The effect of climatic variability on population dynamics of the Cucuteni-Tripolye cultural complex and the rise of the Western Tripolye giant-settlements

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*This paper presents the results of a multi-scalar analysis of 1800 years of Cucuteni-Tripolye population dynamics, with particular emphasis on the rapid Western Tripolye migrations beginning c. 4150 B.C.E. that led to the development of the giant-settlement phenomenon in Central Ukraine. In addition to macro-scale population modeling, statistical analysis is performed to demonstrate a significant correlation between giant-settlement formation in the Southern Bug-Dnieper interfluve and proxies for a concurrent period of sudden, global climate change. Through the use of high-resolution climate data, this research compliments and expands upon existing theories of climate effects on Cucuteni-Tripolye population dynamics and settlement agglomeration.**

Introduction

The Eneolithic Cucuteni-Tripolye cultural complex of Romania, Moldova, and Ukraine poses many questions for the study of ancient population dynamics. Recent international attention has primarily been concerned with the Western Tripolye giant-settlement phenomenon,[1] where at least eleven settlements of 100-335 ha in size were constructed in the land between the Southern Bug and Dnieper rivers (the Southern Bug-Dniper interfluve; SBDI) and each briefly inhabited between *c.* 4150 and 3500 B.C.E.[2] (see figure 1 for geographic reference). Since these are the largest known settlements of prehistoric Europe, the processes of their formation figure prominently into the inevitable archaeological debates surrounding their purpose and degree of sociopolitical complexity. On the basis of ceramic typology, it is generally accepted that several rapid waves of migration brought a large portion of the Cucuteni-Tripolye population into the forest-steppe ecoregion of Ukraine at this time, predominately from the Cucuteni-Tripolye "homeland" in the Siret, Prut, and Dniester river valleys.[3] While initial development of the Cucuteni-Tripolye culture (phases Precucuteni/Tripolye A through Cucuteni A/Tripolye BI; *c.* 4800-4300/4200 B.C.E.) was marked by increasing growth in the West, the forest-steppe region of Ukraine was comparatively unpopulated. I.V. Manzura describes the colonization of the East as being akin to a "steppe valve" suddenly being opened.[4] Probable causal factors behind this opening have been highly speculative.

