SUSTAINING TALIANKI: A MODEL OF ENEOLITHIC SUBSISTENCE ECONOMICS AT A GIANT-SETTLEMENT OF THE WESTERN TRIPOLYE CULTURE, UKRAINE

by

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Abstract

The giant-settlement of Talianki, situated in the Southern Bug-Dnieper interfluve in Central Ukraine, is the largest known settlement of not only the Western Tripolye culture, but also the entire European Neolithic and Eneolthic. As with the rest of the giant-settlements belonging to this culture, Talianki's unusually large size and short habitational period makes understanding its purpose and functioning a confounding and unique archaeological problem. While Talianki and the other settlements of its category are poorly documented in Western archaeological discourse, there is lively discussion of these topics in the Ukrainian archaeological community. The goal of this work is twofold: firstly, to expand discussion of the Tripolye culture outside of Ukraine; and secondly, to introduce research regarding the modeled functioning of an Eneolithic economy in the context of a very large settlement existing in a single-site context. A review of literature, from Ukraine and elsewhere, relevant to the modeling of ancient agrarian systems is presented, as well as recent research into the spatial and demographic character of the settlement. The purpose of this is to assess several previously-held assumptions regarding the functioning of the giant-settlements, which tend 1) to be rooted in notions of environmental determinism; and 2) to assign a degree of social and political complexity that is not perceived in the archaeological materials (due to their assumed incapability of self-sufficiency). This study, supported by mathematical and spatial modeling of settlement functioning, concludes that the giant-settlements of the Southern Bug-Dnieper interfluve would have been economically viable and self-sustaining in a variety of states, both more and less optimized. This research has value not only in modeling the functioning of a single site, but also in understanding the full limits and potential of European Neolithic and Eneolithic subsistence systems.

1: Introduction

Study Area

The research presented in this paper pertains to the Eneolithic settlement known as Talianki, the largest site belonging to the Western Tripolye culture and the largest known settlement in Europe during that time, the early fourth millennium BC. It lies in the Talnoe district of Cherkassy region, Ukraine, some 23 kilometers east-northeast of Uman, situated primarily underneath cultivated fields between the modern villages of Talianki and Legedzino. It is bounded by the Talianka river and its tributaries on three sides, while flat, open fields extend several kilometers to the west. A straight, open stretch of the Uman–Cherkassy (H16) highway cuts across the southern side of the site, while portions of its eastern side are obscured by modern construction. The site is roughly elliptical in shape and is about three kilometers long, with a northwest-to-southeast orientation. Its width varies between 1.1 and 1.8 kilometers, averaging about 1.5 kilometers (Kruts 2008a:58). These measurements do little to convey the sheer size of the settlement as it is perceived "on the ground;" expressed in terms of average walking speed (slightly less than 5 kilometers per hour), it would take approximately 20 minutes to walk the width of the settlement, or 40 minutes to walk its length. The spatial setting of the Tripolye settlement within the modern landscape is illustrated in **Figure 1**.

Owing to its large spatial dimensions, Talianki and other Tripolye settlements of similarly large size are classified as "giant-settlements" (Rus: поселений-гигантов, *poseleniy-gigantov*) in Ukrainian archaeological literature. The giant-settlements are a unique archaeological phenomenon, the largest known settlements in Europe prior to the advent of state societies during the Bronze Age. They are situated exclusively in the Southern Bug-Dnieper interfluve, and belong to a fairly short window of time (perhaps

600–700 years) during the middle-to-late period of the Tripolye chronology. To understand the functioning of these settlements is to understand the limits of the European subsistence economies that were, on the whole, fairly homogeneous over the course of the Neolithic. They inspire many questions that are not easily answered, namely: what was their purpose and why did they develop; why did they collapse; and what circumstances prevented the Tripolye culture from becoming a "civilization?" The existence of seemingly

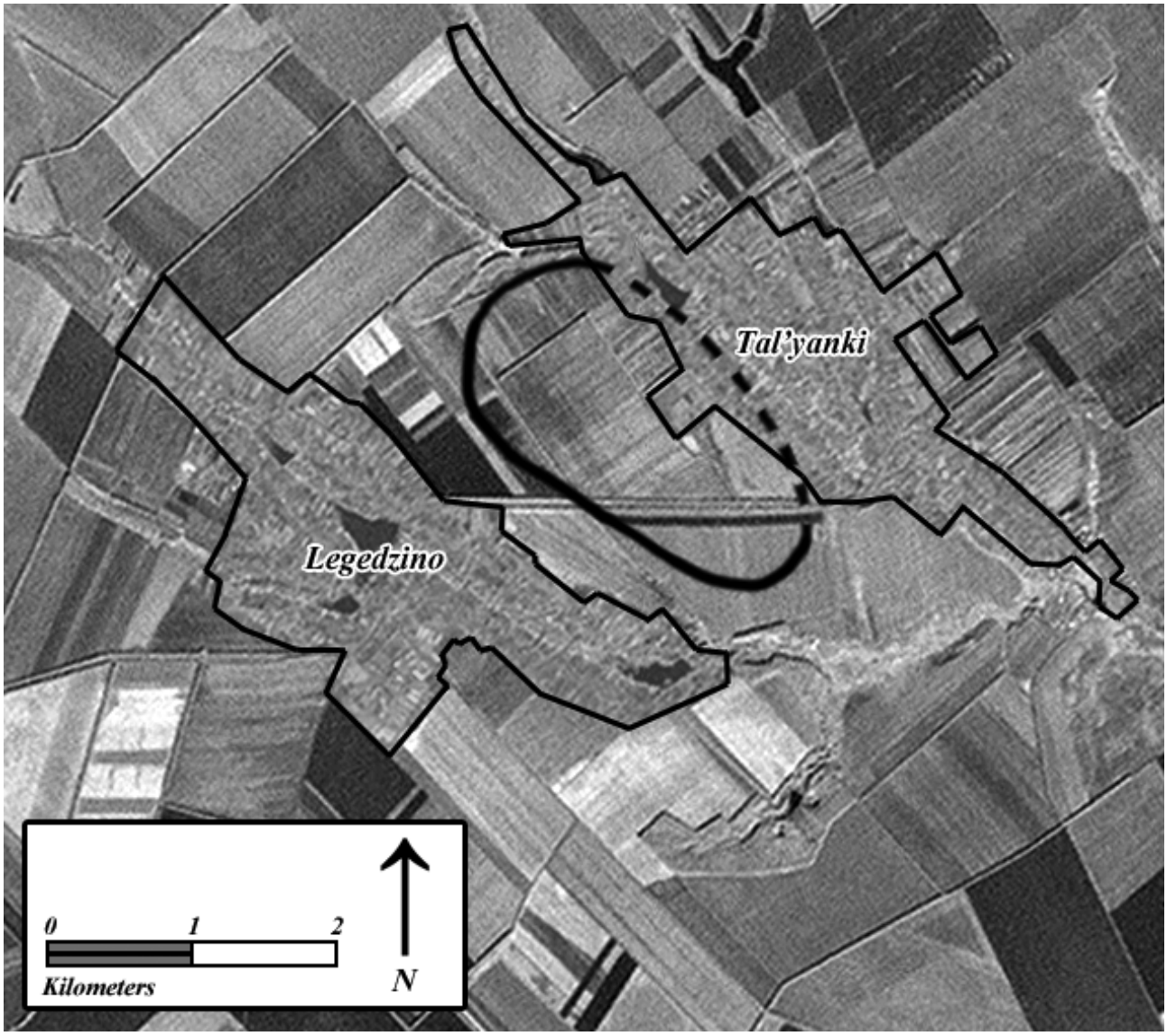

Figure 1. Satellite image illustrating the spatial context of the Talianki giant-settlement (represented by the elliptical black outline) in relation to the modern villages of Legedzino and Talianki in Cherkasy region, Ukraine. *Source: USGS (2001); modified by the author.*

unstratified communities that are larger than many of the early city-states of Mesopotamia does not fit neatly into many archaeological assumptions regarding economics and state formation processes.

This study asserts that focusing on the economic functioning of a single site is useful for informing the construction of a “bigger picture” of life at the giant-settlements in general. Talianki is the largest of these settlements and is assumed to have been the most populated, so studying its environmental and economic sustainability provides an extreme example that may be compared against the rest. Most of the available theories regarding the functioning and collapse of these settlements are based on untested assumptions of environmental determinism, and addressing these theories is a key component of this study. Firstly, however, it is necessary to situate Talianki within its proper cultural, chronological, and environmental context.

The Western Tripolye Culture

Terminology and Categorization

The Tripolye culture (Rus: Триполье, Ukr: Трипілля, *Trypillia*) is an Eneolithic culture of the fifth to third millennia BC, named for the type-site excavated in the Kiev region by V.V. Khvoika in 1893. The material culture of the the Tripolye sites was mainly distinguished on the basis of painted pottery, which, during some phases of the culture's existence, was incredibly ornate. Around the same time as Khvoika's research, evidence for a similar assemblages in Romania emerged, which were named for the type-sites of Cucuteni in Iaşi County and Ariuşd in Transylvania (Lazarovici et al. 2009:15). As it is understood today, each of these archaeological cultures is part of an overarching cultural complex, commonly referred to as “Cucuteni-Tripolye” or “Ariuşd-Cucuteni-Tripolye.” They all share common descent from the Precucuteni culture of the Siret-Prut region of eastern

Romania, which fomed out of a synthesis of the Boian culture and the descendants of the Linear Pottery culture, with additional influence from the Turdaş and Criş cultures (Zbenovich 1996:203). There are significant regional differences in material culture, so the use of differing terms for local complexes is not simply the result of political boundaries or academic tradition. While these differences extend to settlement architecture to some degree (with multi-habitation sites being more common in the Balkans), mostly they are delineated by differences in pottery morphology and decoration. Fairly recently, an important typological distinction was made by S.N. Ryzhov (1999), who suggested that the Western and Eastern Tripolye cultures should be treated as distinct units, based on methods of pottery manufacture and ornamentation. Sites belonging to the western group are located in the forest and forest-steppe regions of Moldova and Ukraine and produced high-quality painted pottery, while sites belonging to the Eastern Tripolye culture are located mainly in the steppe region and almost universally have lower-quality, incised pottery. As such, the usage of the unqualified adjective “Tripolye” or “Tripolian” has generally become deprecated outside of discussions of periodization. Aside from the early giant-settlement at Veseliy Kut, which belongs to the Eastern Tripolye culture (Kruts 2008:48), the giant-settlement phenomenon is exclusive to the Western Tripolye culture.

As a means of typological and temporal classification, the settlements of the Western Tripolye culture are broken up into a variety of local groups and “genetic lines of development” (Ryzhov 1999) which mainly delineate stylistic boundaries in material culture. The population dynamics of various local groups can be charted to understand changes in settlement systems, and sometimes are indicative of large-scale migrations (Diachenko 2010). As an example, the collapse of the giant-settlements belonging to the Tomashovskaya local group (of which the Talianki settlement is a component) was later followed by the arrival of the Kosenovkaya local group to the region, which in turn

established further giant-settlements. This phenomenon, which has a very specific geographic focus, becomes all the more compelling due to its episodic nature; it involved different people at different times, but all occurred in the same general area.

The Giant-settlements

Until the late 1960s, it was believed that the site of Vladimirovka in the Kirovograd region, at 62 hectares, was the largest center, or even the “capital,” of the Tripolye culture (Kruts 2008a:42). This conception changed rapidly after the military topographer K. Shishkin noticed large anomalies in aerial photographs of the Cherkassy region: dark spots, arranged in concentric oval patterns. After consultation with V. Stephanovich of the Uman museum, it was quickly determined that these anomalies were houses, arranged in settlement layouts diagnostic of the Tripolye culture. The newly-discovered sites near the villages of Talianki, Chicherkozovka, Maidanetskoe, Dobrovody, Veseliy Kut and Nebelevka (Kruts 2008a:42) were far larger than previously-known settlements. As has been mentioned, all of these settlements with the exception of Veseliy Kut belong to the Western Tripolye culture; P. Kohl (2007:41) mentions two additional Eastern Tripolye settlements that were discovered around this time, Onoprievka and Pianezkovo, but these are generally considered too small to qualify as giant-settlements.

Subsequent studies undertaken over the next decade by both the Academy of Sciences of the USSR and the Academy of Sciences of Ukraine confirmed the assessments of local specialists. In the early 1970s V. Dudkin produced the first geomagnetic surveys, showing definitively the massive scale of these sites. Dedicated excavation and study of the giant-settlements was begun almost immediately, with the creation of a special four-team expedition funded by the Ukrainian Academy of Sciences and led by archaeologists E.V. Tsvek, N.M. Shmagliy, T.G. Movsha, and V.A. Kruts. Of the

giant-settlements, Maidanetskoe was the first to be excavated and has been subject to the greatest scrutiny. Over the past forty years, these expeditions have conducted excavations throughout the Cherkassy region and neighboring regions, at sites (giant and non-giant alike) including Maidanetskoe, Talianki, Veseliy Kut, Moshurov 1, Peschanaya, Talnoe 2, Onoprievka, Kolodiste 2, and Glubochek. Since the first excavations in 1981, the Talianki expedition has been led by V.A. Kruts, who is the chief authority on its excavation and publication.

The giant-settlements of the Southern Bug-Dnieper interfluve are situated in oxbows of rivers, with structures arrayed in rings around a central area that is generally, though not always, open (for example, Maidanetskoe shows an unusual amount of construction at its center). Early theories emphasized that these settlements coalesced primarily for defensive purposes, but recent investigations at Talianki show that the entrances of structures in the second ring of the settlement faced outwardly (Kruts 2008a:45). In addition, the geomagnetic plan of the settlement shows that some gaps as large as 50–100 meters existed in the outer ring of houses. While Kruts continues to contend that the oval layout of the settlements was itself a defensive characteristic (a sort of “living wall”), they were certainly not fortified to any perceptible degree. The orientation of the domestic entryways perhaps is an indication that orientation towards a communal thoroughfare was preferred over having a more optimized defensive layout, where structures would be expected to be entirely inward-facing.

The population of the giant-settlements is thought to have originated in waves of migration from the west, which occurred due to demographic pressure in the Cucuteni-Tripolye “homeland:” the Siret, Prut and Dniester river valleys. During the early-to-middle (Tripolye B1) stage of the Tripolye culture, the east Balkan societies of “Old Europe” were reaching their zenith, with the area along the Prut experiencing particularly high levels of

settlement density. In the words of I. Manzura, the demographic situation would have resembled “[...] a bomb ready for explosion” (2005:318). As a result of subsequent migrations during the Tripolye B2 stage, the Vladimirovskaya local group moved – or was forced – into the Southern Bug-Dnieper interfluve. This local group formed the basis for the subsequent Nebelevskaya and Tomashovskaya local groups. At the beginning of the Tripolye C1-2 stage (some six centuries later) this process is thought to have repeated, with the Kosenovskaya local group establishing itself in the region after the collapse of the giant-settlements associated with the Tomashovskaya local group. The environment of the Southern Bug-Dnieper interfluve, which is characterized as forest-steppe, constituted the “ideal environment for an agricultural and husbandry[-based] economic system” (Kruts 2008:45). This ideal setting is thought to have provided the driving force for the creation of successive waves of settlements in the South Bug-Dnieper interfluve, some of them consisting of thousands of individuals.

Chronology

The relative chronology of Tripolye settlements is based upon a classificatory scheme created by T.S. Passek in 1949 and further developed by N.M. Vinogradova in 1983 (Zbenovich 1996:201). In this system, cultural development is perceived to occur over three major phases, early (A), middle (B), and late (C). The middle and late phases are divided into further sub-phases, indicated by the addition of a numeral (B1, B2, C1, C2), while several terms are used to describe intermediate developmental phases (e.g. B1-2, C1-2).

There is some dispute regarding how radiocarbon dates can be integrated with Passek's system to form an authoritative absolute chronology. Depending on the source, there are vast discrepancies in dating; for the giant-settlements, which occupy the

threshold between the middle and late phases of the overall Tripolye culture, the implications are severe. V.A. Kruts (2008c), E.K. Chernysh (1982), T.G. Movsha (1985) and V.G. Zbenovich (1996), among others, support a late chronology wherein the giant-settlements of the Tomashovskaya local group are inhabited during the late fourth to middle third millennia BC. Kruts in particular gives an approximate range of 3250–2650 BC (2008c:237–238), with Talianki dated to the first century of the third millennium. However, this chronology is seriously problematic due to its reliance on uncalibrated radiocarbon dates. While these uncalibrated dates are useful for supporting the pre-existing sequence of relative chronology, they can hardly be cited as “absolute” dates.

Proponents for an earlier chronology include I. Manzura (2005), P. Kohl (2002), D.Ya. Telegin (2003), A.V. Diachenko (2010), Yu.Ya. Rassamakin and F. Menotti (2011) . This group contends that, on the basis of calibrated radiocarbon dates, the middle Tripolye phases should be pushed back considerably. Two samples from the nearby, slightly later site of Maidanetskoe yielded results of 3790-3530 cal BC and 3650-3000 cal BC (Telegin et al. 2003:461), providing a *terminus ante quem* for Talianki. Data such as these lead to the construction of a new chronology, where the giant-settlement phenomenon is given ranges such as ca. 4200–3600 BC (Kohl 2002:153) or ca. 4100–3550 BC (Diachenko, personal communication, November 22, 2010). A comparison of the earlier and later chronologies is presented in **Table 1**.

In order to further corroborate the early chronology, fifteen published radiocarbon results from Talianki and Maidanetskoe were calibrated using the IntCal 09 curve (Reimer et al. 2009). The results, which can be found on **Table 2**, differed significantly based on the laboratory used in sample processing as well as when they were collected. Samples from the Kiev Laboratory (such as Ki-1212, Ki-2964, and Ki-15994) tend to be less trustworthy, particularly those dating to the 1970s and 1980s. The more recent dates from the Kiev

Laboratory are closer to those of the Berlin laboratory (processed in the latter part of the 1970s), which were long preferred as being the most reliable results available (Kruts 2008c:232). However, the inaccuracy of these dates still brings up problems for researchers. The recent assertion of Rassamakin and Menotti (2011:653) that the radiocarbon dates from Talianki can be used to chart developmental stages in the settlement's use (including two relatively distinct periods lasting several hundred years, which does not agree with the ceramic microchronology) does not adequately address the long-standing trend of the Kiev laboratory to produce significantly younger dates than facilities in the West. It is somehow unsurprising that samples from the southern end of the settlement, which all returned later dates, were all processed by the Kiev laboratory. While the ability of these dates to reconstruct development within a settlement is questionable, they do conform, more or less, to the early chronology's periods of late Tripolye B2 to C1-2, as is expected.

