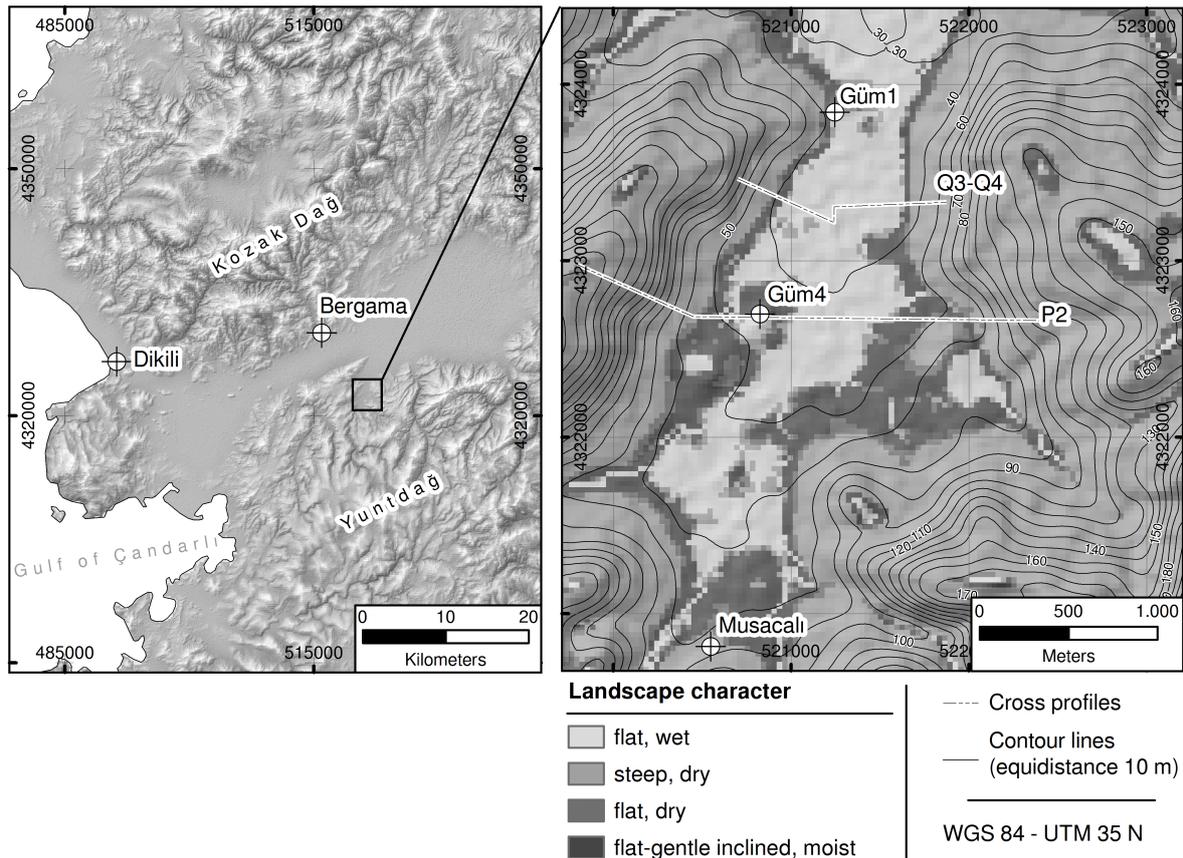
Figure 4.7.: (left) General overview of the study area's location; (right) Map of landscape character resulting from a fuzzy logic system (see chapter 4.2 and appendix A.1 for more information regarding the algorithm). The archaeological sites Güm1 and Güm4 are both located on the *flat to gentle inclined and moist* class, though the proportion of the area around in Güm1 is much smaller than around Güm4. Large parts of the flat area north of Musacalı are classified as *flat, wet* illustrating the high liability to floods in this region (elevation data based on ASTER GDEM, version 2, downloaded 2012-08-14)

western surroundings in contrast to the east (see level in figure 4.11 and 4.13). Converging water west of the settlement flows through the level (figure 4.13) into the Gümüş. Due to its small size and sheltered location—in contrast to areas east of the settlement that are directly influenced by the Gümüş stream—this area is less prone to floods, hence a suitable area for land use practices.

4.3.3. Assessment of the relief's suitability

It is presumed that prehistoric settlements within the lower Gümüş watershed correspond to rural settlements, even if they offer additional functions like cult or craft. There are preferred locations for such settlements that may offer the following prerequisites (in order of their importance): (a) water availability (but absence of flooding), (b) agricultural lands, (c) grazing lands, (d) timber and fuel, (e) building material and resources (Chisholm, 2007, 114–116).
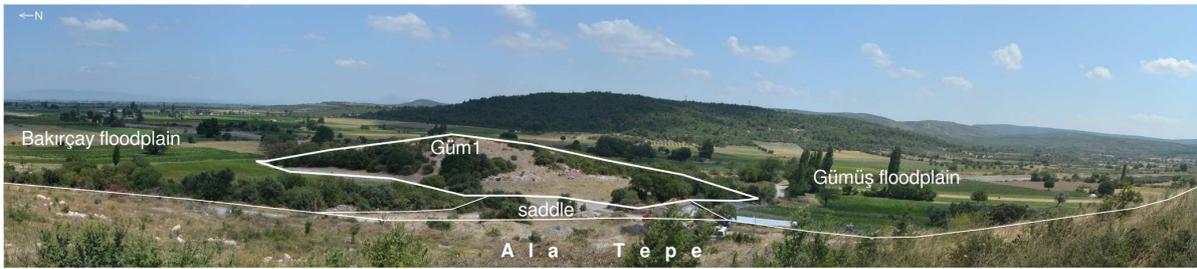
Figure 4.8.: Landscape around Güm1, viewing from Ala Tepe to the East

Figure 4.9.: Eastern edge of Güm1 showing its limestone basement and location in direct vicinity of the Gümüş stream

Further factors involve (f) level sites to build on, (g) sunny, south-facing slopes, and (h) potential for trade and commerce (Nagle, 2000, 248).