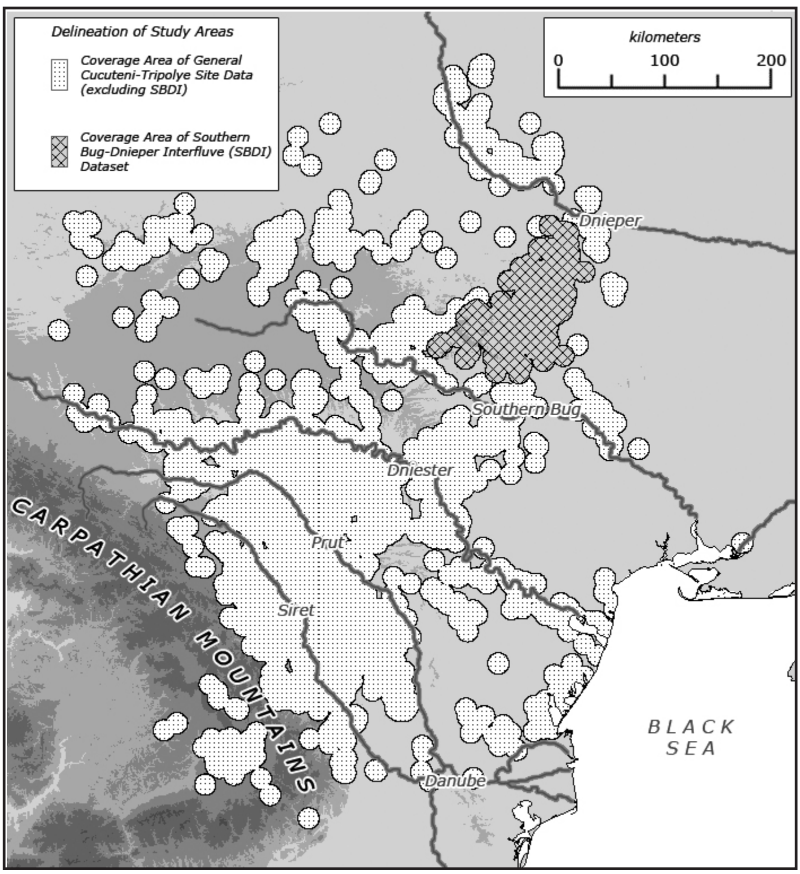

Figure 1: Geographic reference and delineation of study areas, including major river systems.

Previous Scholarship

Most accounts of the territorial and cultural development of the Cucuteni-Tripolye culture are descriptive in nature, featuring qualitative summaries of the proliferation of material culture set against varying periodizations.[5] More analytical, demographic approaches can be found in the writings of S.N. Bibikov, V.M. Masson, N.M. Shmagliy, and A.G. Kolesnikov, and M. Yu. Videiko.[6] Even so, in many cases the demographic work of these authors was abbreviated, limited to certain regions, and usually undertaken as a component of some other analysis (e.g. paleoeconomic calculations). The most dedicated examination of macro-scale Cucuteni-Tripolye demography is the 1993 study of V.A. Kruts.[7] The demographic portion of this present research may be seen as a logical development from the methods and intent of Kruts, which, while they are still relevant, may benefit greatly from recent developments in the understanding of the Cucuteni-Tripolye complex.

In particular, the work of A.V. Diachenko has brought insight into migratory events related to the advent of the giant-settlements belonging to the Vladimirovskaya, Nebelevskaya, and Tomashovskaya local groups in the Southern Bug-Dnieper interfluve. Following extensive work in chronology – both relative[8] and absolute[9] – archaeological understanding of this region during phases Tripolye BII to CI-II (*c.* 4200-3400 B.C.E.) is better than any other area of the Cucuteni-Tripolye complex. On the basis of this improved local chronology, Diachenko has produced a systematization of settlement data[10] from which several models of development and interaction have been derived.[11]

From the perspective of this study, Diachenko's most notable work has been in proposing a correlation between Cucuteni-Tripolye settlement events and eustatic fluctuations of the Black Sea,[12] a paleoclimatic proxy that is related to regional temperature and aridity.[13] According to these data, where sea level regressions signify cool and dry periods, and transgressions warm and wet periods, the middle-to-late Tripolye migrations occurred during periods of cool, dry climate. Essentially, a reduction in regional carrying capacity due to climatically-induced constraints provided an impetus for emigration from the western regions to the forest-steppe.

Application of these sea level trends entails some controversy. Several paleoclimate schemes based on these data (of which there are dozens) were recently criticized by E. Fouache and his colleagues as being highly variable and confounded by active geology throughout the Black Sea basin. In particular, the authors targeted the hydrodynamically-improbable suggestion that the level of the Black Sea was, for extended periods, lower than observed global trends.[15]

However, reservations toward these data aside, Diachenko's suggestion of a climatic determinant for migrations is an improvement over older theories of Cucuteni-Tripolye population dynamics. These typically assume a situation of "explosive" population growth triggering resource shortfalls,[16] which is a problematic assumption. According to F.A. Hassan,[17] the concept of population "pressure" in archaeology is "vague and rather ill-defined" and usually of little substance in reference to empirical observations. Demographic growth rates vary widely and rarely follow the curve of maximum biotic potential, instead being subject to environmental and technological constraints which impose a local carrying capacity.[18] Carrying capacities may be seen as a "hard" limit to population growth, but there are further "soft," human-defined, limits that pertain to resource optimization and other social considerations. In preindustrial societies, the optimal carrying capacity of a given territory is often only a portion of its theoretical maximum,[19] generally providing some buffer for normalization in the event of resource shortfalls. In any case, it is possible to adopt the underlying hypothesis of the current literature – that migration was undertaken due to some form of economic crisis – while rejecting the proposed demographic causation. I will instead turn to issues of climate.