Talianki occupies an intermediate point in the development of the Tomashovskaya local group. Each settlement was inhabited in succession, with the bulk of the local population residing at a single giant-settlement (Kruts 2008a:44). The sequence established by pottery analysis and corroborated to a small degree by radiocarbon dates is as follows: Sushkova, Chicherkozovka, Dobrovody, Vasilkov, Talianki, Maidanetskoe,

Late Chronology (Kruts)	**A:** 4000 – 3600 BC	**B1:** 3600 – 3400 BC	**B1-2:** 3400 – 3300 BC	**B2 to C1:** 3300 – 2850 BC	**C2:** 2850 – 2650 BC
Early Chronology (Diachenko)	**A to B1:** 4800 – 4200 BC	**B2:** 4200 – 3800 BC	**C1:** 3800 – 3600 BC	**C1-2:** 3600 – 3400 BC	**C2:** 3400 – 3000 BC

Table 1. Phases of the Tripolye culture (according to Kruts 2008c:231; Diachenko 2010:41).

Site	Sample ID	Result (BP)	Result (cal BC)	Range (2σ)
Talianki	Ki-2964	4430 ± 60	3119 ± 124	3338-2917
Talianki	Bln-4598	4936 ± 40	3717 ± 48	3791-3646
Talianki	Ki-6865	4755 ± 50	3534 ± 78	3643-3377
Talianki	Ki-6866	4720 ± 60	3503 ± 83	3637-3372
Talianki	Ki-6867	4810 ± 55	3577 ± 70	3702-3382
Talianki	Ki-6868	4780 ± 60	3548 ± 78	3660-3375
Talianki	Ki-15993	4910 ± 70	3713 ± 86	3939-3528
Talianki	Ki-15994	4550 ± 70	3250 ± 126	3513-3023
Talianki	Ki-16025	4970 ± 50	3765 ± 74	3939-3650
Talianki	Ki-16026	4990 ± 80	3797 ± 91	3954-3650
Talianki	OxA-19840	5048 ± 33	3862 ± 56	3956-3766
Talianki	OxA-22515	4976 ± 29	3753 ± 48	3907-3663
Talianki	OxA-22348	5032 ± 31	3850 ± 63	3946-3715
Maidanetskoe	Ki-1212	4600 ± 80	3337 ± 147	3631-3037
Maidanetskoe	Bln-2087	4890 ± 50	3682 ± 54	3788-3536

Table 2. Calibration of radiocarbon dates collected at Talianki and Maidanetskoe (from Rassamakin 2004:8; Kruts 2008c:235; Rassamakin and Menotti 2011:650-651) according to the IntCal 09 curve (Reimer et al. 2009).

Romanovka, Tomashovka (Diachenko 2008:15; Kruts 2008c:237). Each settlement seems to have been constructed and inhabited over a short time span, as there are no considerable changes in material culture from the beginning to the end of the habitational period. If we accept the general time-frame of the available radiocarbon dates (particularly Rassamakin and Menotti's new dates from Oxford), Talianki may be dated to ca. 3800 BC and Maidanetskoe to perhaps ca. 3700 BC.

Environmental and Geographic Context

In Ukraine there exist three main ecological zones: forest, forest-steppe and steppe (Korvin-Piotrovskiy 2008a:13). Cultures residing within these zones have adapted accordingly, with the forest giving rise to small agricultural communities and the steppe giving rise to stock-breeding traditions. Within this scheme, the forest-steppe presents the

optimal environment to practice both of these subsistence strategies. At early sites of the Bug-Dniester culture, dated to ca. 8200 BP, some eighty percent of the animal remains are from wild species, such as roe deer and red deer (Velichko et al. 2009:7). However, impressions of cereals such as emmer, einkorn and spelt are found on pottery, providing a date for the penetration of agricultural practices into the forest-steppe zone.

While farming communities spread throughout Neo-eneolithic Ukraine around 5200–4500 BC, several ecological changes were occurring. Firstly, on the basis of pollen evidence, deciduous forests were attaining their maximum proliferation of the steppe, while sometime between 4600 and 4200 BC the Black Sea attained its current level (Dolukhanov and Arslanov 2007:38). Around 4500-4000 BC, early Tripolye farmers first came to the Pontic lowlands, establishing fully developed farming economies with the cultivation of a wide variety of cereals (Velichko et al. 2009:7). They continued to exploit natural sources of animal protein such as boar, elk, red deer, and roe deer, while also raising domesticated cattle, pigs and ruminants. Towards the end of this phase, the Vladimirovskaya local group had begun establishing giant-settlements in the Southern Bug-Dnieper interfluve.

The giant-settlements of the South Bug-Dnieper interfluve are unique with regard to their size, being several times larger than the largest sites in other regions of Ukraine and Moldova. The reasons why this area in particular was occupied so intensively are not well-understood, but two main theories predominate: that the giant settlements formed to counter an external threat from the steppe to the east (posited by Kruts and Chernysh) or that they formed as a result of internal conflict in the overall Tripolye culture (posited by Zbenovich and Videyko; Kruts 2008a:48). The giant settlements are found in a thirty to forty kilometer strip of territory that was significantly more wooded than surrounding environments and presumably sparsely populated at the time of the first Western Tripolian

migrations into the region. Kruts emphasizes that this woodland constituted a defensive buffer against marauding populations of steppe pastoralists; if not for their assumed defensive purpose, the giant-settlements would have been otherwise “rather inconvenient” (2008:44) due to increased resource demands, crowding, and the risk of contagion.

Late Tripolye period (ca. 3800–3000 BC) was marked by the increasing aridity of the Sub-Boreal climactic phase, prompting a shift in the primary subsistence production from cereal cultivation to stock-breeding, as evidenced by the sites of the Tripolye C2 Usatovskaya local group (Velichko et al. 2009:7). The identification of settlements as defensive bastions can be called into question, as there is no clear evidence to suggest a particularly violent or rapid change beyond the imposition of new environmental constraints. By around 3400–3300 BC (phase C1-2) the Tripolye giant-settlements had shrunk considerably in size (Anthony 2010:53), with the settlement at Kosenovka having less than one-fifth the area (62.8 ha) of Talianki (Diachenko, personal communication, 2 February 2012).

Tripolye Houses and Households

The study of Tripolian houses and settlement architecture has been assigned a great deal of importance, owing mainly to the almost-universal lack of human remains in archaeological assemblages. Inhumation burials are sporadic in the archaeological record and do not generally appear until the Tripolye C2 period at places such as Vykhvatintsi cemetery in eastern Moldova (Zbenovich 1996:210), a time when the Eneolithic system of sedentary agriculturalism was in the process of collapsing. Therefore for the first millennium and a half of the Tripolye chronology people are not “visible” (in a physical sense) in the archaeological record. Information on the rituals, social relations, demographics, gender, production, and diet of the Tripolian people must therefore be gleaned from their houses and the objects within them (Kohl 2007:49). In this area we are

fortunate, as Tripolian houses are generally well-preserved by burning.

The houses of the Tripolye culture were made from wood, wattle, and daub, and are thought to have been predominately two-storey structures (Chernovol 2008:177). All have been subjected to destruction by fire (assumed to be intentional on the part of the residents), so that their archaeological remains consist of raised rectangular areas of burnt clay and other detritus, dubbed *ploshchadki* (Rus: площадки, lit. “little plazas”) by excavators (see **Figure 2**). The preservation of the clay (which is proportional to the temperature of the fire) varies from very poor, crumbly material to hard, vitrified pieces. *Ploshchadki* are commonly found throughout all the local groups of the Tripolye culture, and are morphologically similar to some house remains from the Balkans (Zbenovich 1996:208), as will be discussed later. Excavations at the Tripolye giant-settlements of the Tomashovskaya local group (belonging to the Tripolye C1 phase), which have been the most extensively studied sites of recent years, have been particularly important in understanding the construction and destruction of Tripolian houses.

Figure 2. Tripolian house specialist D.K. Chernovol (standing at middle) oversees the excavation of a *ploshchadka* at the giant-settlement of Talianki, July 2011. *Source: photo by the author.*

Excavated *ploshchadki* typically measure four and a half to six meters in width and seven to twenty meters in length (Chernovol 2008:177; Kruts 2008a:46). Of the 87

examples excavated at the Tomashovskaya giant-settlements as of 2008 (44 at Maidanetskoe, 39 at Talianki, and four at Dobrovody), none deviate from this general layout. As of the time of this writing, a further seven structures have been excavated at Talianki, bringing the total at that settlement to 46. To date, no monumental structures or other major architectural indications of social stratification have been found, and it is generally assumed that the variation in house size is proportional to the number of individuals in each family unit (Chernovol 2008:177; however Diachenko and Chernovol [2009] state that larger houses may indicate greater status). Tripolian houses of this period were highly standardized. Areas for sleeping, cooking, and the performance of ritual activity were located on the upper floor. Meanwhile, the ground floor was likely the site of storage or craft production, a position supported by the presence of elevated platforms, pits, and depressions under some houses (Chernovol 2008:177), as well as well as broken pottery, grinding stones, and agricultural implements (Kruts 2008b:60).

Houses were built upon log pilings, with the walls constructed of wooden cribbing covered with clay, which was sometimes mixed with wheat chaff. This assertion was informed by the discovery of a large intact portion of wall during excavations at Dobrovody (Kruts 2008b:60). The floor of the upper storey consisted of plastered wooden planks; while the wood has long since disappeared, its impression can still be seen on pieces of fired clay. The upper storey had three major subdivisions: an unenclosed porch, a small antechamber, and a large main room which typically had three major features: a hearth, a long raised platform referred to as the *podium*, and an altar (Chernovol 2008:178; Kruts 2008b:60). Podia were generally situated along the length of the left-hand wall, the hearth just inside the entry on the right side, and the altar at the far end of the room. Wall fragments with curvilinear edges have been found in some structures near the altar, which are interpreted as evidence for a single round window in the far wall to let in light and

possibly act as an exit for smoke (Kruts 2008b:60).

The presence and purpose of these features are informed partially by direct archaeological evidence and partially by contemporary depictions of houses in the form of clay models (see **Figures 3b** and **3c**). Hearths, altars and podia all feature prominently in these models; the purpose of the podium as a storage shelf for vessels, food, and utensils was inferred by its depiction on Tripolye house models (Chernovol 2008:179). The significance of these models is unknown, but they are thought to be a reflection of the great ritual value of the domestic space. This is an understandable assumption, as the current understanding of Tripolye architecture does not point to any distinction between domestic, political, economic, or ritual areas. Houses would have constituted the starting point for the entire cultural landscape, an area where "sacred and profane met harmoniously" (Chernovol 2008:182). Citing the large number of anthropomorphic figurines deposited throughout Cucuteni-Tripolye houses in general, J. Chapman sees

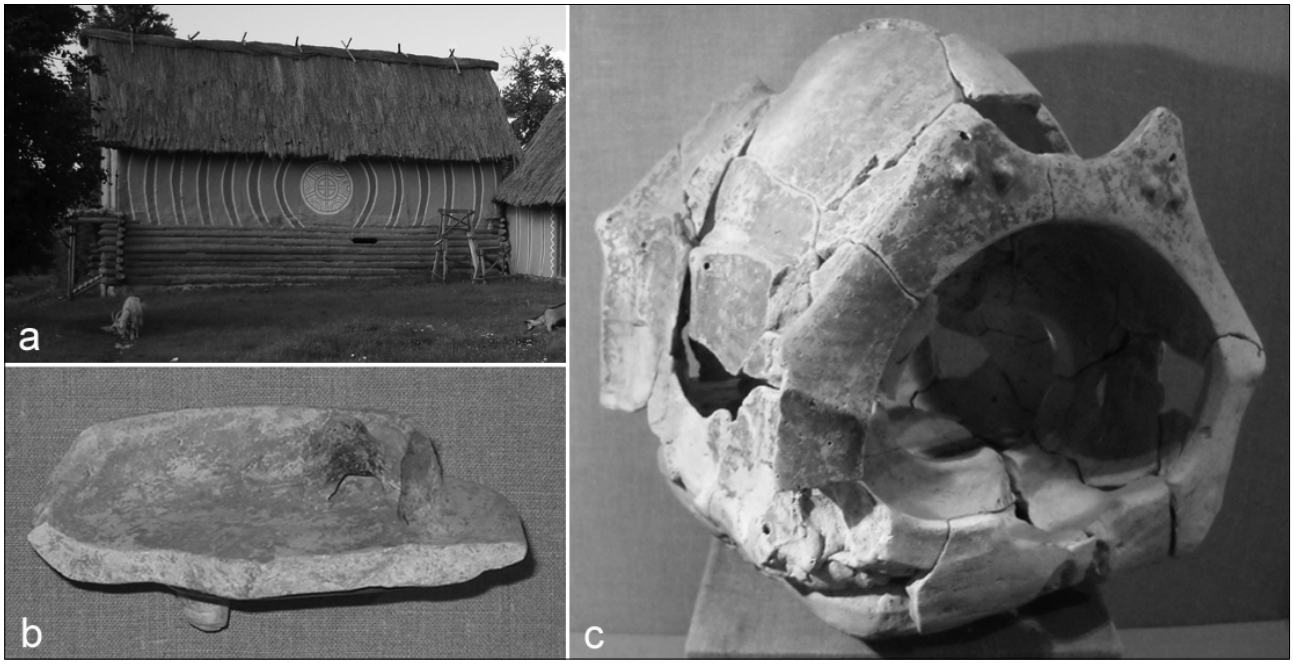

Figure 3. A modern reconstruction of a Tripolye house (**a**) and Tripolye architectural models (**b** and **c**) recovered from Talianki (not to scale). *Source: Photos by the author, Tripolye Culture Museum, Legedzino.*

everyday practices such as sleeping, cooking, eating and food storage as being highly ritualized in nature (2010:82).

House Burning

While the vision of Tripolye houses that has just been explored represents the current majority opinion, it is not uncontested. Opinion is divided as to the origins of the fired clay found in *ploshchadki*; as mentioned, the current theory (originally articulated in Zinkovskiy 1973; Markevich 1981; Chernysh 1982; Kruts 1989) holds that houses had two storeys and were destroyed by fire. Others, such as A.G. Korvin-Piotrovskiy and L. Shatilo (2008), interpret the archaeological evidence as continuing to support the older hypothesis (going back to Krichevskiy 1940 and Passek 1949) that the structures had one storey and the firing of the house was constructive, not destructive. The key point of contention is the interpretation of the *platforma*, a layer of the *ploshchadka* which the two-storey proponents interpret as the collapsed upper floor, while the one-storey proponents see it as the ground floor which was purposely fired during the house's construction. This position is defended on the basis of ethnographic analogy, as one-storey, clay-plastered houses which bear a superficial resemblance to some Tripolian house models were constructed throughout Eurasia until the mid-twentieth century (Korvin-Piotrovskiy and Shatilo 2008:201-202). However, recent experimental modeling by V.V. Chabanyuk (2008) has shown that the intentional destruction of a full-size two-storey house reconstruction (similar to the one pictured in **Figure 3a**) yields remains that are quite similar to the archaeological *ploshchadki*. Additionally, the “constructive fire” perspective fails to address the presence of features underneath the *platforma* that are found in most Tripolian houses, at settlements that are mostly unstratified, single-occupation sites.

The issue of fire as a means of house destruction is not clear-cut, particularly when

viewed on the settlement level. The short habitational period of some settlements has led to the conclusion that an entire settlement would be burned synchronously, perhaps owing to the local exhaustion of natural resources. This is a particularly popular idea among researchers of the Tripolye giant-settlements. While Zbenovich states that “[...] there is no corroboration for the speculation that a Tripolian holocaust simultaneously destroyed hundreds of dwellings,” (1996:208) from a “common sense” perspective it is hard to conceive of this practice as being precisely targeted. When asked what his stance was on this issue, one colleague responded “would you want to live next door to such a fire?” (i.e. a fire hot enough to vitrify clay). Since experiments thus far have only involved the burning of one structure, there is currently no means to adequately confirm or deny these assumptions. However, the necessity of reaching temperatures of at least 500–1000 degrees Celsius (Stevanović 1997:381; confirmed empirically in the modeling of Chabanyuk 2008:221), is enough to give one pause.

Regardless of whether we are discussing the destruction of a single house or an entire settlement, such events were likely dramatic affairs that left an impression on the social memory of a group. However, it is still necessary to explore the intentionality of these events. In discussing house-burning among the Vinča culture, R. Tringham emphasizes this point, stating that it was an act of commemoration that not only consumed a place and its memories, but left “a mess on the landscape” as a reminder of the event (2005:106). The need for additional fuel when burning wattle-and-daub structures at the temperature of 500–1000 degrees (Tringham 2005:104) has seriously undermined theories regarding accidental combustion. Rather, house burning in societies of the Balkan-Pontic region was a “deliberate social strategy” (Stevanović 1997:335) representing the symbolic destruction of a household group (Bailey 2000:165). Similarly, V.A. Kruts views house-burning as a parallel to cremation of the human dead, which is

generally agreed to have been the near-universal mortuary practice of the early to middle Tripolye culture (Kruts 1977; Zbenovich 1996:209-210). The lack of complete hearths in some Tripolian houses may signify that they were ritualistically destroyed and removed prior to the destruction of the house (Chernovol 2008:179; Kruts 2008b:62). Viewed as the "heart" of the house (i.e. the source of heat, the site of food preparation and the center of domestic life), this action would have great symbolic value. Objects left in the destroyed houses, particularly objects assumed to be of ritual importance such as whole, decorated vessels and figurines, could have been intentional tributes to deities or deceased ancestors (Kruts 2008a:44; 2008b:62).

The Conventional Conception of Talianki

Very small samples of the giant-settlements have been excavated; in the case of Talianki, perhaps two percent of the extant structures have been uncovered. However, these samples, combined with knowledge gleaned from geomagnetic surveys, showcase an overall homogeneity to houses and artifacts that is consistent with our knowledge of the Tripolye culture in general. The excavations at Talianki have not suggested any social stratification in terms of house types or material culture. Much like the archaeological materials, the political organization of the settlements is assumed to be fairly egalitarian, with authority perhaps vested in a number of "big men" or chiefs, each of whom would have acted as a family or clan representative. Subdivisions of up to twenty houses can be perceived in the settlement plans of Talianki and Maidanetskoe, which are grouped in small clusters or linear arrangements along presumed thoroughfares. These are interpreted by P. Kohl as being reflective of some form of community or family organization (2007:44).