Method

Based on an analysis of the relief characteristics it is possible to assess the suitability of the area regarding these settlement prerequisites. For this purpose a fuzzy logic system of morphometric parameters (based on ASTER GDEM, version 2, cellsize 30x30 m) is created. It is aimed to identify potentially suitable settlement areas based on the assumption that flat and gentle inclined slopes as well as areas of less liability to floods are preferred settlement locations (further information regarding the methodology and the fuzzy logic system can be found in Knitter et al., submitted; chapter 4.2; and appendix A.1). For this purpose slope and modified topographic index (MTI) are calculated. The latter is an indicator for the delineation of areas exposed to floods (Manfreda et al., 2011, 8). MTI allows distinguishing upper slopes, midslopes, slope toes, and alluvial fans or colluvia. Especially the last three features are important, as these locations are relatively flood save, gently inclined to allow constructions, and better drained than floodplains. Within the fuzzy logic system slope and MTI are combined to classes that can be seen as representative for different landscape utilizations (table 4.1 in chapter 4.2).
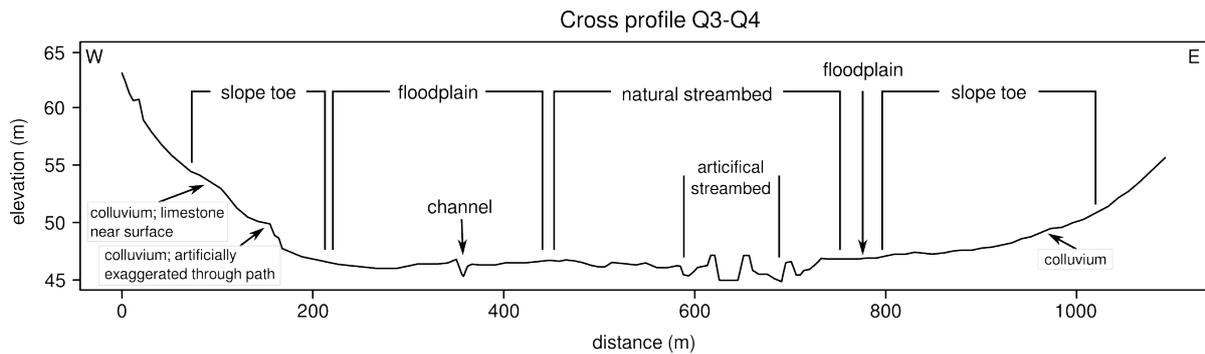
Figure 4.10.: Cross profile south of Güm1 from west to east through the floodplain of Gümüş stream. Besides the trapezoidal profile of the modern, channelized streambed, colluvia at the slope toes get obvious. The natural streambed shows no significant steps to the surrounding floodplain (data is based on field measurements conducted in August 2012)
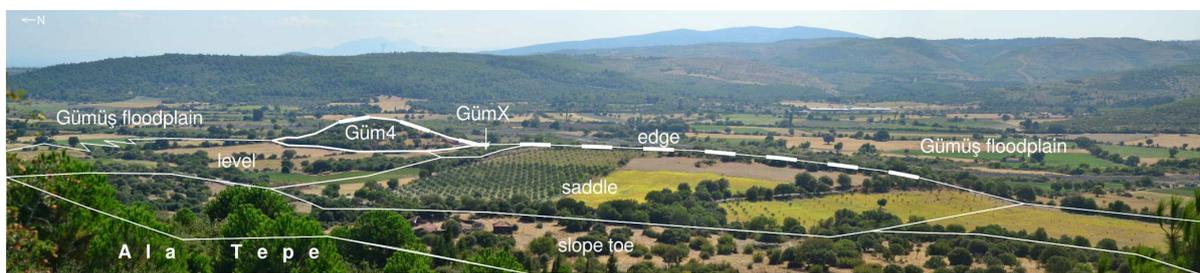

Figure 4.11.: Landscape around Güm4, viewing from Ala Tepe to the East

Results and discussion of the assessment of the relief's suitability

The results of the fuzzy analysis allow to distinguish four zones of distinct landscape character (figure 4.7). The mountainous areas are classified as *steep, dry* (based on field observations, the classification results for the hilltops have to be regarded as artifacts, resulting from the uncorrected and low resoluted data source). The basin is classified as *flat, wet*, illustrating an area of high liability to floods. The transition-area between the classes *steep, dry* and *flat, wet* differs in extent and was classified as *flat, dry* as well as *flat-gentle inclined, moist* (the small fraction of areas classified as *flat, dry* is again a result of the low resoluted data source). The areal extent of these two classes is most pronounced north of Musacalı, around Güm4, and on the eastern side of the valley widening opposite to Güm4 (figure 4.7). Regarding the location of the settlements, it can be seen that Güm4 is located in a more suitable area, with a larger hinterland of favourable relief characteristics than Güm1.

Since the areas classified as *flat-gentle inclined, moist* and *flat, dry* are interpreted as suitable for settling activities, additional surveys were conducted there. They led to further discoveries of archaeological sites, though the majority of these new discoveries were of antique or younger age. Notwithstanding, the occurrence of settlements in these areas indicates that the assumptions about settlement preferences are valid, but not enough to understand the pattern of settlement

Figure 4.12.: Location of Güm4 and GümX on a limestone ridge in direct vicinity of the Gümüş stream as indicated by its former streambed
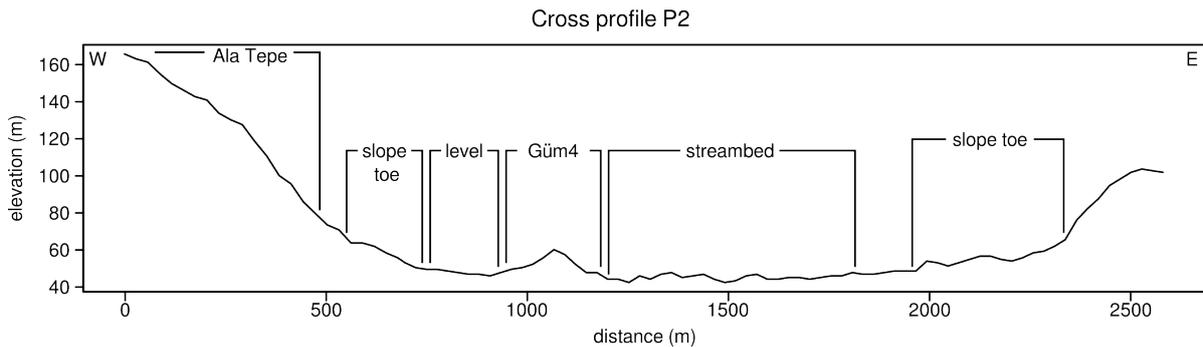
Figure 4.13.: Cross profile from west to east through the Gümüş valley. It becomes obvious that the area west of Güm4 is higher elevated than in the east, where the stream is located (see also figure 4.12) (elevation data based on ASTER GDEM, version 2, downloaded 2012-08-14)

occurrence throughout the area (A complete survey would need to include the mountainous areas as well as the stream's floodplain to prove the smaller suitability of these areas. Nevertheless, settlements at mountainous locations might have been eroded and settlements in the stream's floodplain might have been buried. Therefore, a final verification of the stated hypothesis based on survey methods alone is difficult.).

4.3.4. Conclusions

The investigation in the lower Gümüş catchment offered first insights into the natural environmental dynamics that influence the suitability for settling. Based on field observation and GIS analyses, different zones of settling and land use suitability were detected. It is shown that the prehistoric settlements Güm1 and Güm4 are located in flood save locations (figure 4.7). Differences arise regarding the liability to floods of the sites' hinterland. While most of the hinterland of Güm1 is on the level of the Gümüş and therefore prone to seasonal floods, the western hinterland of Güm4 is relatively flood save due its higher elevation. These observations are confirmed by the fuzzy analysis.

The combination of favourable relief characteristics in the hinterland and a flood-protected position on a limestone ridge causes the suitability of the location of Güm4. Preliminary results of the archaeolgical investigations indicate that Güm4 is potentially a protourban settlement

with central place characteristics. Furthermore, it might be functionally linked to Güm1 that seems to be the outpost for Güm4 which dominated the basin (Horejs, 2012). The natural environmental conditions at Güm4 and Güm1 are favourable and may have supported their site specific functions. Moreover, future archaeological analyses might explore specific, smaller scaled central functions of the settlements what will be an important contribution to the understanding of the centrality pattern of the region and probably beyond.

4.3.5. Acknowledgements

Central places and the importance of the environment

The case studies presented show that *environment* is the result of integrated spatial processes: It is a function of the different influences of the topological, chorological, and chronological dimension on the local (figure 5.1), regional (figure 5.2), and supra-regional scale (figure 5.4).

5.1. The local scale

From a local perspective, settlements have the highest centrality potential when their locations integrate different ecological-zones or metabolic regimes—i.e. the topological characteristics of the environment fulfill the requirements of the settlements. This is proven by empirical analyses (e.g. Chisholm, 2007; Weichhart, 1978; Antrop, 2000) as well as the centrality analyses of Çucuriçi Höyük and Yeni Yeldeğirmentepe (Knitter et al., submitted; Knitter et al., 2012; chapter 4).