Migration and Climate

Based on the suggestion by B. Weninger and his colleagues that the Holocene Rapid Climate Change (RCC) phenomenon[20] may explain diachronic variation in several archaeological contexts,[21] we recently made the qualitative observation that the Tripolye BII period settlement of the SBDI was temporally aligned with the beginning of an RCC interval with a period of *c.* 6000-5000 cal B.P.[22] There is also similar agreement with Bond Event 4, *c.* 5900 cal B.P.[23] There are many proxies (some of them discussed here) which indicate a period of both terrestrial and oceanic climate fluctuation at this time, one among many in a roughly millennial global cycle of variable temperature and aridity. While RCC conditions have global ramifications,[24] in this regional context I am primarily concerned with the mechanics of the Pontic "steppe corridor" and the influence of the Siberian High pressure system, one of the chief indicators of RCC conditions up to the super-regional scale (Fig. 2). The chief objective of this research is to assess whether any correlation can be found between the RCC/Bond Event proxies and Cucuteni-Tripolye population dynamics. To this end, settlement data from the Southern Bug-Dnieper interfluve were tested against a

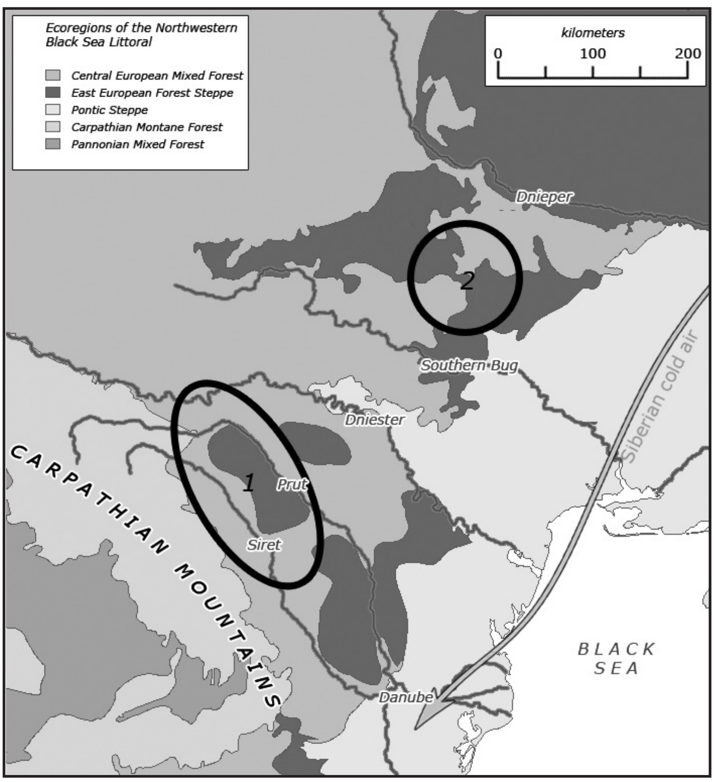

Figure 2: Ecoregions along the Black Sea littoral (data from Olson et al. 2001). Winter cold air emanating from the Siberian High pressure traverses the "corridor" of the Pontic steppe. 1 – nucleus of early settlement (Precucuteni to Cucuteni A/Tripolye BI); 2 – main area of middle to late (Tripolye BII, CI, and CI-II) settlement in the SBDI, including giant-settlements.