While some of the Talianki settlement's shape can be discerned from aerial and

satellite photography, most of the knowledge regarding its size, layout, and architecture comes from a geomagnetic survey conducted by G. Zagniy and V. Dudkin from 1983 to 1986. This survey showed that the structures of the site were arranged in concentric rows separated by gaps of seventy to a hundred meters (Kruts 2008b:59). In the center lay a relatively open space of some sixty hectares, from which discernible streets radiated outwards. It has been suggested that the purpose of these spaces could have been to secure livestock at night or in times of trouble (Kruts 2008b:59). The distinctive layout of Tripolye settlements is quite consistent across all chronological periods, but J. Chapman asserts that a more “planned” character emerges in giant-settlements such as Talianki and Maidanetskoe, perhaps indicative of greater social complexity (Chapman 2010:82). Here it is useful to reiterate the position of Kruts that “[...] it is incorrect to believe that [the Tripolye culture] reached a higher level of development only in the Cherkassy region, just because of the presence of the giant-settlements” (2008a:48). The qualitative assessment of Chapman may well be flawed by differential preservation of sites; compared against the geomagnetic plan of Maidanetskoe, even the layout of Talianki is highly irregular and varies greatly in terms of the density of housing across the settlement. Great care should be taken when assigning complexity to the giant-settlements, as the data tends to wear thin rather quickly.

Some time after the abandonment of Talianki, *kurgans* (burial mounds) containing graves belonging to the pastoralist Yamnaya culture were sited in a northwest-to-southeast line directly over top of the Tripolye settlement (Kruts 2008b:58). These mounds post-date the settlement's abandonment by centuries, hence the two phenomena are not directly related (Kohl 2007:43); however, it is compelling to think that their placement was not a coincidence. Perhaps owing to its status as an old and mysterious anthropogenic landscape, the people of the Yamnaya culture conferred their own significance to the area,

reinterpreting it as a place of ritual and mortuary importance.

Talianki is probably best known for its size, and is indisputably the largest of the giant-settlements. V.A. Kruts estimated the size of the settlement as being 450 hectares, with a total of 2700 structures (Kruts 2008b:58). The areal value was calculated based on the product of the settlement's average width (ca. 1.5 km) and length (ca. 3 km), while the number of structures was generated through extrapolation of the housing density observed on the geomagnetic plan of the settlement. The geomagnetic survey conducted by Zagniy and Dudkin revealed approximately 1400 structures over 232 hectares of the site, for an average of six houses per hectare. While the observed housing density is hardly consistent across the entire settlement (with the northern end having by far the most dense cluster of geomagnetic anomalies), it is difficult to tell whether this should be ascribed to differential preservation of the structures, post-depositional damage by plows, the limitations of Soviet-era survey equipment, or the actual building practices of the Tripolian residents at Talianki. Any values generated for the number of structures should be treated as a tentative “best guess,” necessary for filling in the unsurveyed portion of the site.

In the literature of Tripolian studies, population values for Talianki have tended toward the extreme. The assertion of Kruts that family units of five to seven individuals resided in each structure formed the basis of placing the population at 14,000 people (Kruts 1989:117–126; Kruts 2008a:46). Kohl speculates that the population could have been “possibly more than 15,000 people” in the settlement proper, and twice that number if one counts hypothetical satellite settlements (Kohl 2007:44). Kruts wavers on the issue of satellite settlements (in this case within the same paper), claiming that dozens of small settlements of 7–15 hectares possibly existed in close proximity to each giant-settlement (Kruts 2008a:47), while later stating that “[...] there were no agricultural districts attached.

That is, all of the population of a certain territory was concentrated just in the giant-settlements" (Kruts 2008a:48). This indecision typifies the problems of discussing the population of Talianki; it becomes a vicious cycle of inference. The dearth of known contemporaneous sites close to Talianki has led to the conclusion that it served as the home of the entire Tomashovskaya local group, but the size of the settlement and seeming impossibility of its independent economic functioning prompts speculation about political complexity and satellite settlements. Reminding ourselves of the initial observation (that there are no nearby settlements dating to the same habitational period), we are left with theoretically-necessary hamlets which do not, to our knowledge, exist, supporting the functioning of a supposedly complex, densely-populated settlement where there is no evidence for activities more complex than subsistence and craft production.

Demographic estimates of the Tripolian household other than that of Kruts mostly give a similar range, as they are all based on analogies to ethno-historic data. M.Yu. Videyko is in agreement with the higher end of Krut's values, estimating 6.6 residents per house (Videiko 1992:9–11) while A.G. Korvin-Piotrovskiy gives a lower range of 3.5–4.5 residents per house (Kolesnikov 1993:36–41). A.V. Diachenko takes a different approach, utilizing statistical analysis of the living space within structures and generalized per-person spatial requirements to estimate the number of individuals per household. Initially the results of this analysis were quite low – 2.4–2.5 individuals per household (Diachenko and Chernovol 2009:9). This was later determined to be a miscalculation, and was revised to four people per house (Diachenko 2010:114–120).

Recent Reassessments

The issue of the size and population of the settlement at Talianki are central to answering questions regarding paleoeconomy. Recently, the areal estimates of Kruts have

been tested and rejected on geometric grounds; the product of the length and width of the settlement represents the space as rectangular, and significantly inflates its interior space. Diachenko (2010), calculating the settlement's size as if it were an ellipse, achieved a result of 341.5 ha. For the purposes of this study, a similar value obtained in the same manner was previously used (Harper 2011) until planimeter measurements were taken in an effort to settle the issue more definitely. The results were ultimately quite close to Diachenko's calculations, placing the settlement's size at approximately 335 ha (Harper 2012 *[note: never published; see Rassmann et al. 2014 for current high-precision settlement morphology]*). While planimeter measurements are variable and subject to operator error, numerous iterations returned consistent results, which were then analyzed statistically. This value is asserted to be the most accurate to date. By redressing the size of the settlement, its population must also be recalculated to reflect the change.

Accepting a definitive value for the settlement's population is problematic, as there is little ground to assess one ethno-historical analogy as superior in terms of its application to an Eneolithic settlement belonging to a poorly-understood culture. Diachenko's values are given more credence in this study due to their attempted adherence to the archaeological materials. It has also been suggested (Diachenko, personal communication, December 19, 2010) that the sex-age statistics of the Late Tripolye cemetery at Vykhvatintsi, where 60% of the graves belong to children (Zbenovich 1996:210), additionally point to smaller household sizes due to high childhood mortality. We are still left with uncomfortable problems: firstly, we have no idea how Tripolian cultural values could have affected their conception of per-person spatial requirements; and secondly, it is difficult to assess how appropriate it is to substitute the people buried at Vykhvatintsi for the residents of the giant-settlements, who lived some 300 years earlier. Arguably, it is much more chronologically appropriate than analogies to housing during the

medieval period or later as in the other examples, but for the sake of argument a wide range of values will be employed in this analysis.

Beyond the settlement size and household composition, the final problem of generating a population value is assessing how many structures out of the total number were synchronous. An understanding of this may be formed by looking at the microchronology of ceramics at the settlement. Diachenko contends that 78.4% of structures would have been occupied during the peak habitational period at Maidanetskoe, and that the formation processes of the settlement at Talianki are virtually identical (Diachenko 2008a:14; 2010:120–121). Aside from two structures (houses 2 and 3) that are definite outliers, containing ceramics that date to an earlier phase of the Tomashovskaya local group (Ryzhov 1990:87), differences in the composition of household ceramics amount to very subtle stylistic changes over the course of just a few decades.

Ultimately, assuming a settlement size of 335 ha, a housing density of six houses per hectare, an average family size of 4–7 individuals, and a 78.4% ratio of synchronous structures, we derive the following – ca. 1580 synchronous structures housing 6300–11,000 residents. These values form the basis for the spatial and economic analyses presented in Chapter 4.

2: Characteristics of this Study

Tripolian Archaeology and Theory

The Tripolye culture is underrepresented in Western archaeological discourse, as are many interesting topics in Ukrainian archaeology. Aside from a small body of articles dating from the past fifteen years, most of which are introductory in nature and sparse on details, there are few English publications regarding what is perhaps the most enigmatic culture of the European Eneolithic. This may be attributed to the barrier of language and the lingering social and political differences incurred by decades of enmity between the Soviet Union and the West. Or, if one wants to reduce it to a matter of dollars and cents, it could be asserted that the comparatively poor funding of Ukrainian archaeological efforts is an impediment to participation in conferences and publications outside of the former Soviet republics.

However, a lack of funding should not be construed to be a lack of expertise. It is a common American prejudice to conceive of Continental archaeology, with which post-Soviet archaeology is sometimes lumped, as mired in the theoretical stagnation of Culture History. It is difficult to pigeonhole Ukrainian archaeologists in our typical typology of theory, and from the start I must state my indignation at the thought that branding oneself with theoretical titles automatically equates to some kind of intellectual dynamism. Few seem to realize that Soviet archaeology in many ways paralleled the Anglo-American “New” Archaeology, with its focus on quantification, statistical analysis, and scientific methodology.

Studies of the Tripolye culture run the gamut from highly analytical quantitative studies that bear a resemblance to New (or “Processual”) Archaeology (e.g. Diachenko and Chernovol 2009) to highly interpretive, qualitative studies that would be at home with

Western “Post-Processual” archaeology (e.g. Burdo 2008). Many studies still consist of creating typologies and chronologies to add to the understanding of prehistoric culture history, but they have great utility in both informing the more theoretical studies as well as engendering an admirable knowledge of material culture. As in American archaeology, most researchers lie somewhere in between all of these extremes, utilizing an unarticulated body of theory that is partly interpretive and partly explanatory, informed by the sort of innate archaeological “know-how” that we all tend to take for granted.

Aims of this Study

From the Western perspective, it ultimately can be said that the problem with working in Ukrainian archaeology is not so much a lack of knowledge as it is accessibility to that knowledge. Language can be a formidable barrier and even mundane discussion of the Tripolye culture is unusual in the West. This study originated as an exercise in understanding the culture history of a nebulous archaeological culture, but soon narrowed to have a much more precise goal: creating a speculative model of subsistence at the giant-settlement of Talianki.

Studies of Tripolye agricultural production and settlement economy have been conducted in the past (Bibikov 1965; Kruts 1989; Shmagliy and Videyko 1990; Kolesnikov 1993; Gaydarska 2003; etc.), but they are generally fragmentary investigations utilizing a limited number of variables. Most focus on estimating cereal production as a means of understanding carrying capacity within a certain exploitation limit, but few are performed by specialists in agriculture. As a result, their conclusions often raise more questions than they answer. In their survey of these studies, A.V. Nikolova and G.A. Pashkevich (2003) concluded that this line of research is very much in need of more expert opinion. While this study does not presume to be “expert” in nature, it does attempt to address several areas

that have been neglected in past studies, while testing previously-held assertions and analogies. The presented research has two chief aims: firstly, to assemble as much data as possible from interdisciplinary sources to create a paleoeconomic model; and secondly, to critically assess the existing hypotheses and assumptions about the functioning of Talianki and the other giant-settlements. These hypotheses can be reduced to three arguments (articulated in Kruts 2008a:58):

1. Talianki was a settlement of 450 hectares, with a population of roughly 14,000.
2. In order to sustain the settlement's population, it is likely that a hierarchical system of satellite settlements existed.
3. The abandonment of individual settlements was precipitated by environmental collapse.

As previously mentioned, the first point – at least in part – has already been countered by more precise study of the settlement's areal dimensions. This study aims to demonstrate that the functioning of Talianki was entirely possible under a “typical” Eneolithic economy in a single-site context, while also suggesting optimal population, production, and land use values. As a secondary objective it also discusses the environmental sustainability of ancient agronomic systems, arguing that an examination from the perspective of modern agricultural science disproves much of the “environmental collapse” theory.

Theoretical Perspective and Methods

The key theoretical base of this research is that subsistence economics constitutes a “real” system (after von Bertalanffy 1972:421), the variables of which can be quantified and analyzed. However, in working from archaeological data not all of these variables are known (or possibly knowable), so inference and estimation must serve as stand-ins for certain concrete values. The reasoning employed is mostly not hypothetico-deductive in

nature, as the use of spatial analysis here is essentially inductive; that is, it is more in common with hypothesis creation than hypothesis testing. Oftentimes the assessment of data relies on the inference to the best explanation (Harman 1965:89). Simply put, the most plausible, least complex explanation of the available data is taken to likely be the truth. While this may seem like a reductionist perspective, it can be seen as an intellectual counter-point to the prevailing theories regarding Talianki, which have gone beyond the data in a variety of uncomfortable ways.

Although the approach here is not strictly mathematical, it adheres fairly closely to L. von Bertalanffy's (1950; 1972) framework of General Systems Theory. More particularly, borrowing from the writing of G.R. Conway (1987), we may state that this study focuses on the workings of an agroecosystem. The anthropogenic agricultural landscape represents a system wherein inputs and feedback from both humans and the environment are constantly exchanged and must be kept in a balanced state for optimal functioning. Agricultural systems produce not only raw sustenance (i.e. production), but are also assigned social value on the basis of their stability, sustainability, and equitability (Conway 1987:100). Ideally, dynamic modeling would include the aspect of social value in addition to the environmental variables that dictate the more functional aspects of the subsistence system. However, for the time being this model is effectively a static representation of a dynamic system, with social value inferred from the results rather than incorporated into the analysis. The lack of recursivity is a limitation of the model at this stage in its development, not an assertion of any kind on the part of the researcher.

A system is defined as a set of inputs, outputs, relationships and connections. Applied to an agricultural production system, our inputs are seed and labor and our output is production, which can be defined in both gross and net terms. The key relationship that is examined is that of distance and production, following the writings of M. Chisholm

(1968) on cost-distance analysis. The connection of agronomic production with animal traction and stockherding is examined, as well as the connection between agronomic production and the nutrient content of soils (which is key to the sustainability of the system). Stability is briefly discussed in the context of risk management through dietary diversification (after Gregg 1988).

Much of the work here utilizes a synthesis of interdisciplinary published data to re-assess the “canonical” conception of Talianki. The sources used range from archaeology to agronomy, history, geography and animal science. In surveying these materials, quantitative data and empirical observations are always preferred, though it is certain that some measure of subjective bias was introduced. Where statements are not strictly falsifiable, it is hoped that a well-reasoned argument is given some credence. The modeling that is included relies heavily on the concepts of site catchment analysis (Vita-Finzi and Higgs 1970) and cost-distance analysis (Chisholm 1968). Areal measurements were taken with a planimeter to establish the settlement's size (Harper 2012), while simple geometric calculations established areal estimates for the performance of resource area analysis. Finally, fieldwork was undertaken at Talianki during June and July of 2011. While the focus of this excavation was not directly related to the topic at hand, being in Ukraine offered the opportunity to meet and confer with Ukrainian archaeologists, photograph artifacts, and gain a familiarity with Tripolye material culture.

3: Agricultural Production and Human Diet

Material Evidence

In general, the Tripolye agriculturalists utilized the standard “Neolithic package” of domesticated plants and animals that diffused from the Near East (Kohl 2007:44). Cereals such as barley, buckwheat, einkorn, emmer, millet, and wheat were cultivated, as well as a variety of legumes and fruits (both wild and domesticated) such as plums and grapes. While sheep, goats, cattle and pigs were tended in fairly large numbers, osteological finds of auroch, deer, elk and horse remains show that hunting still played an important role in diet supplementation. Copper and bone fish hooks and flint arrowheads attest to this as well (Kohl 2007:45).

Animal husbandry formed an important part of the Tripolye culture's economy (Kohl 2007:45), with cattle being the most numerous (Bibikov 1965:53). In addition to being kept for meat and milk production, it is believed that they were used as draft animals as well. The morphology of steer bones found at Talianki show large muscle attachments indicative of this use (Videiko 1996:70). Combined with the primitive ards found at the settlement of Novyie Ruseshty (Kohl 2007:45) and clay “transport vessels” interpreted as depicting cattle drawing sledges (**Figure 4**), there is fairly extensive evidence for the use of animal traction. Indeed, it is hard to imagine a large, cereal-dependent population existing in the absence of this technology.

Paleobotanical Remains

Much of our knowledge about the Tripolian agricultural economy comes from paleobotanical assemblages, consisting mostly of carbonized material recovered from the excavation of *ploshchadki*. G.A. Pashkevich (2006) has compiled data on the

paleobotanical remains collected at many Tripolye sites. In general, cereals account for 30–46% of the remains across the Tripolye A, B, and C periods (2006:Figures 3.29–3.31). Emmer wheat (*Triticum dicoccum*) was the most common among these. The largest samples of Tripolian botanical remains come from the giant-settlements of Maidanetskoe and Kosenovka (Pashkevich 2006:Table 6), and for the purposes of this study it is assumed that they are spatially and temporally close enough to Talianki to represent essentially the same type of production system.

Figure 4. Transport vessels – containers with zoomorphic heads and sledge-like features at the base – recovered from Talianki. Not to scale. *Source: photos by the author; collections of the Tripolye Culture Museum, Legedzino.*

In the available materials (summarized in **Table 3**), we see a 1.5:1 ratio of peas to cereals of all types. It is notoriously difficult to infer actual cropping ratios from paleobotanical remains, which represent a biased, very fragmentary record subject to differential preservation. In the case of the Tripolian *ploshchadki*, plant remains were likely intentionally deposited prior to house destruction, representing a ritual offering and not typical food storage practices. The overwhelming majority of pea macrobotanicals at Maidanetskoe attests to this. In an effort to add greater variability than past subsistence models, which are mostly “cereal-only” in scope, we can look to a methodology proposed by R. Dennell (1978), which recommends counting the number of sites where a given paleobotanical category is predominant, then determining ratios by comparing the number

of sites (in our case, “cereal” and “legume” sites) to one another. It is an admittedly crude way to go about doing things and is skewed by a small sample size, but the overwhelming presence of peas in the paleobotanical assemblage is difficult to ignore. Therefore, as discussion proceeds regarding agronomic topics and model development, a 2:1 ratio of cereals (represented by emmer) to legumes (represented by field pea) is assumed.