Central places serve their surroundings with goods and services. Thus, there is always a complementarity between the regions inside and outside the zone of high centrality potential. Intervening opportunities and affordable distances are important when there are more potential central places than settlements that can be served by them. In this regard, the hitherto present central places avoid the development of new ones, even if the environmental conditions are suitable. These aspects are covered by the chorological and chronological dimension (figure 5.1). In essence, all three dimension have to be treated as interdependent on the local scale.
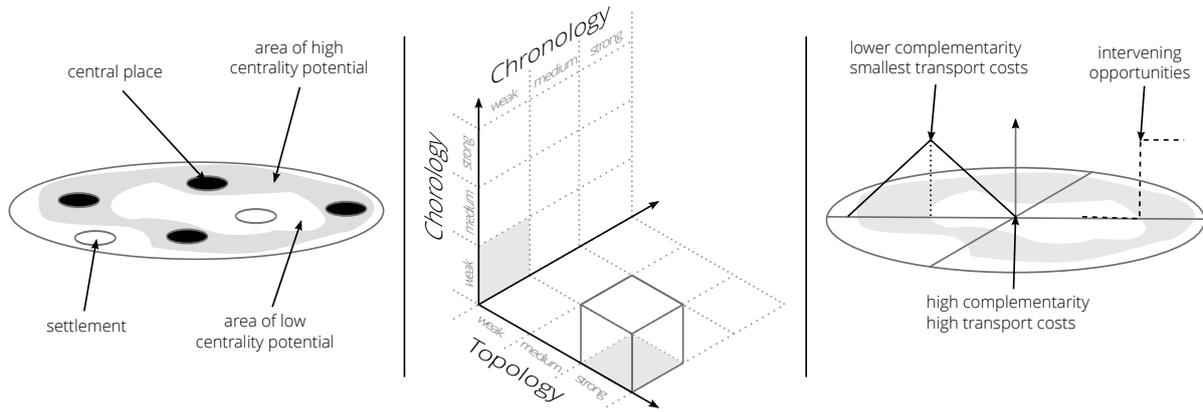
Figure 5.1.: Centrality potential on the local scale

5.2. The regional scale

On the regional scale the centrality potential is highest at the transition between two different areas that are internally homogeneous (figure 5.2). Intervening opportunities are present within the transition area, steering the location of emerging central places.
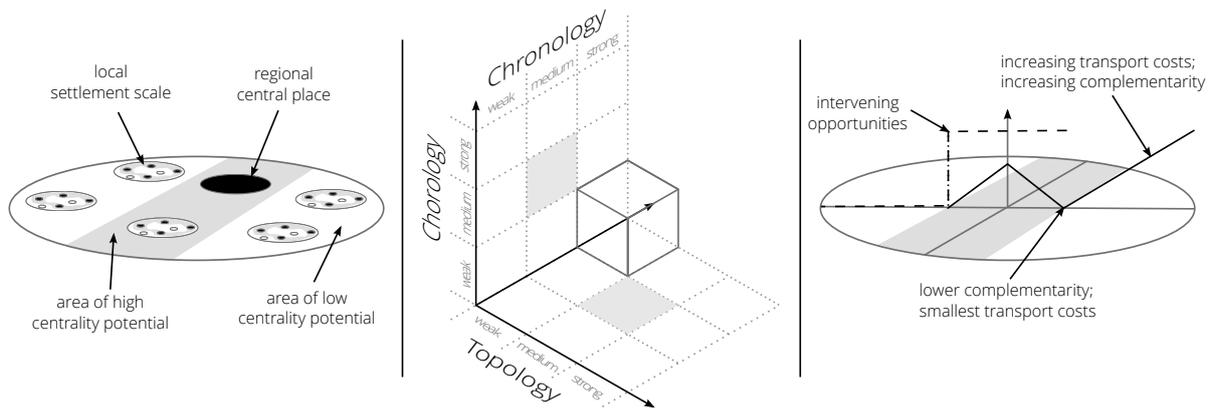
Figure 5.2.: Centrality potential on the regional scale

The environmental characteristics are indirectly able to create such areas of high centrality potential: Depending on the characteristics of the natural environment—e.g. climate, soils, relief—the societal metabolism is different (Sieferle, 1997, 120). Distinct cultural features in combination with different societal metabolisms lead to specific spatial organizations and artifact productions of humans. This specific organization of societies can also be described by Godelier's term *infrastructure* that is "(...) the combination of the different material and social conditions which enable a society's members to produce and reproduce the material means of their social existence" (Godelier, 1986, 130). *Infrastructure* is comprised of (a) the "(...) determinate ecological and geographical conditions (...)", (b) the productive forces, and (c) the relations of production (Godelier, 1986, 130).

Hence, differences in the natural environment are able to produce complementaries between different regions, since it influences the societal organization. For example, the 200 mm isohyet is a border that determines the modes of subsistence between rainfed agriculture and agriculture that is only possible based on irrigation. The different characteristics lead to different forms of societal organization with a majority of farmers in areas receiving more than 200 mm precipitation or along rivers, suitable for irrigation, and with a majority of pastoralists or nomads in areas of less than 200 mm precipitation (e.g. Stier et al., 1956, 41). The relation of complementarity and affordable distances is largest at the transition between natural regions, causing a zone of high centrality potential. Here gateways are able to emerge, integrating these specific societies—as it was shown in the centrality analysis of Aleppo (Knitter et al., in press; chapter 2.2). The study around Aleppo shows also the influence of intervening opportunities, since there was always just one central place in the region throughout history—Ebla (cf. Pettinato, 1976), Chalkis (cf. Benzinger, 1899; Whitcomb, 1999), or Aleppo.

Differences in the societal organization based on natural environmental differences are also observable between the humid-temperate West Anatolia and the arid Inner Anatolia (cf. Wenzel, 1933; Banse, 1919). Hence, it might be assumed that there are favourable locations for the development of central places at the transition between different natural regions (figure 3.1), whose centrality is based on their function as gateway between two societally different organized areas. The repetitive occurrence of central places at this transition supports this argument—in prehistory Beycesultan (Lloyd and Mellaart, 1962), during antiquity Apameia (Strabon XII, 8, 15 in Hamilton and Falconer, 1856, 333; Strobel et al., 2012), in modern times Afyonkarahisar or Isparta (figure 5.3).
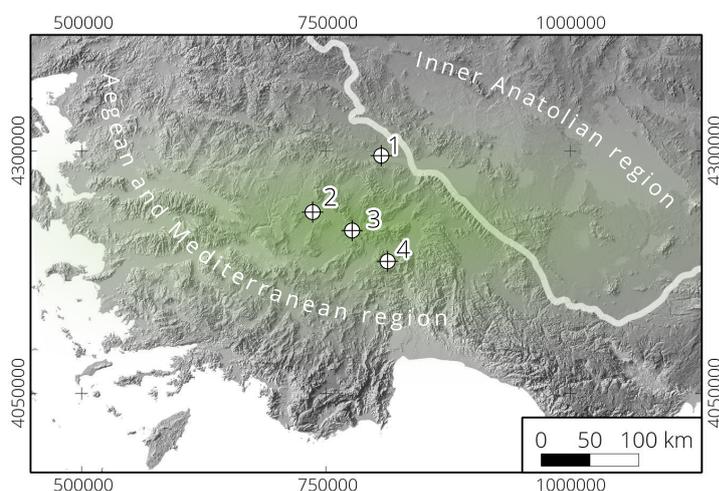
Figure 5.3: Gateway locations at the transition between the temperate Aegean and Mediterranean Natural Region and the arid Inner Anatolian Natural Region. The green shade corresponds to the area integrated by the different gateways (settlements according to the numbers: 1 - Afyonkarahisar; 2 - Beyesultan; 3 - Apameia; 4 - Isparta; Natural regions based on Erol (1982a,b); elevation based on Jarvis et al. (2008); spatial reference system: WGS84, UTM 35 N)

According to these aspects, the topological, chorological, and chronological dimension are interdependent, though the reasons differ from those at the local scale: regional conditions of culture and nature shape the pattern of human interaction.