Phase	Date range (B.C.E.)	Corresponding cultural periods	
		Romania	Ukraine/Moldova
1	*c.* 4800 - 4550	Precucuteni	Tripolye A
2	*c.* 4550 - 4200	Cucuteni A	Tripolye BI
3	*c.* 4200 - 3900	Cucuteni A/B	Tripolye BI-II, Tripolye BII
4	*c.* 3900 - 3600	Cucuteni B	Tripolye CI
5	*c.* 3600 - 3000	Horodistea-Foltesti	Tripolye CI-II, Tripolye CII

Table 1: Simplified Cucuteni-Tripolye periodization for macro-scale model application (after Weninger and Harper, forthcoming). Note that this deviates in some cases from regional schemes of relative chronology due to limitations of settlement and ^{14}C data.

collected body of climate data (defined below) and compared with a macro-scale model of population development.

Model Construction and Analysis Methodology

Chronology – Macro-scale Model

In constructing the macro-scale model, I utilize previous work on the calibration and analysis of available ^{14}C data,[25] which generalizes the Cucuteni-Tripolye periodization into discrete temporal units. The construction of this periodization involved an initial radiocarbon data set of n=244, reduced to a core data set of n=104 due to considerations of data validity. In the results, chronological phases consisted of near-parabolic distributions of ^{14}C envelopes, with the notable exception of phase 3, for which ^{14}C dating is problematic. If cultural periods are conceived as being described by overlapping normal distributions, it is possible to describe their duration according to degrees of statistical confidence, and estimate the location of break-points to form a rough, abstracted periodization for model application. This periodization is described in Table 1.

These results compare favorably to several other recent periodizations,[26] but it must be stressed that the phases outlined here neglect much regional variability. Problems exist with the distribution and accuracy of ^{14}C data, especially during short or transitional periods (Cucuteni A/B, Tripolye BI-BII, Tripolye BII). The conflation of Tripolye BI-II and BII settlement data seen in Manzura's research[27] (and also utilized in this study) is currently a necessary measure. It is a good example of problems that exist in understanding relative chronology between regions, and the compromises that must be made in attempting a meaningful categorization of data. According to numerous studies, Tripolye CI materials are a continuous development of BII. Tripolye BII and CI are, in fact, both synchronous with Cucuteni B, which should have a longer duration than shown here. In the SBDI in particular, settlements of periods BII and CI are partially contemporaneous for approximately a century;[28] estimated here as *c.* 3950-3850 B.C.E. On the other hand, the difference in material culture and the existence of temporal discontinuities between settlement events belonging to phases BI-II and BII makes their combination inappropriate.[29]

Chronology – SBDI Settlements

While the absolute chronology may be used to statistically define cultural periods in a broad sense, it is more difficult on a local level. Very few ^{14}C dates exist for the Southern Bug-Dnieper interfluve and the quality of most of them is suspect. As an example, examination of the four Kiev dates (Ki-6922, Ki-6923, Ki-6924, Ki-6925) from the Ol'khovets settlement belonging to the Kosenovskaya local group (Tripolye CI-II) give a combined 68% range of 2870-2630 cal B.C.E., which is well into the Early Bronze Age. The comparison between older dates (mostly from the 1970s-1990s) for the Tomashovskaya giant-settlements of Tal'yanki and Maidanetskoe with the new Oxford AMS dates from Tal'yanki[30] further reveals the scope of the problem (refer to Fig. 3). It was decided that these newer dates alone should be used to position the relative chronology, with the Tomashovskaya local group settlement phase 3 stage 2 set to *c.* 3850-3800 B.C.E.[31]

Settlement Data

Settlement data were collected into three separate sets. The first is a macro-scale data set (n=2595) of site coordinates georeferenced from the research of Manzura.[32] While it is accurate enough to describe the general locations and clustering of known Cucuteni-Tripolye sites, it lacks any metadata beyond temporal categorization. The second data set consists of SBDI settlement data (n=68; Tripolye BII to CI-II) adapted from the work of Diachenko.[33] This set describes the absolute positions, sizes, and in most cases the microchronological relative dating of sites. The final data set is the author's general collection of Cucuteni-Tripolye settlement and ^{14}C data (n=210), derived from a variety of sources.[34]