Crop	**Kosenovka**	**Maidanetskoe**	**Talianki**	**Total**
Einkorn (*Triticum monococcum*)	77 (35.3%)	-	1 (7.7%)	78 (6.1%)
Emmer (*Triticum dicoccum*)	139 (63.8%)	264 (25.1%)	12 (92.3%)	415 (32.4%)
Spelt (*Triticum spelta*)	-	1 (0.1%)	-	1 (<0.1%)
Common Wheat (*Triticum aestivum*)	1 (0.5%)	-	-	1 (<0.1%)
Barley (*Hordeum vulgare*)	-	8 (0.8%)	-	8 (0.6%)
Millet (*Panicum miliaceum*)	1 (0.5%)	-	-	1 (<0.1%)
Pea (*Pisum sativum*)	-	777 (74.0%)	-	777 (60.7%)
Total	218	1050	13	1281

Table 3. Paleobotanical remains from three giant-settlements, adapted from Pashkevich 2006:Table 6.

Faunal Remains

The reconstruction of livestock population ratios based on assemblages of faunal remains has a long history in Tripolian studies. S.N. Bibikov, based on materials from nine Tripolye culture sites (Soloncheny, Stena, Polivanov Yar, Sabatinovka, two habitations at Nezvisko, Vladimirovka, Kolomiyshchina, and Grebeni) posited an animal population consisting of 44.6% cattle, 34% pigs, 18.2% ruminants, and 3.2% domesticated horses (Bibikov 1965:53). Among the settlements of the Tomashovskaya local group, cattle are

almost completely predominant in the archaeological materials, consisting of 78.9–83.1% of the livestock population at Talianki and 70.6–75.9% of the population at Maidanetskoe (Diachenko, personal communication, 22 October 2011). Utilizing the methodology from an unpublished work by Diachenko on reconstructing herd sizes at Maidanetskoe (using data from Zhuravl'ov 2008), it is possible to find the minimum herd composition at Talianki.

The variables included in this calculation are the ratio of immature to mature cattle known from osteological reconstructions (a), the number of adult individuals (b_1), the reconstructed model value for herd size (b_2), and the number of generational cycles over the course of the settlement's habitational period (t). When known values are inserted, these variables are defined as a = 0.8, b_1 = 10, b_2 = 80 to 96, and t = 6.5 to 8.8 (Zhuravl'ov 2008:Tables 1–29; Diachenko, personal communication, 22 October 2011). This model assumes a settlement habitational period of 50–70 years, an eight-year cycle of animal use, and the necessity of a strong herd to support intensive meat and milk production (10-12 times larger than the number of animals slaughtered in a given period). The following system of equations produced the calculations presented in **Table 4**:

$$b_2 = a(10 \ldots 12)$$

$$t = \frac{50 \ldots 70}{8}$$

$$MNI = (9.1 \ldots 15.2) \cdot \left(\frac{1580}{39}\right)$$

Of course, these calculations are dependent on a very small sample of cattle remains, constituting 10 mature and eight immature individuals found at 39 excavated structures. These remains are but a fragment of the record and represent only those animals that were slaughtered for meat and whose bones were deposited within or directly adjacent to houses. The minimum number of individuals that is calculated on the basis of this data (a herd of 369 to 616) is in all probability far lower than the actual value.

Adult individuals from osteological sample (b_1)	Model value (b_2)	Generations (t)	Generational Composition (b_2/t)	Relation to the settlement	Minimum number of individuals (MNI)
10	80 - 96	6.3 - 8.8	9.1 - 15.2	$\frac{1580}{39}$	369 - 616

Table 4. Calculation of the minimum number of cattle based on the osteological reconstruction of O.P. Zhuravl'ov (2008).

Agronomy

Previous Studies and Analogies

In the literature of Neo-eneolithic archaeology, various estimates have been influential in forming our conception of acceptable yield levels for ancient European agriculturalists. Two older estimates that have been applied to studies of the Tripolye culture are those of S.N. Bibikov (1965) and R. Dennell and D. Webley (1975), with Bibikov's work being particularly influential. Other estimates that should be considered for discussion are those of S.A. Gregg (1988) and A.V. Nikolova and G.A. Pashkevich (2003). Since our understanding of ancient farming behaviors is fragmentary and since crop yields vary greatly depending on available technology and environmental conditions, these studies are necessarily qualitative and rely heavily on the use of comparisons to known historical examples.

While it is true that the modern use of machinery and inorganic fertilizers represents the most significant change in agricultural yield development since the Neolithic, not all pre-modern records of yields can be accepted as analogous to the situation in the Tripolian communities. In comparing studies, there are two key factors that we must try to control for: environmental context and management behaviors. In addition, it must be kept in mind that, for the purposes of this model, which notably incorporates cost-distance analysis, it is important to establish an "optimal" yield value, which will then be modified downwards

according to the model parameters. Most previous studies of agricultural production modeling rely on the application of a predetermined average yield value.

The calculations of S.N. Bibikov (1965) are based on 16th and 17th century records of wheat yields in the Dnieper forest-steppe zone. These yields, including tithes, averaged 50 poods (819 kg) of cereal and 75 poods (1229 kg) of straw per hectare (Bibikov 1965:53). Assuming a monthly subsistence requirement of 1 pood (16.38 kg) of grain per per person and a seeding rate of 10 poods (164 kg) per hectare, Bibikov derived a per-person land use value of 0.3 ha. Including waste and surplus production to stave off periodic crop failures, this value was doubled to 0.6 ha. Expressed as a net consumable yield accounting for seeding but not waste, Bibikov projected a value of 655 kg ha^{-1}.

R. Dennell and D. Webley (1975:106), in analyzing the catchment productivity of settlement systems belonging to the Karanovo culture in Bulgaria, postulated an ancient cereal yield of 400 kg ha^{-1}. This calculation was later applied to the Tripolye culture by B. Gaydarska (2003) in her paleoeconomic estimates for the giant-settlement of Maidanetskoe. After reducing this value by a further 50% to account for seeds and waste, she presented a fairly grim picture of agronomic productivity that called into question whether the settlement could sustain itself, or even whether a giant-settlement existed at the site at all (Gaydarska 2003:215). Her analysis ultimately resorts to making chronologically implausible statements to justify its conclusions, such as suggesting that Maidanetskoe represents an agglomeration of smaller, asynchronous sites. There is also some concern about the overlapping exploitation areas of Talianki and Maidanetskoe (Gaydarska 2003:214), which, given the practice of rapidly shifting settlement, never would have been synchronously utilized. As the population of Talianki moved to establish a new settlement (whether it be gradually or suddenly after a settlement-wide destruction), its exploitation area would have accordingly been reduced in size. However, these issues of

chronology are not the chief concern; the major problem lies with applying an improbably low yield value to the agriculture of the forest-steppe zone. While a net yield of 200 kg ha^{-1} may well be realistic for certain regions of Bulgaria, the chernozemic soils of the forest-steppe region are an altogether different matter.

A.V. Nikolova and G.A. Pashkevich (2003) are also in favor of applying fairly low average yield values (360–400 kg ha^{-1}), but they do not make a distinction between gross and net yield quantities (Nikolova and Pashkevich 2003:93). Their estimates draw from a variety of recorded values for cereal yields in different regions of the Russian Empire and USSR in the early–mid 20th century, favoring the lowest. While they derived in a far more studied way than Gaydarska's calculations, these values are still a very pessimistic view of ancient agronomic potential. It is interesting to note that spring wheat yields in the 1902 records from Poltava governorate (the closest geographic context in the study) average approximately 900 kg ha^{-1} (Nikolova and Pashkevich 2003:91). Despite the intervening two centuries between sources, these are still quite close to the values explored by Bibikov.

The study of any analogy must take into account the technological complexity of its source. However, the proclivity of researchers to take an early modern yield value and revise it downward does not have much basis in reality. Indeed, it seems more natural to assume that a fairly sparse population utilizing fertile soils – in a manner which, by the standards of the last millennium of agricultural practice, is not very intensive – would actually enjoy *greater* yields. From where do these assumptions about marginal yield quantities come? Perhaps it is useful to look at a few examples from the medieval period.

Medieval farming was based mainly around the concept of intensive field rotations, fallow cycles, and almost year-round utilization of land that was often only marginally productive. Draft animals were extensively used and some crops were harvested and stored almost exclusively as animal feed, with winter wheat constituting the main product

for human consumption. Such intensive use of land was made necessary by a large and increasingly dense European population (Platt 1980:304) which was dependent on bread and, not uncommonly, stricken by famine (Duby 1974:28). In discussing medieval agronomy, the historian G. Duby found that cereal yield ratios – that is, the ratio of seed sown to net consumable product – were often no greater than 1.6:1 to 2.2:1 (Duby 1974:21). By comparison, Gaydarska's projected net yield of 200 kg ha^{-1}, assuming a seeding rate for emmer of 150 kg ha^{-1} (Brink and Belay 2006:185; comparable to Bibikov 1965:53), would constitute a yield ratio of 1.3:1. Such a value, which is scarcely in the productive range, is ecologically implausible. Yet more importantly, it seems unlikely that a population producing such marginal yields would even coalesce into a giant-settlement in the first place, particularly when a huge area largely devoid of other sites is open to more efficient, dispersed forms of subsistence procurement. It is also worth mentioning that, despite the grim assertions of Duby, some medieval agriculturalists found great success. Agricultural historian R.S. Loomis (1978), based on observations of the long-running Rothamstead crop trials in England, suggests that wheat yields of 1 t ha^{-1} could be expected in areas of high productivity. Therefore the estimate of Nikolova and Pashkevich, while it compares favorably to Duby's model of medieval agronomic productivity, is still fairly marginal (2.4:1). The key difference between medieval European peasantry and Neolithic agriculturalists is that the former had no economic alternative to pursuing a life of highly variable subsistence farming on oftentimes marginal land, while the latter had a far freer hand in selecting nearly unoccupied areas of abundant production.

While medieval agriculture was predicated on extracting as much production as possible, to the point of performing multiple sowings per year in highly regulated rotation schemes, we do not have evidence to suggest that prehistoric agriculture was anything like this. P.I. Bogucki (1988:81) mentions that winter sowing of crops probably did not

occur before the 1st millennium BC. The lack of multiple sowings per year puts far less of a burden on soil nutrients and precludes the necessity for field rotations. Coupled with this, the tendency of prehistoric agriculturalists to site their settlements in areas of fertile soils, such as loess or chernozem, suggests, generally speaking, a higher level of productivity.

It is instructive to also examine agronomic yields within different environmental contexts in order to put various estimates into perspective, notably those of areas with more marginal precipitation and soil composition. Three examples from the Near East – the studies of S. Hillman (1973), A. Karagöz (1996), and S.R. Simms and K.W. Russell (1997) – are particularly illuminating. All of them are ethnohistorical studies of dryland emmer or wheat cultivation using traditional methods and technology. Hillman's study of villagers in Aşvan, Turkey, reported net emmer yields of 630 kg ha^{-1} (Hillman 1972:237), while the study of Karagöz reported gross emmer yields of 618 kg ha^{-1} in several villages in Çorum province (Karagöz 1996:176). The low yields in the latter study, which are characterized as "hardly at subsistence levels," can be attributed to shallow topsoil, soil compaction due to livestock ranging during fallow periods, and problems of erosion associated with steep topography (Karagöz 1996:175–176). Simms and Russell, on the other hand, report that mean wheat production among Bedouin farmers in the Petra valley of Jordan in 1986 approached 1 t ha^{-1}, with a range of 330–2480 kg ha^{-1} (Simms and Russell 1997:698).

It seems clear that higher yield quantities can be expected from the agriculturalists of prehistoric Ukraine than has been previously suggested. Owing to the above arguments, as well as unsuccessful attempts at their application during this model's development, the values of Bibikov, Gaydarska, and Nikolova and Pashkevich have been rejected. Returning to Neolithic studies, J. Kruk and S. Milisauskas (1999:294), in accordance with S.A. Gregg's (1988:58–59) writings on Neolithic cereal production,

believe that yield levels of 1t ha^{-1} were achieved in the loess soils surrounding Linearbandkeramik (LBK) culture settlements in Central Europe, and indeed in many fertile areas from the Neolithic right up to the beginning of the 20th century (when rapidly changing field inputs and plant genetics prompted widespread yield development in the Western world). In support of her claim (which echoes that of Loomis [1978]), Gregg states that in German statistical yearbooks of the years 1850 to 1905, mean wheat yields were found to be 1045 kg ha^{-1} (Gregg 1988:72–73). These records represent a time when fairly precise yield measurements were being taken, yet widespread mechanization and changes in field treatments had not yet taken place. To enumerate a modern analogy, this yield level is similar to the results of durum wheat farmers in the uplands of Ethiopia, who, utilizing mostly traditional technology and methods, obtain yields of 800–2500 kg ha^{-1} and average slightly under 1t ha^{-1} (Brink and Belay 2006:186). Following the work of Loomis, Gregg, Kruk and Milisauskas, this model accepts a value of 1000 kg ha^{-1} as being an "optimum" for Eneolithic cereal production.

In the case of pea cultivation, it is of concern that peas, by weight, contain only about 87% of the energy content of wheat. However, this deficiency is more than made up for by the fact that pea plants generate a much larger amount of edible matter per areal unit. For the sake of this model gross pea yields were calculated at 1400 kg ha^{-1}, which corresponds with the values of Gregg observed (1988:76) in 19th Century German sources. This value constitutes less than half the modern European average for field peas (approximately 4 t ha^{-1}) and is below the modern world average of 1700 kg ha^{-1}, which includes many marginal yields grown in tropical environments (Brink and Belay 2006:424).

Yield Calculation

Accepting 1000 kg ha^{-1} and 1400 kg ha^{-1} as our optimal gross yield for emmer and

field pea, respectively, we must then address the issue of how this yield is reduced by a variety of factors. Some past studies (Bibikov 1965; Gaydarska 2003) of Tripolye agronomic production have agreed on a proportion of 0.5 as being a suitable measure of waste and seed requirements for the next year. This figure is assumed to account for variables such as rot and the activities of grain threshing and milling, when the inedible mass of the grain (the chaff and bran) is separated and discarded. However when a constant variable – the seeding rate of emmer wheat – is known, when using this method the actual proportion of "waste" fluctuates greatly as the size of the initial gross yield is adjusted. **Table 5a** illustrates the problems this poses for generating an accurate estimate of net yield values.

Since the seeding rate is unchanging, we should expect to see higher net yields (expressed as a percentage of gross production) as the values are increased. **Table 5b** shows net yield calculations wherein losses are broken into several additional categories. After the removal of the seed required for the next year of cultivation, which is obviously left viable and unprocessed, threshing and milling of the grain is assumed to remove at least 10% of the mass of the gross yield (Clark and Haswell 1967:67). It is difficult to find accurate values for losses incurred during grain storage, particularly for pre-modern subsistence production systems where the entire process is contained "on-farm." S.A. Gregg found that, in studying records of wheat yields in Germany from the years 1850 to 1905, mean gross wheat yields were 1045 kg ha^{-1}, with waste due to rodents and fungus accounting for a mean loss of 200 kg ha^{-1} (Gregg 1988:72–73). She assumes these losses (comprising 19.1% of the gross product) to be fairly representative of pre-industrial storage systems. Although a radically different environmental context, the experiments of C. Sukprakarn (1986) regarding post-harvest cereal losses in tropical southeast Asia are illuminating. This study found that, over a span of ten months, untreated rice harvests were

reduced by 2.06 to 24.3 percent, with a mean value of 4.54 percent (Sukprakarn 1986:34). The unpredictable nature of waste should prompt us to adopt a conservative estimate, comprising 25% of the annual harvest after the seed stock has been removed. Overall, we may express the following formula for net yield determination:

$$Y_n = (Y_g - s) \cdot p \cdot w$$

where Y_n is net yield, Y_g is gross yield, s is the seeding rate, p is the processing coefficient, and w is the waste coefficient. The determination of pea yields follows the same formula, with the exception that the variable p is omitted. Therefore, our final calculations for net production (expressed in kg ha^{-1}) are as follows:

$$Y_n(emmer) = (1000 - 150) \cdot 0.9 \cdot 0.75 = 574$$

$$Y_n(peas) = (1400 - 200) \cdot 0.75 = 900$$

Since this study utilizes cost-distance analysis, the value of Y_n will be modified further depending on the distance of cultivated plots from the settlement boundary. As such, the base values outlined here should be considered the maximum potential values for the net consumable agronomic production.

Variable	**Losses per yield quantity (gross)**		
	400 kg ha^{-1}	**655 kg ha^{-1}**	**1000 kg ha^{-1}**
Seeds	150 kg (37.5%)	150 kg (22.9%)	150 kg (15.0%)
All waste	50 kg (12.5%)	178 kg (27.1%)	350 kg (35.0%)
Net yield (% of gross)	200 kg ha^{-1} (50.0%)	327 kg ha^{-1} (50.0%)	500 kg ha^{-1} (50.0%)

Table 5a. *The problem of "waste" in assuming a loss proportion of 0.5 when a constant variable (the seeding rate) is known.*

Variable	**Losses per yield quantity (gross)**		
	400 kg ha^{-1}	**655 kg ha^{-1}**	**1000 kg ha^{-1}**
Seeds	150 kg (37.5%)	150 kg (22.9%)	150 kg (15.0%)
Threshing and milling	25 kg (6.3%)	51 kg (7.8%)	85 kg (8.5%)
Waste	56 kg (14.0%)	114 kg (17.4%)	191 kg (19.1%)
Net yield (% of gross)	169 kg ha^{-1} (42.3%)	340 kg ha^{-1} (51.9%)	574 kg ha^{-1} (57.4%)

Table 5b. An effort to resolve this problem by incorporating more variables.

Environmental Sustainability

It has been asserted on occasion that the depletion of soil nutrients had a significant effect on the lifecycle of Tripolian settlements. For example, V.A. Kruts states that “[...] migration was caused by the exhaustion of the soil fertility around the settlement, deforestation, and possibly epidemics” (2008:44). The last two scenarios are conceivable, as a dense settlement of several thousand people would certainly use a great deal of forest resources and would be more vulnerable to contagion than smaller contemporary settlements. However, the first scenario involving soil nutrient depletion can be shown to be very unlikely, if not impossible.