5.3. The supra-regional scale

At the supra-regional scale networks of communication and exchange cause the centrality of a place (figure 5.4)—as it is shown for Aleppo (Knitter et al., in press; chapter 2.2) and Ephesos (Knitter et al., 2013; chapter 3.2). These networks are very large and spread over diverse natural environments and cultures since the early history (Sherrat, 2010). Local and regional cultural or natural conditions are of minor importance. Rather, it is the shape of the coastlines as well as the location and direction of mountains that influences the network routes, because these influence the affordability of transport costs. The smaller the number of possible routes, the higher is the persistence of specific routes—as it gets most obvious by passages through mountains (e.g. Küster, 1995, 204–205). The development of a central place along such supra-regional routes of exchange causes intervening opportunities (e.g., resulting from pulling factors due to the development of economies of scale: cf. Ullman, 1973 or Gill and Goh, 2010, 240). Therefore, settlements whose centrality is based on supra-regional exchange are long-lasting: Aleppo or Damascus as two of the world's oldest cities are nodes in the intersection of routes from Africa, Asia and Europe (Knitter et al., in press; chapter 2.2; Wirth, 1966; Issawi, 1988, 159); examples for the long-lasting centrality of sea-side central places are Apaşa and Çucuriçi Höyük during prehistory, Ephesos during antiquity (Knitter et al., 2013; chapter 3.2).
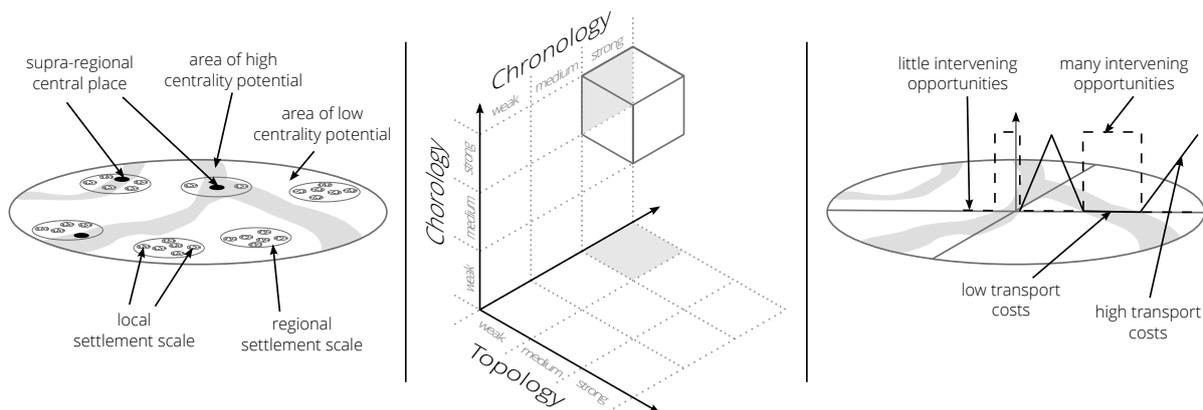
Figure 5.4.: Centrality potential on the supra-regional scale

Accordingly, the characteristics of the chorological and the chronological dimension have a strong influence on the centrality potential, since these steer the intervening opportunities and affordability of transport costs in a network that is based on continuous complementarity. The strong relation between the time of settlement's emergence at a locally suitable location and its subsequent function as a supra-regional exchange node again shows the interdependent character of the topological, chorological, and chronological dimension.

5.4. The importance of environment – a matter of scale

The environmental characteristics that are different at every spatial scale influence the emergence, development, and persistence of central places. Nevertheless, the assessment of specific environmental features is difficult because of the interdependent character of the topological, chorological, and chronological dimension on different spatial scales. For instance, the interdependence of the spatial scales and dimensions may cause the emergence of central places at locations, whose environmental characteristics are unsuitable and such central places can avoid the development of competing places at environmentally more favourable locations due to their production of intervening opportunities. Hence, each central place has its own history that has to be studied in order to understand the reasons for the concentration of interactions at a specific location and to evaluate the influence of environmental characteristics.

It is also possible to describe the discovered characteristics in another way, integrating central place theory (chapter 1.5) and central flow theory (see below and chapter 3.2) and pointing out their complementary character (for an attempt to model these aspects see appendix A.2).

On the local scale, the concentration of interaction is influenced by the exchange potential of a settlement that can be related to natural environmental characteristics in the settlement's vicinity: The higher the exchange potential of a settlement is, the more services it is able to offer (Knitter et al., submitted; Knitter et al., 2012; chapter 4). Hence, the more central is the settlement in terms of the central place theory.

On the regional and supra-regional scale the concentration of interaction is based on exchange and cooperation between places—i.e. its chorological characteristics. This corresponds to the theory of central flows. Central flow theory refers to city networks that are constituted by the interlocking of cities via specialists in the course of their economic activities (Taylor, 2004; Taylor et al., 2010, 2814). "Vibrant, dynamic cities have always been interlocked by 'foreign' commerce—this has been what has made them cosmopolitan" (Taylor et al., 2010, 2814). Thinking of raw material exchange in prehistory, trading specialists might have produced such an interlocking network of places (regarding obsidian exchange e.g. Perlès et al., 2011, 47). In the context of central flow theory, these specialists have a vested interest in all places being successful. In the end, this reinforces once established patterns of exchange between central places in different regions.

The complementarity of central place and central flow theory is shown in the historical development of urban places. During their growth, they interact with (a) their surroundings, (b) with one another, and (c) with larger sociopolitical units (Hohenberg and Hollen Lees, 1995, 4). Similarly, Jacobs (1970, 35) states that a city does not grow only by trading with its rural hinterland but that it requires a group of cities trading with one another. This shows that both concepts, i.e. central place and central flow theory, are necessary to understand the complex aspects that influence a settlement's centrality and development.

It can be hypothesized that these variables of dynamic urban development are also applicable

to periods that occurred before intense urbanization. This view is based on Jacobs' argumentation of an epigenetic theory of cities that commences with "(...) the idea that a city grows by a process of gradual diversification and differentiation of its economy, starting from little or nothing more than its initial export work and the suppliers to that work. If I am correct, cities radically differ in their growth processes from inert towns and from villages even when they are still as small as towns or villages" (Jacobs, 1970, 129). Most recent publications point to this special character of cities in contrast to towns or villages even in prehistoric periods (cf. Soja, 2001, 2003, 2010; Taylor, 2012). Towns in this regard are determined by aspects of central place theory while cities are the results of processes described by central flow theory (Taylor et al., 2010, 2809–2810). This functional differentiation between places is important, since it allows a more detailed interpretation of central places.

In essence, a place of high centrality—indicated in the real world e.g., by a large amount of exchange indicating material—might be the result of a high interaction potential—i.e. favourable environmental characteristics—*or* an advantageous location within smaller scaled exchange networks. Hence, to be able to interpret the reasons for the centrality of a place it is required to integrate results of local investigations regarding central place aspects and regional to supra-regional investigations regarding aspects of network exchange, i.e. central flows.