The second and third sets, owing to their detailed metadata, were used to determine trends in the spatial and temporal variation of settlement sizes, which were then applied to the macro-scale model. The disparity between my collected settlement data from the SBDI (n=68) and all other regions (n=29) is but one example of the comparative systematization of Cucuteni-Tripolye archaeology in this region. Calculations for settlement size in different spatio-temporal contexts are described in Table 2. The lower median values are representative of the vast majority of settlements, but the contribution of large settlements reflected by the mean values must also be considered. In order to overcome dubious values caused by the small sample size, a weighted mean was calculated based on four model scenarios:

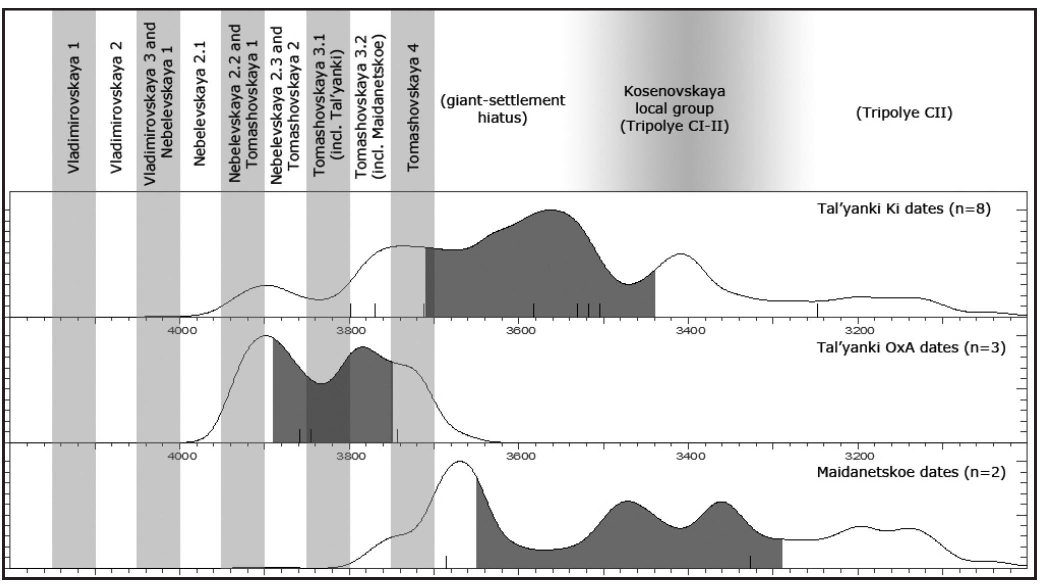

Figure 3: Problems in the relationship of ^{14}C dates to relative chronology in the SBDI. The darkened regions of the radiocarbon envelopes indicate the interquartile range (50% confidence interval). This study relies on recent AMS dates from Tal'yanki to situate the relative sequence of settlements.

Phase	Southern Bug-Dnieper interfluve				All other regions			
	mean	median	weighted mean	n	mean	median	weighted mean	n
1	n.d.	n.d.	n.d.	0	2.1 ha	1 ha	2.5 ha	5
2	n.d.	n.d.	n.d.	0	5.8 ha	3.8 ha	4.1 ha	8
3	46.4 ha	39.3 ha	37.4 ha	15	5.4 ha	4.5 ha	4.2 ha	11
4	50.8 ha	14.1 ha	32.2 ha	41	4.8 ha	2.6 ha	3.6 ha	3
5	27.8 ha	11.8 ha	25.9 ha	12	2.0 ha	1.8 ha	2.7 ha	4

Table 2: Calculated spatial and temporal variation in settlement sizes.