The idea of soil nutrients as a key environmental determinant for explaining shifting settlement patterns in Neolithic Europe was first proposed by V.G. Childe (1929), who drew an analogy with modern slash-and-burn agriculture practiced by tropical agriculturalists. This analogy is completely inappropriate on the basis of the radically dissimilar environmental contexts, and was discredited by P.J.R. Modderman forty years ago (Modderman 1970). Ideas of this sort do not carry much weight with agricultural specialists, yet they continue to arise periodically in the archaeological discourse. The key problem for these theories is that soil nutrient depletion, depending on the environmental context, can operate on a very large time scale. For the nutrient-poor soils of tropical climates, loss of productivity from continual cropping can be perceived over just a few years. But for comparatively deep, rich soils – such as those found in the European loess and chernozem belts – productivity can be sustained for decades or centuries even in poorly-managed field systems.

The nutrient composition of soils dictates how well plants mature, and is a key factor in yield determination. The most vital and commonly measured nutrients are nitrogen, phosphorous, and potassium (N, P, and K). Plants utilize these nutrients in fairly

predictable ways, though the huge amount of variables involved and our relatively basic understanding of their functioning means that any model estimates must be reinforced by empirical observation of crop trials. Through the creation of a simple nutrient “budget” and consideration of data from modern crop trials we can get a general view of how Tripolian farming could have impacted soil fertility.

In this example of a nutrient “budget,” only the vital macronutrient nitrogen (N) is considered. By calculating the addition and subtraction of N in the field system, we can make inferences regarding whether nutrient depletion would have been probable in this context, and the rate at which it would have progressed.

Calculating the removal of nitrogen is relatively simple: nitrogen is taken up from the soil by maturing plants, and their subsequent harvest removes it from the field system. According to the United States Department of Agriculture (USDA), harvested emmer contains approximately 19.2 kg N per ton, while field pea contains 37.2 kg N per ton (USDA, “Appendix I: Nutrient Uptake and Removal”). If it is assumed that straw from the emmer plants is also harvested, this contains an additional 5.5 kg N per ton and yields roughly 120% of the weight of the caryopsis (Mullen et al. 2009:6). Adjusted according to our yield estimates, the annual per-hectare nutrient removal values are 25.8 kg N ha^{-1} for emmer and 55.5 kg N ha^{-1} for field pea.

Accounting for additions to the system is more difficult. Nitrogen is made available to plants by a wide variety of mechanisms, not all of which can accurately be accounted for without the use of site-specific testing and crop trials. The variables which have been accounted for here are seeding, nitrogen fixation by legumes, and sources of atmospheric deposition (rain, wind, and bird feces).

In the nitrogen cycle available nitrogen is mineralized by bacteria from soil organic matter, which becomes available to plants slowly (Bellows 2001:28). In general this

process conforms to an inverse exponential curve, with approximately 25–35% of nitrogen being mineralized in the year of application, 12% in the following year, 5% in the third year, and 2% in the fourth. Particularly in highly humic soils, massive reserves of soil organic matter are mineralized slowly over the course of centuries, constantly adding to stocks of available nitrogen. Relatively small amounts of nitrogen are also gained through atmospheric deposition, and lost through volatilization.

Leguminous plants are perhaps the most important part of maintaining the nitrogen balance of a field system. Legume crops, due to symbiotic *Rhizobium* bacteria that live in their root structures, act as highly efficient conduits for the introduction of atmospheric nitrogen into the soil (Phillips 1980:29). They are therefore an important component of modern crop rotation schemes and do much towards making nutrients available for subsequent cereal crops. The nitrogen removed through the harvest of a leguminous crop such as field pea is partially counteracted by the addition of atmospheric nitrogen into the field system via the process of fixation. Following field pea cultivation, approximately 20.8 kg ha^{-1} of residual nitrogen is left for every ton of production (McKay et al. 2003:5); in the example of our model, this amounts to an annual input of 31.3 kg N ha^{-1}. Even more significant, however, is the nitrogen fixation of clover (genus *Trifolium*) in fallow and pasture land (and also as a weed in cropped areas). B. Bellows (using calculations from Whitehead [2000]) states that unfertilized pasture composed of grass and clover will fix 94.1 kg N ha^{-1} (Bellows 2001:16). Under “moderate” grazing, this figure is adjusted to 62.7 kg N ha^{-1} to account for nutrient removal by livestock.

Table 6 summarizes the various additions and subtractions of nitrogen to the field system. The values for the cultivated crops include nitrogen removed by harvesting and nitrogen added via seed sowing, rhizobium fixation, and atmospheric deposition. Generalized values for atmospheric deposition and leguminous weed fixation are taken

from the calculations of Loomis (1978:480).

While these calculations project an inexorable loss of soil N due to emmer monoculture cropping, it should be stressed that annual losses are quite small and do not take into account N mineralization from soil organic reserves. Modern long-term soil fertility studies, such as the Magruder plots at the Oklahoma State University or the Ivanovice Crop Rotation Experiment (ICRE) in the Czech Republic, do not show anything approaching a catastrophic reduction in the yield of control groups even after many decades of monoculture. At the Magruder plots, a nitrogen-limited growth response was first perceived after approximately 70 years of continual winter wheat production (Mullen et al. 2001:7-8), but even at the 110-year mark yields had not been significantly affected (Mullen et al. 2001:Figure 1). In discussing the ICRE, which was conducted on chernozemic soils, E. Kunzová and M. Hejcman state that after 50 years of continual cropping, even the control treatments still had adequate natural reserves of N, P, and K (Kunzová and Hejcman 2008:232). They are dismissive of archaeological theories regarding the necessity of shifting cultivation, and cite cereal-legume rotation as a possible explanation for why crop yields and soil nutrient reserves have remained consistent and productive since the Neolithic (Kunzová and Hejcman 2008:233). Even if we accept a

Treatment	Yield (gross)	N removed	N added	Net change
Emmer (*Triticum dicoccum)* cropping	1000 kg ha^{-1}	19.2 kg ha^{-1} (cereal) 6.6 kg ha^{-1} (straw)	2.9 kg ha^{-1} (seeds) 8-12 kg ha^{-1} (atmospheric and animal deposition) 2-10 kg ha^{-1} (leguminous weed fixation)	-12.9 to -0.9 kg ha^{-1}
Field pea (*Pisum sativum*) cropping	1400 kg ha^{-1}	52.1 kg ha^{-1}	7.4 kg ha^{-1} (seeds) 29.1 kg ha^{-1} (pea fixation) 8-12 kg ha^{-1} (atmospheric and animal deposition) 2-10 kg ha^{-1} (leguminous weed fixation)	-5.6 to +6.4 kg ha^{-1}

Table 6. Projected nitrogen additions and subtractions to the field system per year of cultivation.

steady decrease in available soil N over the lifetime of a giant-settlement, a substantial loss of productivity would probably not be discerned within a 50–70 year window of habitation. In fact, whether incidental or by design, a simple cereal-legume rotation could have the effect of ameliorating these problems indefinitely.

Dietary Calculations

Without detailed analysis of human remains, reconstructing the composition of the Tripolian diet is difficult. Many works have been published in recent decades regarding dietary reconstruction through the analysis of isotope ratios in human bone, as well as use wear and the pathology of dental remains. In recent years, inductively coupled plasma mass spectrometry (ICP MS) and inductively coupled plasma-atomic emission spectrometry (ICP-AES) have been used to great effect in the field of paleodiet reconstruction; in some cases, even absolute ratios of food sources can be determined (e.g. the use of ICP MS and analysis of the output using a linear mixing model as in Ogrinc and Budja 2005). In an example from Poland, K. Szostek and his colleagues (2005:38–39), by analyzing concentrations of strontium, zinc, and calcium in human teeth, were able to conclude that meat from animals played little dietary role at the Lengyel culture village at Osłonki (ca. 4300–4000 BC). At the Ajdovska jama Neolithic site in Slovenia (ca. 4450-3350 BC), N. Ogrinc and M. Budja (2005:111–114) perceived quite the opposite: a population that subsisted primarily on the products of domestic animals (44% of the diet), with cereals as a secondary source of nutrition (39%). The role of agriculture in communities across prehistoric Europe is disputed and may not have always accounted for the majority of the residents' diet (Marciniak 2005:220). Perhaps the discrepancy between the results of Ogrinc and Budja (2005) and Szostek et al. (2005) may be

attributed to differences in ecological context - Ajdovska jama is located in a mountainous region more suited for hunting and stockherding, while Osłonki lies in the fertile farming territory of the North European Plain.

Contribution from Agronomy

The studies of Bibikov (1965) and Dennell and Webley (1975) decided that, for a population subsisting solely off of cereal, approximately 197–210 kg of wheat was required per person per year. Others (e.g. Hillman 1973; Neustupný and Dvořák 1983; Gregg 1988) have elaborated on these calculations by expressing values in terms of required daily kilocalories (kcal) per person or per family. Older models that reduce calculations to cereals or cereal-equivalent production are problematic, because not only do they misrepresent the prehistoric diet, but, as Gregg (1988) has demonstrated, to subsist off of cereals alone would be functionally impractical. With the aid of computer modeling, she reported that if wheat represented 60% of a subsistence diet, famines could be expected 5% of the time. If this was increased to 65%, famine risk jumps to 32% (Gregg 1988:139–140). It should be noted that the production of a surplus largely ameliorates this risk; for instance, the utilization of an additional 0.1 ha per person allows for a 2% risk of famine at 75% cereal consumption (Gregg 1988:139). However, Gregg's modeling illustrates the need for a particularly diverse range of food resources in a strictly subsistence scenario, as drought and disease can easily decimate a monoculture crop.

The caloric content of wheat is variable depending on the species in question and where it is cultivated. As emmer is an uncommon wheat race in modern agriculture, precise data on its nutritive qualities can be difficult to find. In a 1964 join U.S.-Canadian publication on the characteristics of various livestock feed products, emmer is cited as containing 3212 kcal/kg at a moisture content of 9%, and 3530 kcal/kg on a dry matter

basis (NRC 1964:56). It should be noted, however, that this particular study is neither recent nor is it focused on understanding the digestible energy content for human consumption. The most recent published nutritional values from the USDA (2010d:509) give a figure of 3390 kcal/kg for durum wheat (*Triticum durum*), which is also a tetraploid wheat and is the closest modern relative to emmer. Modern commercial wheat varieties range from 3270 to 3420 kcal/kg, with moisture contents ranging from about 9 to 13% (USDA 2010d:509-524). While it is a hexaploid wheat, it is worth mentioning that spelt (*Triticum spelta*), a contemporary of emmer which is notably also present in Tripolian paleobotanical assemblages, has a nutrient content of 3380 kcal/kg (USDA 2010d:418).

One problem that is sometimes present in archaeological literature is confusion regarding the moisture content of foods. Both Gregg (1988) and Kruk and Milisauskas (1999), who depend on her calculations, assume an energy content for wheat which is consistent with dry matter measurements – 3500 kcal/kg. Neustupný and Dvořák (1983) and Hillman (1973) offer more realistic projections of 3200 and 3150 kcal/kg, respectively.

For our purposes, a slightly higher value (3300 kcal/kg) is employed. This arises out of a desire to prefer more recent nutritional studies as well as a desire to create a generalized value that can include some small measure of other, somewhat more energy-rich cereals in cultivation, such as the spelt and common wheat observed in the paleobotanical record. With regards to field pea, the caloric value of 3030 kcal/kg is employed (as reported in Grubben and Denton 2004:421).

In calculating the provisioning requirements for the settlement, we must come to a generalized figure of kilocalories needed per person per day. Most previous studies have assumed a value in the neighborhood of 2000 kcal per day, which is a typical modern recommendation for adults leading a fairly sedentary lifestyle. However, it is likely deficient when one takes into account the level of physical activity inherent in an ancient agrarian

society (or a modern one, for that matter). Both the U.N. Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have published nutritional guidelines that exceed this value. According to the WHO (1974), adolescents and adults should ideally intake far greater amounts than 2000 kcal per day; recommendations range from 2200 kcal/day for moderately active females to 3500 kcal/day for very active males. It is also worth noting that for pregnant females, caloric intake increases by 15–25%. In terms of obtaining a value for basic subsistence, adults laboring in a seasonally cold climate must consume at least 2500 kcal daily to maintain health (FAO 1957).

Table 7 summarizes several of the Neolithic dietary models discussed here, standardized according to the caloric values utilized in this model. It is interesting to note the disparity between archaeological models and Hillman's (1973) ethno-historical study of Turkish villagers involved in a traditional mixed agriculture and herding economy. Hillman's calculations were obtained not only through agronomic calculations, but also via interviews with families regarding typical food consumption. He concluded that 3100 kcal per person per day was the minimum desired intake, and that production beyond this threshold was almost universally obtained (Hillman 1973:228). Cereal alone, which accounted for 78.5% of dietary intake, amounted to over 2700 kcal per day.

We unfortunately lack the capacity to interview the people of the Neolithic, and therefore must rely on mechanically-applied generalizations. Additionally, we are dealing with a significantly denser population than in Hillman's study area, where vast tracts of land were utilized for the food-producing needs of single families. However, it stands to reason that the desired diet of the Tripolian agriculturalists was likely far more varied and nutritious than that reflected in past calculations. It was surely more adequate than grim estimates such as those of Bibikov (1965) and Dennell and Webley (1975), which, for a physically active population, would undoubtedly result in malnutrition. Bibikov's estimate of

Model (author[s] and year)	Cereal produced per year (kg/person)	Cereal as a component of diet (%)	Energy from Cereal per day (kcal/person)		Total energy per day (kcal/person)	
			Original	*Adj.*	*Original*	*Adj.*
Bibikov 1965	197	100.0	n/a	1781	n/a	1781
Hillman 1973	320	78.5	2762	2893	3518	3685
Dennell and Webley 1975	210	100.0	n/a	1899	n/a	1899
Neustupný and Dvořák 1983	200	83.3	1753	1808	2105	2170
(this model)	161	58.2	1455	n/a	2500	n/a

Table 7. Original and adjusted calculations of cereal consumption adapted from four models (expressed in common terms, assuming 3300 kcal per kilogram of cereal), compared against this model.

the amount of cereal required for subsistence is based 16th and 17th century Russian sources which reported that one pood (16.38 kg) of cereal was needed per person per month (Bibikov 1965:53). It is not specified whether this was accompanied by further diet supplementation; the assumption is that this level of caloric intake is adequate for little more than long-term survival. As previously mentioned, our model assumes a 2:1 cultivated ratio of cereal to legumes, which results in cereal constituting 58.2% of the dietary intake. This is coincidentally within the confines of Gregg's (1988:139) limit of 60% for a system in which no surplus is produced. Even a severely poor cereal harvest (50% of normal) would still result in a daily caloric intake roughly on par with Bibikov's estimate.

Of course, there is little to no material evidence to guide our assumptions with regard to diet. This is yet another way in which more detailed study of the few available inhumation burials (such as the late Tripolye C2 cemetery at Vykhvatintsi) would benefit our understanding of Tripolian society. Until the materials indicate otherwise, it seems fair to avoid postulating levels of food production that are either deficient, on one hand, or surplus, on the other. For the time being, an adequate level of nutrition is assumed that is based almost entirely around cereal and legume consumption.

Contribution from Other Sources

The cultivation of fruits and vegetables in small gardens within the confines of the settlement, hunting, fishing, and the raising of livestock for milk and meat all would have been valuable supplementary sources of nutrition for the residents of Talianki. However, it is difficult to understand the relative value of this contribution as a component of the whole diet. As a means of analogy, we can look further at Hillman's study, in which meat and milk products accounted for 16% of food energy consumed (Hillman 1973:229). Considering that, in this case, one family could hold two milk cows, numerous chickens, and as many as 42 head of sheep, we can see that large quantities of livestock are needed to make even a marginal contribution to diet.

Since cattle constitute the most numerous livestock kept at Talianki and other settlements of the Tripolye culture, calculations for non-agronomic food sources are understandably centered around their utilization. Yet, compared to agronomy, there is far less return from stockherding per hectare of utilization. This becomes a key limiting factor with regards to a highly-populated settlement such as Talianki. As an example, 50 head of cattle would require between 250 and 315 ha of land, depending on the grazing strategy and land types utilized. In a strategy combining cattle grazing on a small amount of optimal pasture land and browsing in a large amount of forest land, approximately 18 ha of pasture and 297 ha of forest would be necessary (Gregg 1988:108). In an alternative scenario involving the utilization of large areas of cleared pasture, a sustainable, moderate grazing density of one animal per 5 ha would require 250 ha of territory. These differing schemes, which are hereafter referred to as the “pasture and browse” versus the “pasture-only” models of grazing behavior, are both included in this model.

The aforementioned 50 head of cattle, given an “optimal” composition based on sustainable herd maintenance and maximized meat and milk production (as detailed in

Bogucki 1988:87), could be expected to produce 1928 kg of meat and 2744 kg of milk annually (Gregg 1988:110). After computing the caloric value of these products, which contain 2280 kcal/kg and 640 kcal/kg, respectively (USDA 2010a:545; USDA 2010c:1841), we may obtain an annual production of 6,150,860 kcal. While this may seem like a formidable number, it is only sufficient to provision 6.7 individuals (effectively, one large nuclear family) for a year. By contrast, the same caloric output could be obtained from 3.2 ha of emmer or 2.3 ha of pea cultivation. While cattle should be taken into account both for their use in diet supplementation and for their role in tillage, the land required for their upkeep becomes increasingly problematic as population levels increase. Applied to Talianki, even Hillman's modest two milk cows per family would use nearly 200 km^2 of grazing resources. This would seem to suggest a much higher dependence on cereals at the giant-settlements than has been indicated elsewhere in Neolithic Europe.

IV: Modeling and Results

Model Characteristics

There are two main components to the model discussed here: one spatial and the other mathematical. As has been mentioned, the cornerstone of the spatial analysis are new values for the settlement's area that were first proposed by A.V. Diachenko (2010) and corroborated by digital adjustment and planimeter measurement of the site geomagnetic plan (Harper 2011). Distance contours for the purposes of cost-distance analysis are measured outwards from the settlement boundary, which is defined by the outer ring of geomagnetic anomalies. Excavations over the years have shown these to conclusively represent house remains. While the widely-propagated geomagnetic plan of the settlement has been shown to contain some problems of cartographic error, it is the best available source for understanding the extent and layout of the settlement. In understanding land use patterns, a map was prepared in order to differentiate arable land from swampy, forested riparian zones unsuited to agronomic production. Other than accounting for this terrain type, it assumes a layout of the settlement territory similar to J.H. von Thünen's (1826) isolated state, wherein territory is a flat plane with uniform transport costs and near-universal arability.