Conclusion and Outlook – the relative importance of location

There is an influence of the environment on the formation, development, and persistence of central places. But environmental characteristics do not determine the degree of centrality of a place: Environment—understood as the result of integrated spatial processes—is just one factor in the complex of human spatial organization.

Models of the environmental influence on settling activities and thus on the formation of central places were formulated before by Kohl (1841). The continuous formulation of models and theories—e.g. by Thünen (1910), Weber (1922), Christaller (1933), Vance (1970), Fujita et al. (1999)—implies that none of these are sufficiently holistic to explain human spatial organization.

This is also documented in this work that detected different factors of the development of specific central places. It is shown that these factors are of different importance for different central places, depending on the development stage and network integration during specific periods of time. There are no *general* environmental features that determine the formation and development of central places. Every place has its own history. Thus, to assess a place's centrality its topological, chorological, and chronological characteristics need to be studied in an integrated framework of different spatial scales. This knowledge allows to compare different central places and the features shaping them. Furthermore, it offers insights in the interdependence of central places and gives hints how one place is related to another.

The strong integration and interrelation of social and natural features throughout time, on different spatial scales, shows the complexity of questions regarding the centrality of a place. Future analyses that aim to develop *computational models* of how humans, settlements, and societies are organized within diverse natural environments and in different world regions need

to implement these interdependent parameters from the beginning. In this regard, complex system science seems to be a promising tool. Mitchell (2009) defines a complex system as a "(...) system in which large networks of components with no central control and simple rules of operation give rise to complex collective behavior, sophisticated information processing, and adaption via learning or evolution" (Mitchell, 2009, 13). Substituting the term *complex system* with *settlement* in the previous sentence illustrates the strong connection. The most important contribution of complexity studies of settlements is that they verify the intuitive views of Jacobs (1970, and chapter 5.4) regarding bottom-up processes: "The local interaction between agents at a local scale, conducted by very few and simple rules gives rise the complexity we term 'city' " (Portugali, 2009, 7987). Therefore, complex system science can offer the required tools for a quantitative analysis of the aspects that were touched throughout this thesis and may lead to new insights in the field of central place analysis in (pre)history and far beyond. Urban scientist utilize these tools for many years (cf. Batty and Longley, 1994; Batty, 2005; Batty, 2008; Portugali et al., 2012) and most recent applications investigating scaling in cities (Bettencourt et al., 2007; Bettencourt, 2013) are successfully applied in archaeological context (Ortman et al., 2013). Accordingly, in the next steps these new insights must be expanded to the more general questions of human spatial organization to integrate not only the urban scale but the scale of human interactions and their relation to the natural environment in general. This will be an important contribution to the questions of how to model the environmental influence on the centrality of places.

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Appendix

A.1. Fuzzy logic system

The fuzzy logic system was created using GRASS GIS addon r.fuzzy.system, developed by J. Jasiewicz available at https://svn.osgeo.org/grass/grass-addons/grass6/raster/r.fuzzy.system/. Further information concerning the addon and methodology is provided in Jasiewicz (2011). The following options were chosen to create the fuzzy system:

- Fuzzy logic family: Zadeh

- Defuzzification method: bisector

- Implication method: minimum

Fuzzy map - definition of the fuzzy sets

Syntax explanation:

```
Name of the raster: %XXX
Name of the fuzzy set: $ XXX
Definition of the fuzzy set:{border_side; points,border_shape; hedge; height}
The fuzzy sets of the resulting output map are defined in: %_OUTPUT_
```

Syntax:

```
%MTI
$ small {right; 1,4; linear; 0; 1}
```

```
$ intermediate {both; 3,4,5,6; linear; 0; 1}
$ high {both; 5,7,8,9; linear; 0; 1}


%SLOPE
$ small {right; 0,5; linear; 0; 1}
$ intermediate {both; 4,5,8,10; linear; 0; 1}
$ high {both; 8,10,15,90; linear; 0; 1}


%_OUTPUT_
$ flat_wet {right; 0,0.3; linear; 0; 1}
$ steep_dry {both; 0.2,0.3,0.5,0.7; linear; 0;1}
$ flat_dry {both; 0.6,0.7,0.8,0.9; linear; 0;1}
$ flat-gently_moist {left; 0.9,1; linear; 0;1}
```

Fuzzy rules

The different classes correspond to the highest membership based on the following linguistic rules:

- flat, wet: if `MTI` is high and `SLOPE` is small;

- steep, dry: if MTI is high and `SLOPE` is high or if `MTI` is small and `SLOPE` is intermediate;

- flat, dry: if MTI is small and `SLOPE` is small;

- flat-gently inclined, moist: if MTI is intermediate and `SLOPE` is small or if `MTI` is intermediate and `SLOPE` is intermediate

Syntax explanation:

- $ equals `consequent {antecedents}`

- = equals `is`

- | equals `OR`

- & equals `AND`

Example

If the `MTI` is high and `SLOPE` is small than it is flat, wet

```
$ flat_wet {MTI=high & SLOPE=small}
```

Syntax

```
$ flat_wet {MTI=high & SLOPE=small}
$ steep_dry {(MTI=small & SLOPE=high) | (MTI=small & SLOPE=intermediate)}
$ flat_dry {MTI=small & SLOPE=small}
$ flat-gently_moist {(MTI=intermediate & SLOPE=small) ...
   ... | (MTI=intermediate & SLOPE=intermediate)}
```

A.2. A simple agent-based model showing the complementary character of central place and central flow theory

The agent-based model applies basic theoretical assumptions of central place theory—to model the connection of central places and their hinterland—and central flow theory—to model the connection between settlements via cooperating traders.

In the course of the model, centrality is understood as the relative concentration of interaction. This corresponds to the definition of Nakoinz (2012b), who enhanced the theoretical concept of Christaller (1968) to be applicable in archaeological contexts (see chapter 1.5).

In the course of the agent-based model, the neutral term *site* will be used for the sake of universality of the resulting outcomes.

Method

Agent-based modeling is a computational method to create, analyze, and experiment with models composed of agents that interact within an environment (Gilbert, 2008, 2; Abdou et al., 2012, 141–142). Further informations regarding the basics and applications of agent-based modeling can be found in Gilbert (2008), Heppenstall et al. (2012), as well as Railsback and Grimm (2012).

The present agent-based model is created to illustrate the different occurrence of interactions between sites that follow basic assumptions of central place theory, central flow theory, and a combination of both. Accordingly, three scenarios are modeled:

1. CP-scenario, i.e. interactions are modeled in terms of central place theory

2. CF-scenario, i.e. interactions are modeled in terms of central flow theory

3. CF-CP-scenario, i.e. interactions are modeled as a combination of the assumptions of central place and central flow theory; this scenario is of particular interest, since its intended purpose is to show the complementarity of central place and central flow theory.

The model was designed and written by the author using NetLogo software, version 5.0.3, developed by Wilensky (1999); the source-code of the model can be found in appendix A.2.1.

The model setup

In the agent-based model, sites correspond to immobile agents in a world with a size of 100 x 100. They have specific *ranks* representing the central places' different levels of hierarchy. Depending on the rank, the area of potential interactions of a central place is different. This is called *interaction-radius*. The model uses the same ten *random seeds* for every scenario to allow a comparison of the results. Every random seed differs regarding the sites' location and rank as

well as interaction- and *favored sites* (see below). For every site the number of interactions is recorded. Furthermore, *relative interactions* are recorded every time step using the following expression:

$$\text{relative interaction}(i) = \frac{\text{interactions at time}(i)}{\text{sites within interaction radius} + \text{time}(i)}$$

CP-scenario

A central place serves its surroundings with goods. Accordingly, at every time step, a random interaction partner within the interaction radius of a site is chosen for interaction. The number of these interactions per time step depends on the site's rank, since interactions correspond to the exchange of specific goods. Because the rank corresponds to the amount of different central functions offered, a site of rank four is able to have four interactions per time step, while a site of rank three is only able to have three interactions, etc.

CF-scenario

The CF-scenario aims to show the pattern of cooperating agents between sites. Therefore, two favored sites are selected within a site's interaction radius that correspond to the cooperating partners. A cooperation of partners occurs in terms of a specific central function. Therefore, the number of interactions is not linked to the rank of a site.

CF-CP-scenario

In the CF-CP-scenario the setups of the aforementioned scenarios are combined. The amount of interactions per time step is linked to the sites rank and during every time step, a site interacts either (a) with one of its favored sites or (b) with a random site within its interaction radius.

Results

The model results for the CP-scenario show a linear relationship between the rank of a site and its number of interactions (figure A.1). The higher the rank, the more interactions occur at the site. The links between the sites create a strongly integrated network. The values for the maximal relative interactions at the sites are related to the maximal interaction radius: The larger the radius is, the more similar are the maximal relative interactions for the sites of different ranks.

The model results for the CF-scenario show no direct relationship between a site's rank and its number of interactions (figure A.2). Furthermore, an increase in the interaction radius does not influence this behavior. The links between the sites create only a weak integrated network.

The combination of both models, the CF-CP-scenario, shows *in general* a linear relationship between site rank and number of interactions as well as a high network integration (figure A.3).

Nevertheless, there are local deviations of this pattern that are amplified with increasing interaction radius.
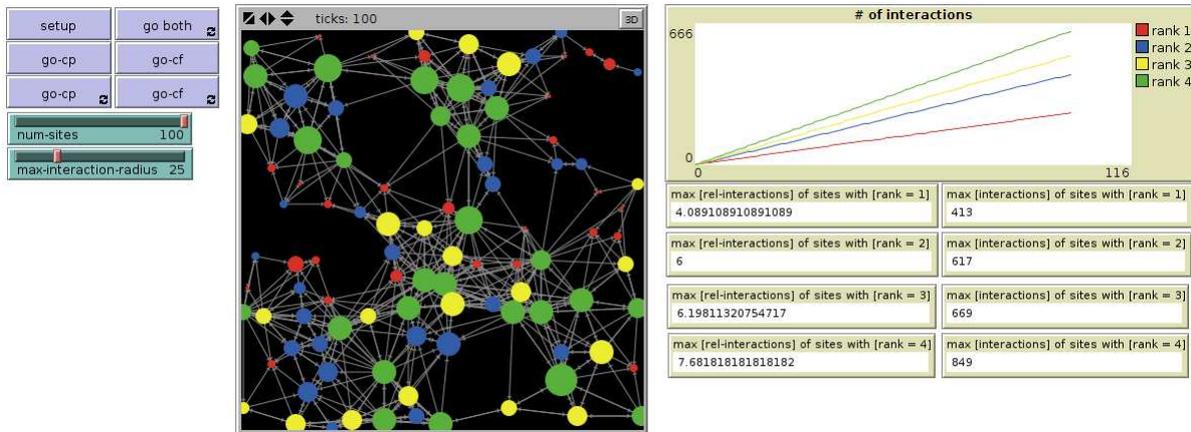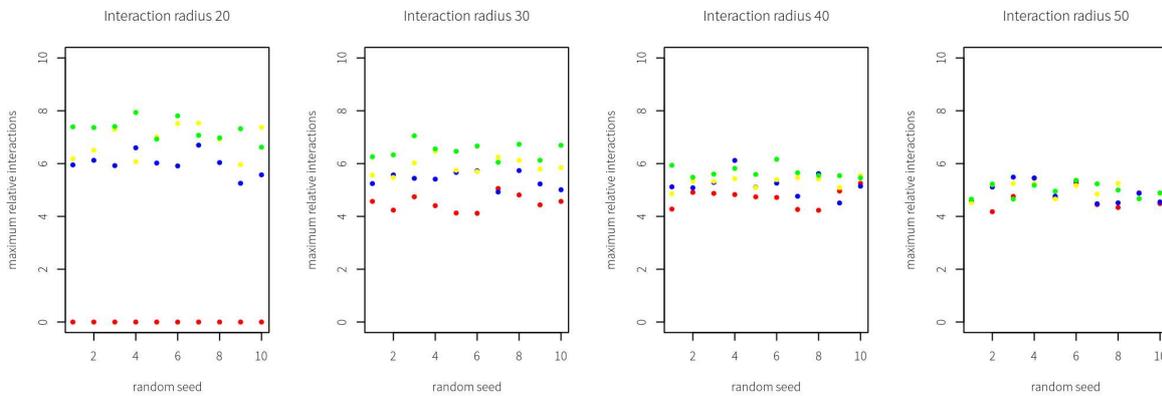
Figure A.1.: Results of the agent-based model for the CP-scenario; site ranks are indicated by color: red dots correspond to sites of rank 1, blue dots correspond to sites of rank 2, yellow dots correspond to sites of rank 3, green dots correspond to sites of rank 4. (top): a screenshot from the end of one model run showing the general pattern of sites; the more interactions occurred, the larger are the points. Lines correspond to connection between sites and illustrate a high integration of the sites. (bottom): scatterplots showing the maximal relative interactions for different interaction radii; it gets obvious that the influence of a site's rank decreases with increasing interaction radius
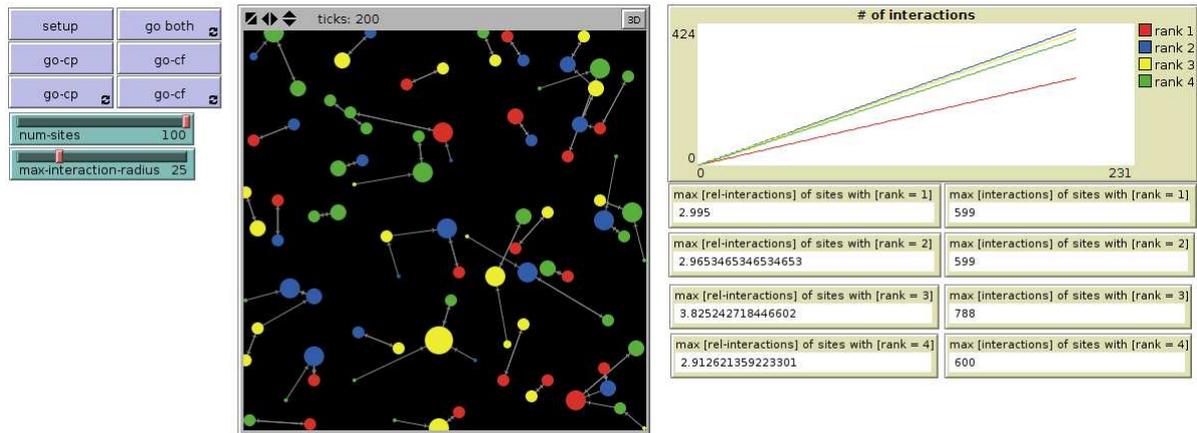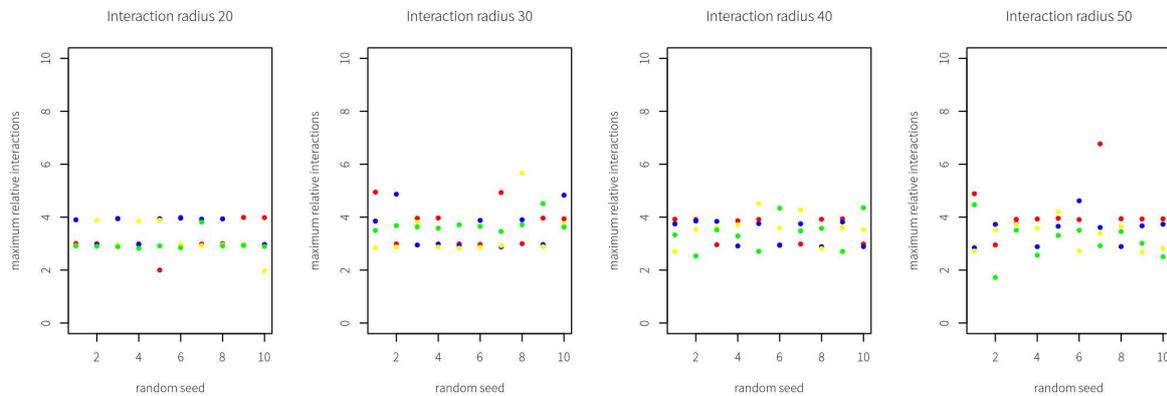
Figure A.2.: Results of the agent-based model for the CF-scenario; site ranks are indicated by color: red dots correspond to sites of rank 1, blue dots correspond to sites of rank 2, yellow dots correspond to sites of rank 3, green dots correspond to sites of rank 4. (top): a screenshot from the end of one model run showing the general pattern of sites; due to the smaller amount of all interactions, the model was run for 200 ticks to have a corresponding visual output of the models; the more interactions occurred, the larger are the points. Lines correspond to connection between sites and illustrate a low integration of the sites. The graph (top right) shows that in general the most interactions occurred at sites of rank 2. On a site specific level the most interactions (*max [interactions]* or *max [rel-interactions]*) occurred at a site of rank 3. (bottom): scatterplots showing the maximal relative interactions for different interaction radii; no pattern can be discerned between the sites' number of interactions and an increase in the interaction-radius.