Mathematically speaking, thirty population states were modeled, from 500 to 15000 individuals. While the demographic estimates of settlement population only range from about 6300 to 11,000, the model values were expanded to better illustrate statistical trends. Instead of working from a predetermined catchment area and calculating a site carrying capacity, this analysis assumes that subsistence production is only limited by the working capacity of the labor force. In this case, a workforce (assumed to be 76% of the overall population) working twelve-hour days to till and plant as much land area as

possible during the two-week window necessitated by spring wheat cultivation in Ukraine. The introduction of cattle in terms of both diet and animal traction is dictated by the point at which hand labor is no longer sufficient to meet the agricultural needs of the settlement. Outside of the scope of agriculture, calculations were also performed to determine the use of forest resources (specifically, for fuel wood and construction material) over the lifetime of the settlement, following Kruts (1989) in assuming a per-person usage of 0.87 ha over a fifty year period.

Overall, the model is a static representation of a variety of different hypothetical population states that also illustrates land use, production efficiency, and, ultimately, the maximal population that can be supported at one settlement given the model assumptions. It is not by nature dynamic, although one variable (forest use) is time-dependent. While this discussion will reference various model states and describe some results, a more exhaustive listing of all results and the calculations used to receive them is presented in Appendix I. Before discussing the results of the model environment, let us discuss the spatial component and its methodological basis.

Methods of Analysis

Site Catchment, Cost-distance, and Labor

Research into the resource demands and economic potential of archaeological societies is generally seen as being a component of settlement or landscape archaeology, and more specifically the discipline of paleoeconomics. It is inherent to this line of inquiry that our focus is more on the territory around a settlement than the site itself, as we create a speculative model for carrying capacity and land use. Spatial analysis of this nature is usually referred to as “site catchment analysis” after the terminology of C. Vita-Finzi and E.S. Higgs (1970). The catchment area of a settlement is the total area available for

exploitation, while the area of actual utilization is known as the “settlement territory” or “settlement area” (e.g. Neustupný 1993:29). There is some confusion regarding these terms and what it is they are meant to describe, and in practice they are sometimes conflated (Roper 1979:124).

Understanding the extent of these territories can be problematic. On the basis of studies such as M. Chisholm’s (1968) analysis of mean house-to-field distances in modern societies, as well as R.B. Lee’s (1968:31) observation that !Kung bushmen regularly exploited resources within six miles (~10km) of a camp, “exploitation limits” are sometimes employed. Chisholm's studies in economic geography established that certain distance trends are nearly universal, regardless of differing technology or environmental context:

> Beyond about 1 kilometre, the costs of movement become sufficiently great to warrant some kind of response; at a distance of 3–4 kilometres the costs of cultivation necessitate a *radical* modification of the system of cultivation or settlement – for example by the establishment of subsidiary settlements – though adjustments are apparent before this point is reached (Chisholm 1968:131).

Chisholm's conclusions are based heavily on the work of von Thünen and are particular to agricultural land use in settled societies. The concept of generalized "catchments" for resources of all types was particularly reinforced by Higgs and Vita-Finzi (1972:31), who stated that exploitation generally ceases at five kilometers for settled groups and ten kilometers for mobile groups. A development of this idea is the use of time contours (usually expressed as a one-to-two hour walk), which helps to ameliorate the problem of differential energy expenditure due to changing terrain. While these measurements can be useful in measuring our calculations against presumed normative conditions, we should

not automatically assume their applicability. Indeed, the giant-settlement phenomenon can be considered anything but normative, archaeologically speaking. So while these limits should be kept in mind, it is best to find an alternative that takes into account both the labor potential of the settlement and the deleterious effect of distance on production.

Chisholm's cost-distance analysis, which informed his statement quoted above, measures the rising cost of land use as distance from the habitational site increases. It provides an alternative to the unquestioning application more mechanistic limits; effectively, it allows for agronomic cultivation beyond something like a five kilometer limit, while still modeling the diminishing returns that are to be expected. Assuming no change in land features or terrain, reduced production of approximately 20% occurs with each kilometer traveled from a habitational site (Chisholm 1968:52–53). In this manner, agronomic production exponentially decays the further one travels from the settlement boundary (**Table 8**). Since the area of cultivated land is limited by the amount of labor that can be mobilized from the settlement's population, in concert with losses in production due to cost-distance this has the effect of eventually imposing a carrying capacity (*K*) when production efficiency is outstripped by distance. An illustration of how reductions in gross and net production were perceived in the model is shown in **Figure 5**.

Distance from settlement boundary	**Productivity**	**Emmer gross yield (kg ha^{-1})**	**Emmer net yield (kg ha^{-1})**	**Field pea gross yield (kg ha^{-1})**	**Field pea net yield (kg ha^{-1})**
1 km	100.00%	1000	574	1400	900
2 km	80.00%	800	439	1120	690
3 km	64.00%	640	331	896	522
4 km	51.20%	512	244	717	388
5 km	40.96%	410	175	574	280
6 km	32.77%	328	120	459	194
7 km	26.21%	262	76	367	125

Table 8. The modeled diminishing yield quantities as one moves farther from the settlement boundary.

Land Use Patterns

In understanding the expected layout of resource zones, it is helpful to refer to J.H. von Thünen's (1826) concept of the "isolated state" (Chisholm 1968:20–32). This concept dictates that, given an isolated settlement with no economic ties or neighboring settlements, land use will conform to a predictable pattern of distance, with the settlement surrounded by bands of different use-types. The inner bands will understandably be utilized most intensively, and are therefore devoted to products with the highest value.

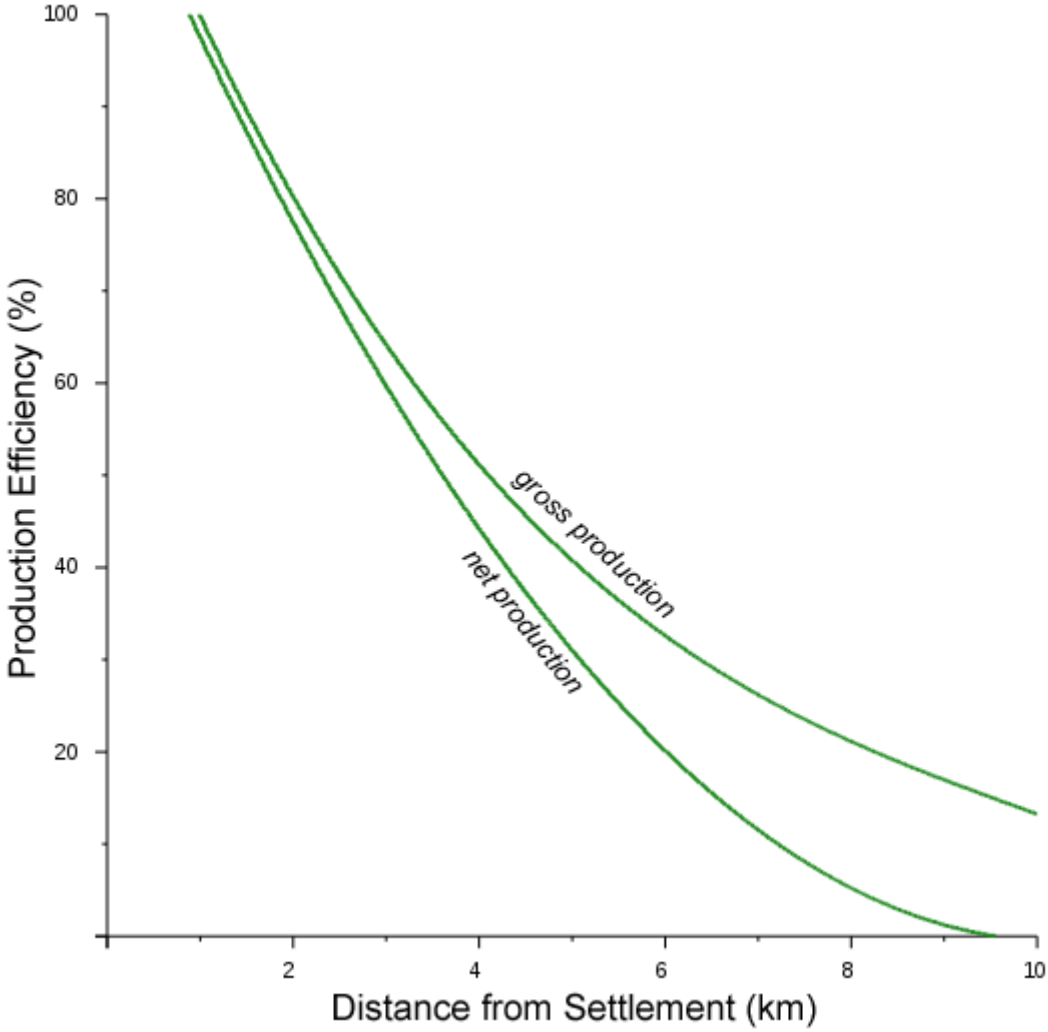

Figure 5. Reductions in yield quantity due to factors of cost-distance. While gross production will theoretically never reach zero, net production becomes negative when yield quantities are lower than the initial seeding rate.

While this was originally conceived as a monetary value, in our case we may conceive of value as being proportional with labor cost or energy production.

While we have little idea of the relative value that the residents would have placed on different resources, we can deduce that, in terms of labor inputs, cultivated land would have required the most attention. While stockherding also requires a large amount of labor, its land requirements are comparatively immense (additionally, livestock have the virtue of being animate and movable). Therefore, this model assumes that, moving outwards from the site boundary, the first zone would have been comprised agronomic land devoted to cereal and legume cropping. This is followed by cleared pasture lands, which give way to forested areas where wood is harvested, game is hunted, and cattle are browsed.

Of course, von Thünen's model is highly abstract; however, Talianki mostly conforms to its expectations in two ways. Firstly, the settlement is assumed to have been a nearly self-sustaining economic unit (given the absence of contemporaneous nearby sites); and secondly, the relatively flat terrain and small watercourses around the settlement mean that movement and transport costs would have been fairly uniform.

Determination of Arable Land

The proportion of arable land to non-agronomic territory (i.e. riparian zones) within the first few kilometers of the settlement boundary was determined by imposing a 250 meter grid over Landsat 7 imagery of the local area (**Figure 6**). Where this grid was intersected by watercourses, each square was designated as representing territory unfit for cultivation. The end result is in fairly close agreement with modern land-use patterns, where a margin of anywhere between 50 and 500 meters is typically left uncultivated on each side of a watercourse. While these territories are excluded from the modeled agronomic calculations, they are by no means considered to be non-producing zones.

Riparian zones constitute an important grazing environment for cattle. In particular, lactating cows with unweaned calves will prefer to stay close to water sources, where the quantity and quality of forage is at its greatest (Bailey 2005:110). Therefore, riparian zones are included in calculations of grazing and forest land, and should be recognized as having a large resource potential for the residents of Talianki, both animal and human.

Parameters of the Production Model

While it is possible to model a regime of agronomic production in which *K* is dictated by the point at which distance renders production to no longer be viable, this scenario is highly unlikely the be observed anywhere in reality. In our case, the use of cattle for animal

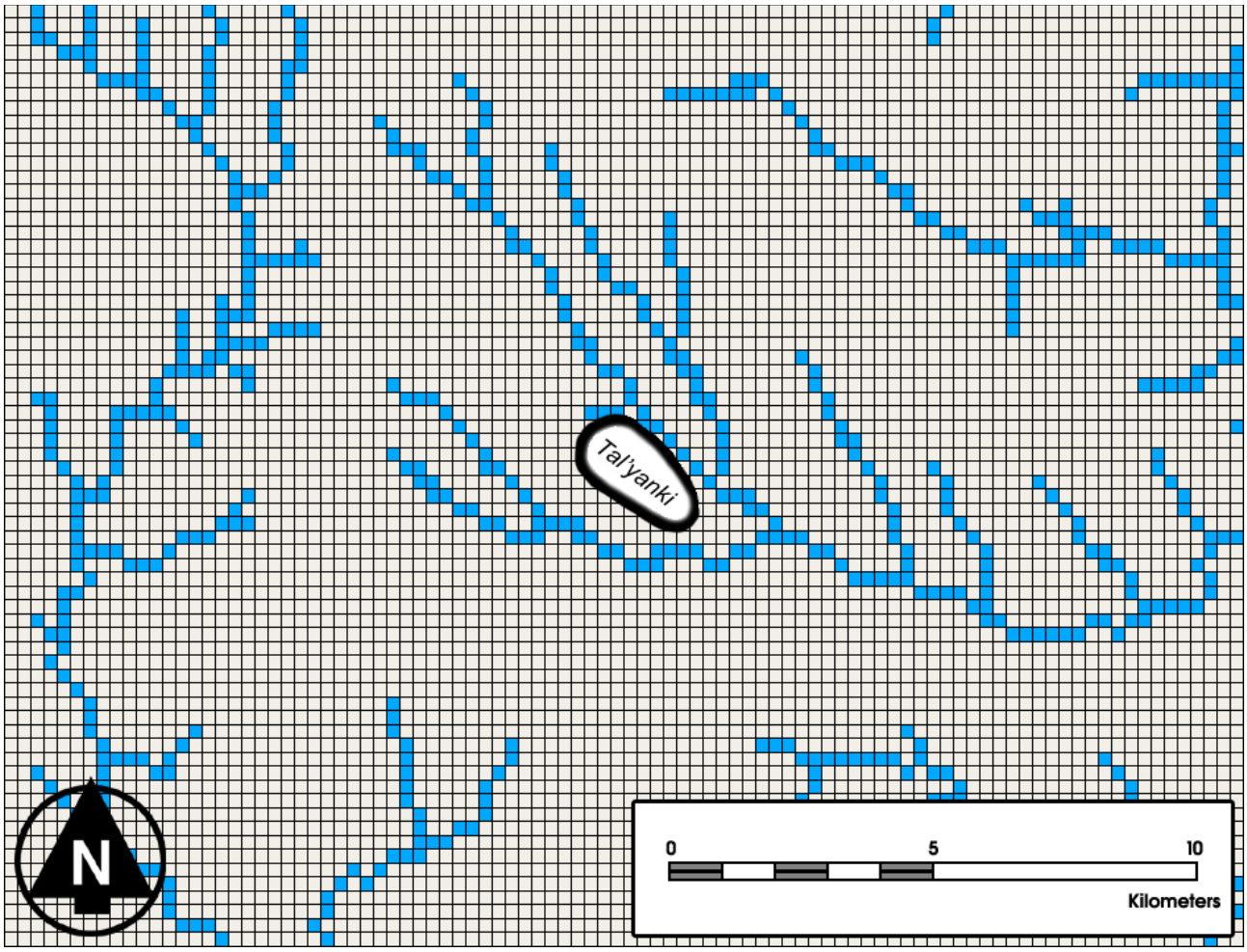

Figure 6. The map used in the determination of arable and riparian zones near the settlement. Each grid square has an area of 6.25 ha (62,500 m^2). *Source: map prepared by the author.*

traction is deemed to be a key determinant of production capacity. The manner in which the calculations were performed is as follows:

Firstly, the entire labor capacity of the settlement was determined, in person-hours per day, given a 12-hour working day and a mobilization of the entire able-bodied workforce (deemed to be ~76% of the settlement population). The amount of land that may be cultivated by this labor force is constrained by the necessity to sow spring wheat within a two-week window in Ukraine (Diachenko, personal communication, 17 November 2011). The amount of labor required to till and sow each hectare of cultivated territory was derived from the labor studies of G.F. Korobkova (1980) and S.R. Simms and K.W. Russell (1997). Korobkova's study experimented with the efficiency of Tripolye tillage, determining values for hand tillage (~172 hours/ha) versus ard tillage (~56 hours/ha) in chernozemic soils. Her findings indicated that three people working with horn hoes accomplished approximately the same amount of tillage in one day as one person driving an ard. It is notable that the estimates of Simms and Russel (1997:700) are far more costly and do not find as significant a savings in labor for ard use in southwestern Asia (200 hours/ha, compared to 350 hours/ha for hand tillage). Perhaps the discrepancy can be attributed to differing soil types; the chernozemic soils of the Southern Bug-Dnieper interfluve are deep, easy to process, and free of rocks. Korobkova's estimates for tillage are utilized here, as are Simms and Russel's estimate for sowing (specifically, the hand broadcasting of cereals), approximately 80 hours per hectare.

Secondly, the labor force must be segregated into two groups: those driving ards and those tilling and sowing plots by hand. Coefficients for the relative contribution of each were manually configured out to four decimal places until the caloric requirements of the settlement at a given model value were and the size of the cattle herd required for tillage matched the size of the cattle herd required as food, which were separately-computed

variables. The method chosen to model this situation dictated that animal traction and stockherding were not taken into account until the settlement could no longer mobilize the hand labor to feed itself with agronomy alone; this occurs when population (*p*) reaches a value of 5000.

Concerns Regarding Model Parameters

The nature of certain aspects of this model environment cause some concern regarding the accuracy of its output. Firstly, there is the problem of what to do with the settlement itself, notably the open space of some sixty hectares at its middle. This area has been excluded from agronomic calculations, but it has been previously proposed that not only are the immediate areas of settlements used for agricultural purposes, but they can be highly productive due to the introduction of nutrients from domestic waste (Hirth 1984:136). Secondly, the nature of the cattle calculations is such that, at low population values, the contribution of cattle to tillage and the human diet is not taken into account. And thirdly, the manner in which the amount of available labor is calculated (and therefore the amount of cultivated land) assumes that tillage is performed directly before the sowing of crops. While this would result in optimal sowing conditions, tillage is not nearly as time-dependent and could conceivably take place before the required sowing period.

The first two concerns can be dealt with rather easily. While the site area itself lacks any quantified production output, it is assumed to be the site of secondary food production (i.e. garden horticulture) that, while important for dietary supplementation, is a minor source of food energy. Additionally, by the time the model reaches population values that are relevant to our demographic estimates of 6300-11,100 people, sixty hectares (or even 350, taking the entire site area) is of little consequence when compared against the required land area for cultivation. Similarly, the number of cattle rises to an acceptable

level by the time this threshold is reached; at p = 6000, the estimated cattle population lies within the projected minimum number of individuals calculated in Chapter III.

The final issue is more difficult to adequately address. In its defense, the reliance on labor and the imposition of the two-week constraint is largely what enabled the functioning of this model without reliance on an arbitrary percentage of domestic animals as a dietary component. Understanding the relative contribution of foods to the Tripolian diet is a crucial step to overcoming deficiencies in models such as this, and is certainly a direction of research which should be encouraged and pursued.

Results

Much of the purpose for creating this model was to try and ascertain the most "ideal" population value for the Talianki giant-settlement given a more detailed spatial and economic reconstruction of settlement functioning than has been previously attempted. As such, several regression analyses were performed in an attempt to settle this issue. We are concerned mostly with calculations for the settlement carrying capacity (K) and the variables related to its determination; namely, the amount of land exploited and its distance from the edge of the settlement.

Areal Extent of Resource Extraction

We may begin by looking at regression models detailing land use across all of the modeled population values. The total values for land use were determined as the sum of all use types: agronomic land, pastures, forest land for wood harvesting and forest land for cattle browsing. The differences in land use between the two modeled cattle management scenarios were in some cases quite large, particularly for the middle range of population values. Despite uncleared land being far less efficient for grazing than managed pasture

systems, there is a significant economy of space that comes from ranging cattle partially in the same territory that is being used to harvest wood. Therefore, looking at distance contours from a “site catchment” perspective, we receive a range of supportable population values that are differentiated based on these practices. **Figure 7** illustrates trends in land use in comparison to 5- and 10 kilometer catchment radii.

For nearly the entire range of demographic estimates, the total area of resource exploitation lies within a one- to two-hour walk from the settlement boundary. While the

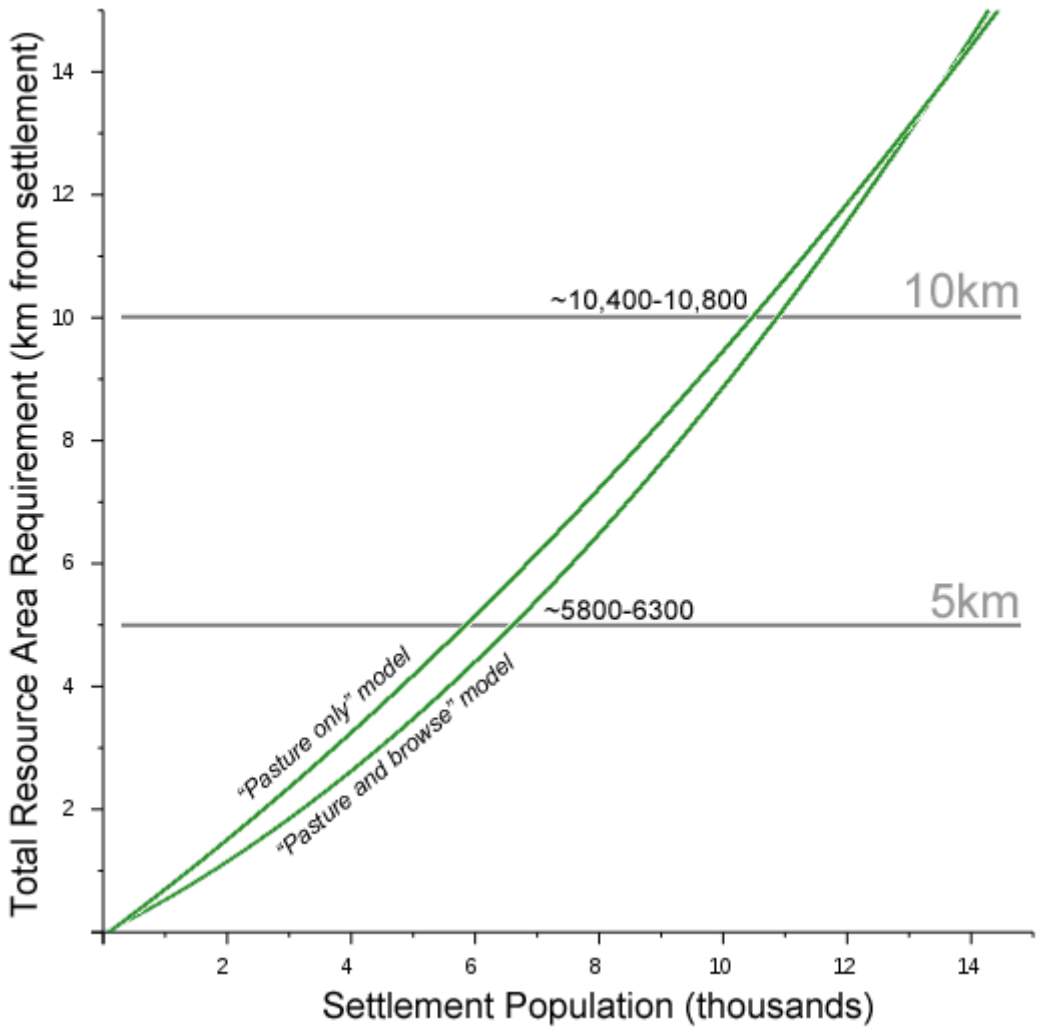

Figure 7. Regression lines illustrating the relationship between population and the required radius of resource procurement given two different livestock management strategies. Site catchments of 5 and 10 km are noted, along with the approximate population that may be supported within each.

exploitation of territory beyond the five kilometer limit disagrees with the generalized assumption for what is appropriate in a sedentary society, this does not cause undue concern. Notably, all of the cultivated land is within this limit (2.56 km at p = 6000 and 4.13 km at p = 11,000), while the vast majority of territory not being utilized for agronomy constitutes range land for cattle. In a qualitative sense, we may characterize values between the “settled” and “mobile” limits as having characteristics of each. At any given time, some subset of the population would lead a more itinerant existence than the day-laborers tending to fields, ranging cattle over wide territories and possibly not returning to the settlement on a daily basis.

Population

The most reasonable assumption for an “optimal” population value is generally $K/2$. According to E.B. Zubrow's work on carrying capacity, this point represents homeostasis between the variables of population and resource availability (Zubrow 1975:24). This is not to say that a higher population value is not possible, up to the maximum value of K, but the imposition of a resource limit (i.e. due to a failed harvest or ecological crisis) would more easily create a kind of Malthusian catastrophe for the local population. In any case, given the population values extrapolated from the number of houses present and assuming a logistic model of population growth, such an extreme population does not seem possible. In a scenario of logistic growth, the rate of population growth increases rapidly until reaching a value of $K/2$, whereupon it decelerates at an inversely proportional rate (Strogatz 1994:23). While the attainment of a population value of K is theoretically possible, it is more likely that homeostatic forces will force a compromise dictated by optimal resource availability within an exploitation area. In our situation, K was determined by extrapolation of the regression line produced by plotting the maximum distance to fields

perceived over all population states of the model (**Figure 8**; see also **Figure 5**). The maximum estimate supported by the demographic reconstructions discussed in Chapter 1 is 11,100, which nearly coincides with the estimated value of *K/2* (11,000).

However, even at a population value of *K/2*, the necessary exploitation area of the settlement falls outside of Higgs and Vita-Finzi's exploitation limits, and with a cultivated radius of 4.13 km it also lies outside of the 3-4 kilometer maximum outlined by Chisholm. According to Chisholm, "if the distances involved are actually greater than [3-4 kilometers],

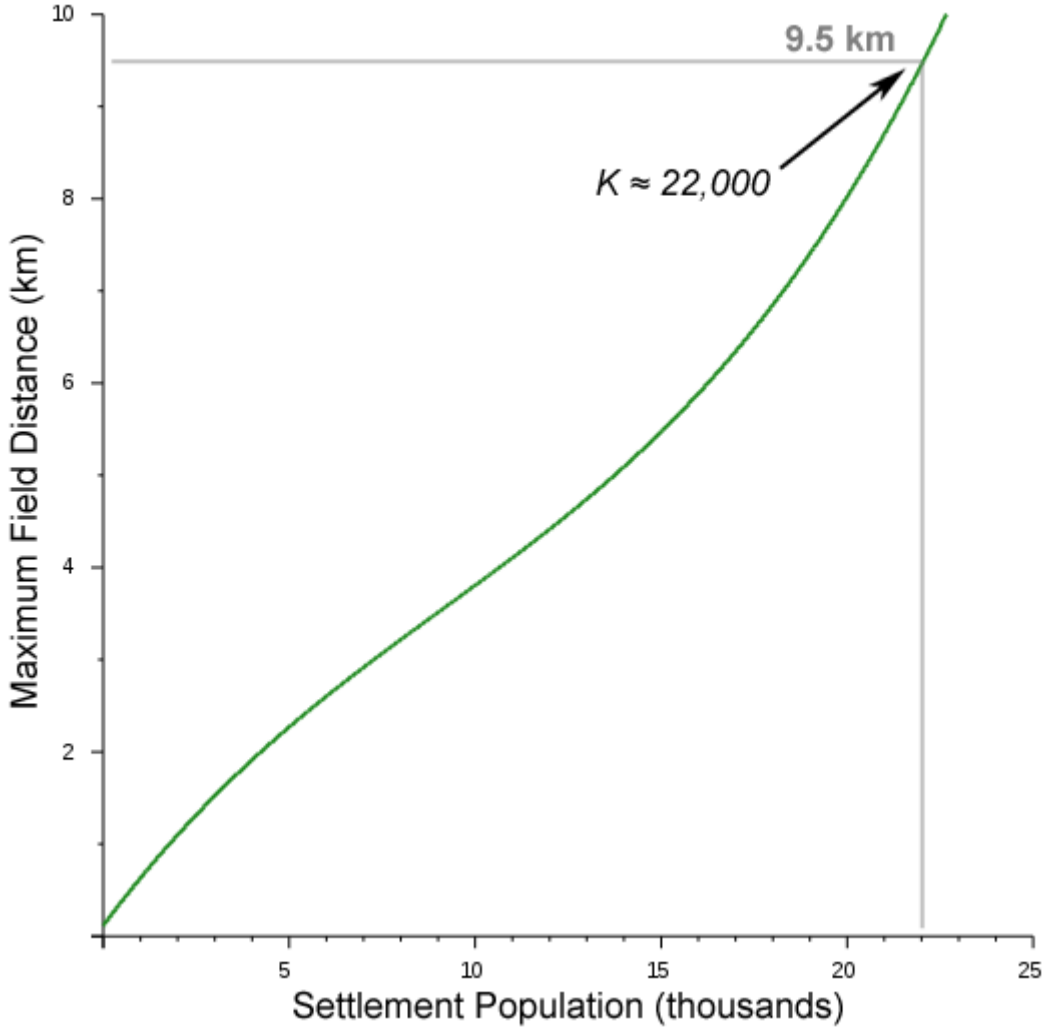

Figure 8. Calculation of the settlement's maximum theoretical carrying capacity, defined as the utilization of an exploitation radius where agronomic productivity ceases.

then it is necessary to look for some very powerful constraining reason which prevents the establishment of farmsteads nearer the land" (Chisholm 1968:131). To our understanding, there are no environmental constraints of this sort; as has been mentioned, the gentle topography and near-universal arability of the study area lends an unusually favorable comparison to the ideal "isolated state" of von Thünen. If any constraints to settlement dispersion existed, they can be assumed to be social in nature. This leads us to two distinct interpretations regarding the functioning of the giant-settlement of Talianki: one that is grounded in the spirit of economic optimization and favors the lower end of the demographic estimates, and another that assumes population maximization was the primary motivation for giant-settlement development.

Beyond our estimate for the value of *K/2*, we can postulate further optimization of production by examining the relationship between the mean values of agronomic production efficiency (MAE) and the maximum values for field distance (MFD) observed in the model. By applying a scaling factor to each set of data (accomplished by dividing the results by one standard deviation), we may plot the regression curves over top of each other (**Figure 9**). The point at which the scaled regressions for MFD and MAE intercept is interpreted as being the far end of the "optimal" range of agronomic productivity. This occurs at a population value of approximately 12,600, which is 14% greater than our value for *K/2*. While agronomic productivity is still theoretically viable out to 9 kilometers from the settlement, the scaled MFD-MAE intercept represents a point of diminishing returns. To the right of this point, the disparity between productivity and distance will continue to accelerate until the value of *K* is finally reached. The mid point of this "optimal" corresponds closely with the lowest demographic estimate of 6300 individuals, roughly equivalent to the closest modeled value of 6500.

Table 9 illustrates the most important characteristics of the model values of *p* =

6500 and p = 11,000. Due to its close correspondence with the reconstruction of the cattle population outlined in Chapter 2, its use of agronomic land within Chisholm's three- to four-kilometer limit, and its radius of total land use falling close to Higgs and Vita-Finzi's five kilometer limit for sedentary societies, the lower value is presented as a stronger interpretation. However, there is no evidence to dismiss the higher value if we discard assumptions regarding the necessity for economic optimization. The modeled necessity of

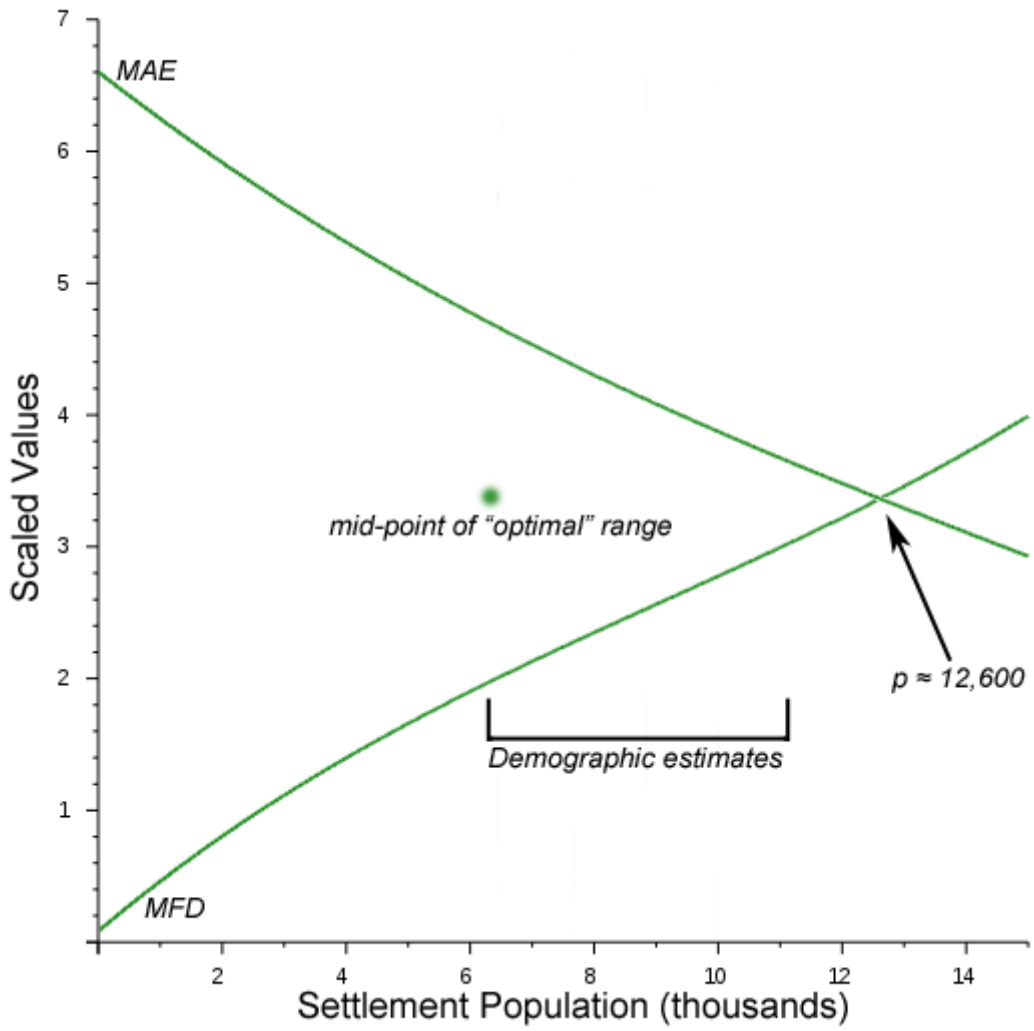

Figure 9. Regressions illustrating scaled values of mean agronomic efficiency (MAE) and maximum field distance (MFD) perceived in the model. It is proposed that at a population of approximately 12,600 a point of diminishing returns is reached which represents the maximal extent of an optimal range of population values.

keeping cattle at population levels over eight times higher than the calculated minimum number of individuals (MNI) is somewhat suspect, but the faunal assemblage is sufficiently sparse enough to produce substantial ambiguity. These assumptions exist to characterize perceived “normative” situations of resource extraction and use, and we have no compelling reason to think that they must apply to what is certainly not a normative archaeological phenomenon.

Population	**Agronomic efficiency (%)**	**Average gross and net cereal yields (kg ha^{-1})**	**Total land use (km^2)**	**Maximum field distance (km)**	**Total exploitation radius (km)**	**Cattle (number and % of highest MNI estimate)**
6500	74.26	743 | 400	96	2.71	4.53	930 (151%)
11000	58.89	589 | 296	402	4.13	10.26	5210 (846%)

Table 9. Characteristics of two notable modeled population values, one geared towards production optimization and the other geared towards population maximization.

5: Conclusion

Assessing Hypotheses: a New Vision of Talianki

In cases such as this one where the use of models is constrained by a paucity of archaeological materials, there are many deficiencies and many arguments that could be made against the reasoning employed here. No amount of number-crunching can dispel the fact that this work is highly speculative in nature. However, we can make inferences which may be assessed on the of the strength of the analogies in which they are rooted.

The modeling here has demonstrated that, given fairly modest average yields and a limited application of animal traction, the residents of Talianki could have easily met their subsistence needs in a single-site context, without the need for satellite settlements. Rather than proceeding from the assumption that Eneolithic agriculture was inherently inefficient and developing theories of complex economic systems that do not exist, to our knowledge, in the context of this settlement, we have taken a somewhat different tack. The distinction lies in using observed systems (or analogies to observed systems), not unobservable constructs, in an effort to understand observed archaeological materials.

Part of our new vision of Talianki is informed by very basic research, such as taking planimeter measurements of the settlement plan to amend the long-standing incorrect areal estimate (450 ha). But even simple observations such as these can have wide-reaching results. Within the conceptual framework of Tripolian demographic reconstructions, a settlement of 14,000 people is no longer a valid assumption. While the amended population range given here (approximately 6500 to 11,000) is still surely sufficient to keep debates regarding “proto-urbanism” alive, it is in itself a fairly radical transformation.