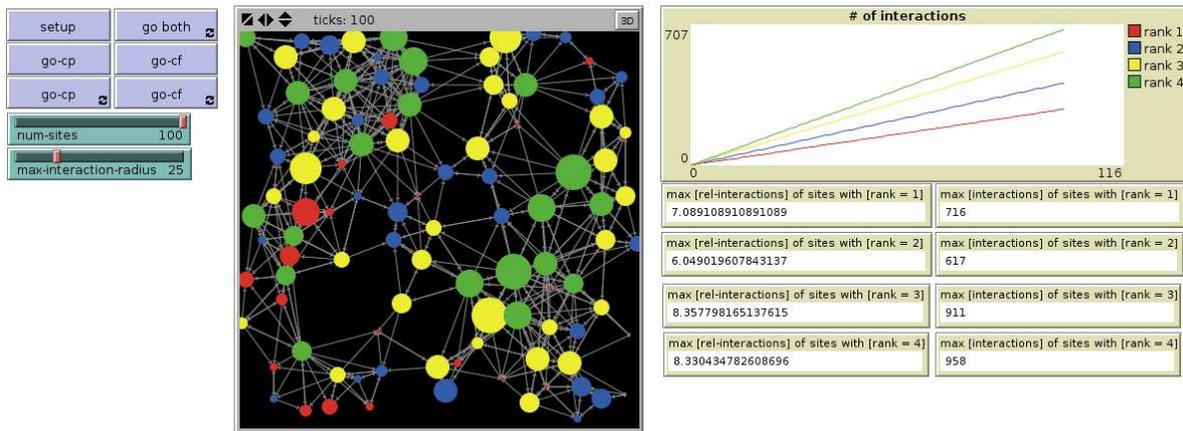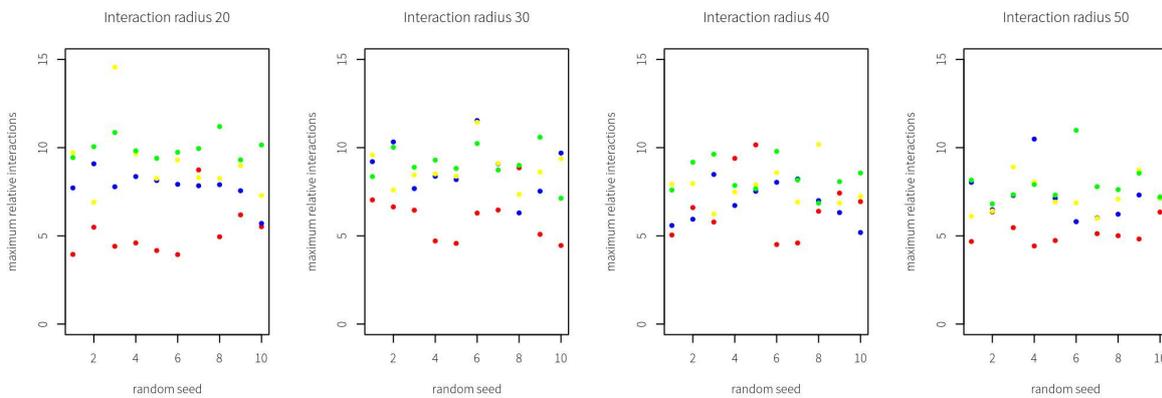
Figure A.3.: Results of the agent-based model for the CF-CP-scenario; site ranks are indicated by color: red dots correspond to sites of rank 1, blue dots correspond to sites of rank 2, yellow dots correspond to sites of rank 3, green dots correspond to sites of rank 4. (top): a screenshot from the end of one model run showing the general pattern of sites; the more interactions occurred, the larger are the points. Lines correspond to connection between sites and illustrate a high integration of the sites. Though the general pattern shows that sites of higher rank have more interactions than sites of a lower rank (see graph), there are also local deviations, as seen for some sites of rank 3 (see world map). (bottom): scatterplots showing the maximal relative interactions for different interaction radii; throughout the different model runs and changing interaction radii the sites that concentrate the most relative interactions have different ranks. Note that at an interaction radius of 40 in random seed 5, even a site of rank 1 has the highest value for maximal relative interactions.

Discussion

The results show that the CP- and CF-scenarios reproduced the theoretical assumptions. In the CP-model a high rank leads to a high number of interactions. With increasing interaction radius, these differences get obsolete. Therefore, as the CP-scenario indicates, centrality has its strongest influence on the local scale, where the general interaction radius is small.

The CF-scenario shows interactions between specific sites whose rank is not important. Due to the restriction that a site is only able to have two favored sites for interaction, the overall

integration of the sites is weak. The concentration of interaction is the result of a random choice of the favored sites and the distribution of sites in the world. Accordingly, the rank or importance of a site is not essential but the good that causes an exchange between sites. Hence, this model grasps, on a very basic level, potential cooperating partners.

The results of the CF-CP-scenario show that the model inherit the fundamental features of the CP- and CF-scenario. They indicate their mutual influencing character, since the rank of a site as well as its favored interaction partners influence the final configuration of interactions: Different random seeds at different interaction radii show sites of differing rank who have the most relative interactions. Hence, the site's location, its rank, as well as its favored partners have an influence on the amount of interactions at the site—and thus its centrality.

The presented agent-based model is by far not complete or comprehensive. To mention only a few weaknesses:

- The model is not dynamic in terms of the development of sites from one rank to another

- interaction partners are chosen randomly and not by specific goods they might offer

- the number of interaction partners is not dynamically linked to the situation of the site's surroundings

- distance is integrated as a static parameter, though a distance decay function might be more realistic

Future versions of the model need to implement these and further features to create a more advanced theoretical model. Furthermore, real world configurations of sites and environmental features could be implemented to assess the empirical validity of the model.

Nevertheless, besides more detailed data, a more comprehensive model always introduces more assumptions. It has to be tested whether such models are able to reproduce the complexity of real world patterns. The presently little importance of agent-based model approaches in context of holistic settlement analysis seems to indicate the difficulty to produce sophisticated models of human environmental relationships.

Conclusion

The different models are able to retrodict the theoretical assumptions: In terms of central place theory, sites of a higher rank concentrate more interactions. In terms of central flow theory it is the location of a site and its selection of interaction partners that steers the concentration of interaction. The rank of a site is of minor importance. The combination of both models brings these two aspects together and shows patterns of strong network integration where the sites that concentrate the most interactions profit either from their relative location or from their high rank.

A.2.1. Source code of the agent-based model

```
globals [
  ;[slider] num-sites
  ;[slider] max-interaction-radius
]


breed [sites site]


sites-own [
  rank
  interaction-radius
  num-interactions
  favored-sites
  interactions
  rel-interactions
  partner
]


to setup
  ca
  resize-world 0 99 0 99 ; create a world with 100x100 patches
  ;random-seed 2147483647
                        ;; create and define sites
  create-sites num-sites
  [
    setxy random-xcor random-ycor ; create sites at random locations
    ask sites [move-to one-of patches with [not any? sites in-radius 5 ] ]
    set rank ( random 4 ) + 1
    set interaction-radius floor ( (rank / 4 ) * max-interaction-radius )
    set partner []
    set shape "circle"
    if rank = 4 [set color green]
    if rank = 3 [set color yellow]
    if rank = 2 [set color blue]
    if rank = 1 [set color red]
    set num-interactions rank
  ]
```

```
    reset-ticks
end

to go-cf-cp
  ask sites
  [
    interact-cf-cp
    set size floor ( length partner / 100 )
  ]

  tick

  if ticks = 100
  [
    stop
  ]
end

to go-cp

  ask sites
  [
    interact-cp
    set size floor ( length partner / 100 )
  ]

  tick

  if ticks = 100
  [
    stop
  ]
end

to go-cf

  ask sites
```

```
  [
    interact-cf
    set size floor ( length partner / 100 )
  ]

  tick

  if ticks = 200
  [
    stop
  ]
end

to interact-cp
  let actor self

  repeat rank
  [
    let temporary-partner (sites in-radius interaction-radius)
    set temporary-partner one-of temporary-partner with [self != actor]

    if temporary-partner != nobody
    [
      set interactions interactions + 1
      set rel-interactions
          (interactions / ( count sites in-radius interaction-radius + ticks ) )
      set partner lput temporary-partner partner

      ask temporary-partner
      [
        set interactions interactions + 1
        set partner lput actor partner
      ]
      ask actor [ create-link-to temporary-partner ]
    ]
  ]

end
```

```
to interact-cf
  let actor self
  let potential-partner1 (sites in-radius interaction-radius)
  let potential-partner2 (sites in-radius interaction-radius)
  set potential-partner1 one-of potential-partner1 with
   [self != actor]
  set potential-partner2 one-of potential-partner2 with
   [self != actor and potential-partner1 != potential-partner1]

  let coin random 2
  ifelse coin = 1
  [
    if potential-partner1 != []
    [
      ifelse partner = []
      [
        set favored-sites potential-partner1
      ]
      [
        set favored-sites one-of modes partner
      ]

      if favored-sites != nobody
      [
        set interactions interactions + 1
        set rel-interactions
            (interactions / ( count sites in-radius interaction-radius + ticks ) )
        set partner lput favored-sites partner

        ask favored-sites
        [
          set interactions interactions + 1
          set rel-interactions
              (interactions / ( count sites in-radius interaction-radius + ticks ) )
          set partner lput actor partner
        ]
        ask actor [ create-link-to favored-sites ]
```

```
        ]
      ]
    ]
    [
      if potential-partner2 != []
      [
        ifelse partner = []
        [
          set favored-sites potential-partner2
        ]
        [
          set favored-sites one-of modes partner
        ]

        if favored-sites != nobody
        [
          set interactions interactions + 1
          set rel-interactions
              (interactions / ( count sites in-radius interaction-radius + ticks ) )
          set partner lput favored-sites partner

          ask favored-sites
          [
            set interactions interactions + 1
            set rel-interactions
                (interactions / ( count sites in-radius interaction-radius + ticks ) )
            set partner lput actor partner
          ]
          ask actor [ create-link-to favored-sites ]
        ]
      ]
    ]

end


to interact-cf-cp
  let actor self
  let potential-partner1 (sites in-radius interaction-radius)
```

```
let potential-partner2 (sites in-radius interaction-radius)
set potential-partner1 one-of potential-partner1 with
    [self != actor]
set potential-partner2 one-of potential-partner2 with
    [self != actor and potential-partner1 != potential-partner1]


repeat rank
[
  let coin random 3
  if coin = 0
  [
    if potential-partner1 != []
    [
      ifelse partner = []
      [
        set favored-sites potential-partner1
      ]
      [
        set favored-sites one-of modes partner
      ]

      if favored-sites != nobody
      [
        set interactions interactions + 1
        set rel-interactions
            (interactions / ( count sites in-radius interaction-radius + ticks ) )
        set partner lput favored-sites partner

        ask favored-sites
        [
          set interactions interactions + 1
          set rel-interactions
              (interactions / ( count sites in-radius interaction-radius + ticks ) )
          set partner lput actor partner
        ]
        ask actor [ create-link-to favored-sites ]
      ]
    ]
```

```
      ]
      if coin = 1
      [
        if potential-partner2 != []
        [
          ifelse partner = []
          [
            set favored-sites potential-partner2
          ]
          [
            set favored-sites one-of modes partner
          ]

          if favored-sites != nobody
          [
            set interactions interactions + 1
            set rel-interactions
                (interactions / ( count sites in-radius interaction-radius + ticks ) )
            set partner lput favored-sites partner

            ask favored-sites
            [
              set interactions interactions + 1
              set rel-interactions
                  (interactions / ( count sites in-radius interaction-radius + ticks ) )
              set partner lput actor partner
            ]
            ask actor [ create-link-to favored-sites ]
          ]
        ]
      ]
      if coin = 2
      [
        let temporary-partner (sites in-radius interaction-radius)
        set temporary-partner one-of temporary-partner with [self != actor]
        if temporary-partner != nobody
        [
          set interactions interactions + 1
```

```
      set rel-interactions
          (interactions / ( count sites in-radius interaction-radius + ticks ) )
      set partner lput temporary-partner partner

      ask temporary-partner
      [
        set interactions interactions + 1
        set rel-interactions
            (interactions / ( count sites in-radius interaction-radius + ticks ) )
        set partner lput actor partner
      ]
      ask actor [ create-link-to temporary-partner ]
    ]
  ]
]

end
```

A.3. Curriculum vitae

For reasons of data protection, the curriculum vitae is not included in the online version

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Der Lebenslauf ist in der Online-Version aus Gründen des Datenschutzes nicht enthalten

Eidesstattliche Erklärung

Hiermit erkläre ich, dass ich die Dissertation *Central Places and the Environment—Investigations of an Interdependent Relationship* selbständig angefertigt und keine anderen als die von mir angegebenen Quellen und Hilfsmittel verwendet habe.

Ich erkläre weiterhin, dass die Dissertation bisher nicht in dieser oder in anderer Form in einem anderen Prüfungsverfahren vorgelegen hat.

Berlin, den   Daniel Knitter

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