Most of our new vision is informed by analogy. As was stated at the start of this

discussion, this study is not the work of an expert in agricultural systems; the author is not a professor of agronomy or animal science. However, it does not require an expert to see that many archaeological ideas regarding these systems are often poorly-informed. We cannot go back in time and conduct crop trials to assess the nutrient content of ancient soils or the expected yield quantities of the Tripolian agriculturalists. However, we can infer from modern data that shifting settlement patterns were not the result of soil nutrient depletion, that fallow cycles would have been unnecessary, and that the residents of Talianki were not hapless amateurs fighting with a frail and capricious earth. It seems likely that the life of a giant-settlement was constrained by one thing at least – that thing being deforestation – but the gradual realization that traveling two hours to retrieve fuel wood is tiresome and inefficient hardly equates to a sudden and catastrophic collapse.

The conclusions based on this model should not be mistaken for some manner of utopian self-sufficiency; that the land of the Southern Bug-Dnieper interfluve was a indefinite giver of all that is good and wholesome. The life of people living in an Eneolithic agrarian society would not have been the least bit easy, but neither do we have reason to believe that it would it have been particularly nasty, brutish, and short by most standards of pre-modern society. As has been said several times (it bears repeating), quantitative studies of health and nutrition are essential to the further development of models such as these, conducted using skeletal assemblages that are as analogous as possible to the specific study area.

Despite the relatively short habitational periods of the giant-settlements, they are each part of a fairly continuous phenomenon that persisted for centuries. They did not form out of any visible necessity, and depending on our interpretation of population values, they could have served different purposes. Talianki could have been a center of agricultural production that was optimized to the greatest degree possible, or it could have been a

highly-populated place of great social importance, where the great gathering of many lineages was perceived as an important social accomplishment. Perhaps the reality lies somewhere in between. Regardless, the oval rings of the settlement circumscribed almost the entirety of the society that its residents would have known, a self-sustaining world within a world.

Ramifications

This exercise in modeling the functioning of subsistence at Talianki is applicable not only to the other giant-settlements of the Western Tripolye culture, but also to Neolithic and Eneolithic production systems as a whole. More broadly, it is asserted that our understanding of ancient agriculture, in this case agronomy in particular, could benefit greatly from the application of studies that cross disciplinary boundaries, notably those of archaeology, anthropology, and the agricultural sciences. The potential of this manner of work is truly great, and certainly extends far beyond the admittedly rather simplistic model that has been presented here. The fondest hope of the author is that it at least represents a good first step that is proceeding in the right direction. Humankind's association with agriculture is too important to exist within discrete, discontinuous theories and models that only make sense in some abstract dimension of archaeological thought. Rather, this association is a continuum that is bound by the same rules in the past as it is in the present. The variables may change, but the structure remains much the same; our job is to do our utmost to identify and quantify those variables.

6: Appendix I (Data Tables)

Data Table 1

Population	Required Energy (kcal)	Labor per Day	Tillage Coefficient (Hand)	Tillage Coefficient (Plow)	Daily Tillage and Sowing (ha)
500	456250000	4560	1.0000	0.0000	18.10
1000	912500000	9120	1.0000	0.0000	36.19
1500	1368750000	13680	1.0000	0.0000	54.29
2000	1825000000	18240	1.0000	0.0000	72.38
2500	2281250000	22800	1.0000	0.0000	90.48
3000	2737500000	27360	1.0000	0.0000	108.57
3500	3193750000	31920	1.0000	0.0000	126.67
4000	3650000000	36480	1.0000	0.0000	144.76
4500	4106250000	41040	1.0000	0.0000	162.86
5000	4562500000	45600	0.9932	0.0068	185.26
5500	5018750000	50160	0.9850	0.0150	209.50
6000	5475000000	54720	0.9782	0.0218	233.71
6500	5931250000	59280	0.9724	0.0276	257.96
7000	6387500000	63840	0.9674	0.0326	282.24
7500	6843750000	68400	0.9626	0.0374	306.96
8000	7300000000	72960	0.9529	0.0471	337.25
8500	7756250000	77520	0.9442	0.0558	367.70
9000	8212500000	82080	0.9365	0.0635	398.10
9500	8668750000	86640	0.9297	0.0703	428.40
10000	9125000000	91200	0.9235	0.0765	458.80
10500	9581250000	95760	0.9179	0.0821	489.19
11000	10037500000	100320	0.9086	0.0914	525.45
11500	10493750000	104880	0.8988	0.1012	563.61
12000	10950000000	109440	0.8899	0.1101	601.64
12500	11406250000	114000	0.8817	0.1183	639.69
13000	11862500000	118560	0.8741	0.1259	677.79
13500	12318750000	123120	0.8670	0.1330	716.00
14000	12775000000	127680	0.8581	0.1419	758.30
14500	13231250000	132240	0.8468	0.1532	806.14
15000	13687500000	136800	0.8363	0.1637	853.89

Data Table 2a

Population	Maximum Cultivation (ha)	Distance Contours					
		1 km (100%)	2 km (80%)	3 km (64%)	4 km (51.2%)	5 km (40.96%)	6 km (32.77%)
500	253.33	253.33	0	0	0	0	0
1000	506.67	506.67	0	0	0	0	0
1500	760.00	760	0	0	0	0	0
2000	1013.33	782	231.33	0	0	0	0
2500	1266.67	782	484.67	0	0	0	0
3000	1520.00	782	738	0	0	0	0
3500	1773.33	782	991.33	0	0	0	0
4000	2026.67	782	1244.67	0	0	0	0
4500	2280.00	782	1409	89	0	0	0
5000	2593.63	782	1409	402.63	0	0	0
5500	2932.97	782	1409	741.97	0	0	0
6000	3271.95	782	1409	1080.95	0	0	0
6500	3611.47	782	1409	1420.47	0	0	0
7000	3951.34	782	1409	1760.34	0	0	0
7500	4297.42	782	1409	2072	34.42	0	0
8000	4721.53	782	1409	2072	458.53	0	0
8500	5147.76	782	1409	2072	884.76	0	0
9000	5573.46	782	1409	2072	1310.46	0	0
9500	5997.65	782	1409	2072	1734.65	0	0
10000	6423.27	782	1409	2072	2160.27	0	0
10500	6848.70	782	1409	2072	2585.7	0	0
11000	7356.24	782	1409	2072	2685	408.24	0
11500	7890.47	782	1409	2072	2685	942.47	0
12000	8422.93	782	1409	2072	2685	1474.93	0
12500	8955.65	782	1409	2072	2685	2007.65	0
13000	9489.08	782	1409	2072	2685	2541.08	0
13500	10024.02	782	1409	2072	2685	3076.02	0
14000	10616.24	782	1409	2072	2685	3369	299.24
14500	11285.95	782	1409	2072	2685	3369	968.95
15000	11954.42	782	1409	2072	2685	3369	1637.42

Data Table 2b

Population	Effective Production (ha)	Production (kcal)	Percentage of Diet
500	253.33	549478850	120
1000	506.67	1098979390	120
1500	760.00	1648458240	120
2000	959.10	2080314113	114
2500	1153.05	2500994848	110
3000	1347.00	2921670048	107
3500	1540.94	3342345248	105
4000	1734.89	3763020448	103
4500	1912.15	4147493011	101
5000	2093.44	4540714613	100
5500	2289.59	4966175305	99
6000	2485.54	5391191319	98
6500	2681.79	5816874349	98
7000	2878.25	6243002056	98
7500	3073.12	6665678865	97
8000	3254.47	7059013321	97
8500	3436.72	7454321380	96
9000	3618.74	7849136038	96
9500	3800.12	8242552728	95
10000	3982.11	8637285152	95
10500	4164.02	9031853110	94
11000	4332.00	9396202373	94
11500	4496.25	9752478313	93
12000	4659.96	10107571622	92
12500	4823.76	10462842326	92
13000	4987.77	10818586082	91
13500	5152.24	11175335074	91
14000	5305.69	11508162443	90
14500	5447.50	11815761567	89
15000	5589.05	12122790545	89

Data Table 3

Population	Mean Agronomic Efficiency	Maximum Field Distance (km)	Cattle Requirement	Stock Suitable for Traction	Forest Requirement (ha)
500	100.00%	0.39	0	0	435
1000	100.00%	0.71	0	0	870
1500	100.00%	0.98	0	0	1305
2000	94.65%	1.19	0	0	1740
2500	91.03%	1.39	0	0	2175
3000	88.62%	1.57	0	0	2610
3500	86.90%	1.74	0	0	3045
4000	85.60%	1.90	0	0	3480
4500	83.87%	2.05	0	0	3915
5000	80.71%	2.22	177	39	4350
5500	78.06%	2.39	427	94	4785
6000	75.96%	2.56	681	149	5220
6500	74.26%	2.71	930	205	5655
7000	72.84%	2.87	1175	260	6090
7500	71.51%	3.01	1448	320	6525
8000	68.93%	3.19	1959	430	6960
8500	66.76%	3.35	2454	541	7395
9000	64.93%	3.52	2954	652	7830
9500	63.36%	3.67	3465	761	8265
10000	62.00%	3.82	3965	872	8700
10500	60.80%	3.97	4466	983	9135
11000	58.89%	4.13	5213	1146	9570
11500	56.98%	4.30	6026	1327	10005
12000	55.32%	4.46	6848	1506	10440
12500	53.86%	4.62	7669	1686	10875
13000	52.56%	4.77	8486	1866	11310
13500	51.40%	4.92	9295	2047	11745
14000	49.98%	5.08	10298	2265	12180
14500	48.27%	5.26	11506	2532	12615
15000	46.75%	5.44	12719	2799	13050

Data Table 4a

Population	Necessary Pasture Land (ha; PO Model)	Necessary Pasture Land (ha; P&B Model)	Necessary Forest Land (ha; P&B Model)
500	0	0	0
1000	0	0	0
1500	0	0	0
2000	0	0	0
2500	0	0	0
3000	0	0	0
3500	0	0	0
4000	0	0	0
4500	0	0	0
5000	885.46	63.47	1051.93
5500	2136.88	153.17	2538.62
6000	3406.38	244.17	4046.78
6500	4648.77	333.22	5522.73
7000	5873.08	420.98	6977.22
7500	7237.65	518.79	8598.33
8000	9794.84	702.09	11636.27
8500	12271.81	879.64	14578.90
9000	14768.83	1058.63	17545.37
9500	17322.67	1241.69	20579.33
10000	19823.03	1420.92	23549.77
10500	22330.08	1600.62	26528.14
11000	26065.36	1868.37	30965.65
11500	30128.78	2159.63	35792.99
12000	34240.27	2454.34	40677.44
12500	38344.54	2748.54	45553.32
13000	42429.59	3041.35	50406.36
13500	46473.78	3331.24	55210.85
14000	51490.26	3690.82	61170.43
14500	57532.14	4123.90	68348.18
15000	63597.18	4558.65	75553.45

Data Table 4b

Population	Total Land Use (km^2; PO Model)	Total Land Use (km^2; P&B Model)	Exploitation Radius (km; PO Model)	Exploitation Radius (km; P&B Model)
500	6.88	6.88	0.74	0.74
1000	13.77	13.77	1.26	1.26
1500	20.65	20.65	1.69	1.69
2000	27.53	27.53	2.05	2.05
2500	34.42	34.42	2.38	2.38
3000	41.30	41.3	2.67	2.67
3500	48.18	48.18	2.97	2.97
4000	55.07	55.07	3.23	3.23
4500	61.95	61.95	3.47	3.47
5000	78.29	70.07	4.00	3.75
5500	98.55	78.71	4.61	4.02
6000	118.98	87.36	5.15	4.28
6500	139.15	96.00	5.64	4.53
7000	159.14	113.50	6.10	5.01
7500	180.60	134.15	6.56	5.52
8000	214.76	170.60	7.24	6.35
8500	248.15	206.06	7.85	7.07
9000	281.72	241.77	8.43	7.74
9500	315.85	278.19	8.99	8.37
10000	349.46	313.94	9.50	8.96
10500	383.14	349.77	10.00	9.51
11000	429.92	401.90	10.65	10.26
11500	480.24	458.43	11.31	11.03
12000	531.03	515.55	11.95	11.76
12500	581.75	572.58	12.55	12.44
13000	632.29	629.37	13.13	13.10
13500	682.43	685.66	13.68	13.71
14000	742.86	754.77	14.32	14.44
14500	814.33	837.58	15.04	15.26
15000	886.02	920.67	15.73	16.05

7: Appendix II (Formulae)

Calculations Pertaining to Data Table 1

Population

The entire population of the settlement. Defined by the variable ***p***.

Required Energy (kcal)

The annual food energy required to sustain the settlement population defined in column 1. Defined by the variable ***e***. A daily dietary requirement of 2500 kcal is assumed (after FAO 1957).

$$e_r = 2500\mathrm{p} \cdot 365$$

Labor per Day

The total agronomic labor capacity of the settlement in person-hours at peak production times (planting and harvesting), assuming a 12 hour working day and a 0.76 ratio of able-bodied individuals. Defined by the variable ***l***.

$$l = 0.76\mathrm{p} \cdot 12$$

Tillage Coefficients (Hand and Plow)

The proportion of labor spent using hand tools versus animal traction. The necessity of animal traction was determined by the point at which cereals and legumes cease to provide 100% of subsistence requirements. Coefficients were determined by comparison of the calculated herd strength required for diet and the calculated herd strength required for traction, adjusted manually out to four decimal places. Defined by the variables $\boldsymbol{t_h}$ and $\boldsymbol{t_p}$.

Daily Tillage and Sowing (ha)

The areal extent of fields that may be prepared over the course of a single day. Defined by the variable ***d***. Values for the amount of labor required for hand and ard tillage are adapted from Korobkova (1980) and Simms and Russell (1997).

$$d = (l \cdot \frac{t_h}{252}) + (l \cdot \frac{t_p}{56})$$

<u>Calculations Pertaining to Data Tables 2a and 2b</u>

Population

The entire population of the settlement. Defined by the variable ***p***.

Maximum Cultivation (ha)

The maximum land territory that may be cultivated, assuming a necessity to complete tilling and sowing of crops within a two-week window of time. Defined by the variable $\boldsymbol{c_m}$.

$$c_m = d \cdot 14$$

Distance Contours

Arable land area within various distance contours was determined by calculating the area of an ellipse, the axes of which are equivalent to the settlement's dimensions plus *x* kilometers. The amount of non-arable land and the area of the settlement itself were then subtracted from the result.

Effective Production (ha)

The value of ***c*** reduced to take into account reductions in yield due to issues of cost-

distance. Equivalent to the sum of land within each distance contour multiplied by its cost-distance proportion. Defined by the variable $\boldsymbol{c_p}$.

Production (kcal)

The total energy produced by agronomy, determined by the sum of the products of the land area within each distance contour and a generalized value of energy production per hectare. Defined by the variable $\boldsymbol{e_p}$.

Percentage of Diet

The percentage of the diet accounted for by agronomy. Equivalent to $\boldsymbol{e_p}$ divided by $\boldsymbol{e_r}$.

<u>Calculations Pertaining to Data Table 3</u>

Population

The entire population of the settlement. Defined by the variable $\boldsymbol{p}$.

Mean Agronomic Efficiency (%)

The efficiency of the agronomic system given cost-distance reductions. Equivalent to $\boldsymbol{c_p}$ divided by $\boldsymbol{c_m}$.

Maximum Field Distance (km)

The maximum distance of agronomic fields from the settlement boundary. Given a value for the land area being exploited, determined by solving for x in the following equation which determines the axes of an ellipse:

$$a = \left(\frac{(2.9 + 2x)}{2} \cdot \frac{(1.5 + 2x)}{2} \pi \cdot 100\right) - 335$$

where ***a*** is the inputted area, and ***x*** is the result in kilometers.

Cattle Requirement

The amount of cattle required for human nutrition if agronomy does not suffice. Defined by the variable ***k***.

Stock Suitable for Traction

The number of steers within a cattle herd, assuming an "ideal" herd composition for maximized milk and meat production. Equivalent to ***k*** multiplied by 0.22 (after Bogucki 1988).

Forest Requirement (ha)

The amount of forest resources needed to sustain the settlement's population for fifty years. Defined by the variable $\boldsymbol{f_a}$, which is equivalent to ***p*** multiplied by 0.87 (after Kruts 1989).

<u>Calculations Pertaining to Data Tables 4a and 4b</u>

Population

The entire population of the settlement. Defined by the variable ***p***.

Necessary Pasture Land (ha; PO model)

The land territory required to sustain a given cattle population, assuming exclusive use of pastures. Defined by the variable $\boldsymbol{q_a}$ *and equivalent* to $\boldsymbol{k}$ multiplied by 5.

Necessary Pasture Land (ha; P&B model)

The partial land territory required to sustain a given cattle population, assuming the use of pastures and forests. Defined by the variable $\boldsymbol{q_b}$ and equivalent to $\boldsymbol{k}$ divided by 50 and multiplied by 17.92 (after Gregg 1988).

Necessary Forest Land (ha; P&B model)

The partial land territory required to sustain a given cattle population, assuming the use of pastures and forests. Defined by the variable $\boldsymbol{f_b}$ and equivalent to $\boldsymbol{k}$ divided by 50 and multiplied by 297 (after Gregg 1988).

Total Land Use (km^2; PO model)

The total land area required for the settlement's functioning under the "pasture only" grazing model. Defined as $\boldsymbol{L_a}$.

$$L_a = \frac{(c_m + f_a + q_a)}{100}$$

Total Land Use (km^2; P&B model)

The total land area required for the settlement's functioning under the "pasture only" grazing model. Defined as $\boldsymbol{L_b}$.

$$L_b = \frac{(c_m + f_b + q_b)}{100}$$

However, in cases where $\boldsymbol{f_a} > \boldsymbol{f_b}$ (i.e. the required forest land of $\boldsymbol{f_b}$ has already been

included under the normal forest requirements), that value should be substituted.

Exploitation Radius (km; PO model)

The total exploitation radius required for the settlement's functioning under the "pasture-only" grazing model. The same equation that appears under the entry for maximum field distance is used in determining this, by inputting the value of $\boldsymbol{L_a}$ and solving for *x*.

Exploitation Radius (km; P&B model)

The total exploitation radius required for the settlement's functioning under the "pasture and browse" grazing model. The same equation that appears under the entry for maximum field distance is used in determining this, by inputting the value of $\boldsymbol{L_b}$ and solving for *x*.

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