•scenario 1 utilizes mean values, geographically but not temporally segregated;
•scenario 2 utilizes mean values, geographically and temporally segregated;
•scenario 3 utilizes median values, geographically but not temporally segregated;
•scenario 4 utilizes median values, geographically and temporally segregated.

Beyond the calculation of weighted settlement sizes, these data must be processed further to account for temporal factors before estimating population values. Firstly, our macro-scale chronological phases are not of equal duration; utilizing the commonly-accepted assumption that settlements were inhabited for roughly 50 years,[35] the number of settlements must be divided by the number of settlement generations. Secondly, the number of dwellings per hectare of settlement and the coefficient of synchronously-functioning houses must be determined. For this, the average value of 9.66 buildings per hectare from the SBDI data set is used, as well as Diachenko's observation[36] that, according to studies of settlement microchronology, only 78.4% of structures at the Tripolye CI giant-settlement of Maidanetskoe are synchronous.[37] Finally, the received value for the number of synchronous structures should be multiplied by estimates for household composition – four to seven individuals; middle value: 5.5.[38] All of these considerations may be expressed in the formula:

$$p = \left(\frac{\sum_{i=1}^{n} a_i}{t} \right) bsd$$

where p is total population at a given time reference, a is the area of settlement i in a series of n settlements, t is the number of settlement generations, b is the number of houses per hectare (constant; 9.66), s is the coefficient of housing synchronicity (constant; 0.786), and d is the household composition (constant; 5.5).

Demographic Interpolation and Comparison with Climate Data

A key limitation of this macro-scale model is its poor temporal resolution. All settlement and climate data were temporally justified in a time series spanning 4800 to 3000 B.C.E. (ten-year increments). This necessitated linear interpolation of demographic data over intervals of centuries. Owing to this, it was decided that statistical testing of the model environment would likely yield spurious correlations. Therefore the empirical SBDI data constitutes the testing environment, while the macro-scale model is descriptive, used to compare our results against the demographic context of the Cucuteni-Tripolye complex as a whole.

Climatic proxies were derived from the climate database provided with the University of Cologne Radiocarbon Calibration Program software package (CalPal).[39] The following data sets were used: Holocene Non-Sea-Salt K+ ion series from GISP2 with 200-year moving Gaussian filter,[40] Holocene Sea-Salt Na+ ion series from GISP2 with 200-year moving Gaussian filter,[41] North Atlantic Holocene Drift Ice Proxy (Stack),[42] Global Sea Levels,[43] SL21 *S. elongatus* prevalence,[44] LC21 Aegean warm-water foraminifera species prevalence,[45] and MD04-2788/2760 XRF Ca intensity.[46] In most cases these were high-resolution data sets that conformed easily to our measurement interval, but in some cases linear interpolation or slight temporal adjustments (+/- 5 years) were required. An explanation of each of these climatic proxies is presented in Table 3.

Results and Discussion

Demographic Calculations

The manner in which the area of settled territory should be calculated within the model environment quickly became a concern, as density calculations are contingent on a fixed search radius.[47] In the end I utilized an adaptation of Hassan's[48] methodology, wherein an arbitrarily-defined zone of resource extraction (defined here as 10 km) is applied to each settlement and its population distributed over this area. This distance contour reflects the author's previous modeling in the area of Cucuteni-Tripolye paleoeconomy,[49] which suggested that resource extraction at the largest settlements would have likely extended beyond the normative five-kilometer exploitation assumption for sedentary societies.[50] Still, functionally speaking, the resource extraction area will be far less for most settlements in

Dataset name	Abbreviation	Measured phenomenon	Proxy for:
Holocene Non-Sea-Salt K+ ion series from GISP2 with 200-year moving Gaussian filter	GISP2 NSS K+	Non-seat-salt K+ ion deposition in GISP2 ice core, Greenland	Strength of Siberian High pressure system
Holocene Sea-Salt Na+ ion series from GISP2 with 200-year moving Gaussian filter	GISP2 SS Na+	Sea-salt Na+ ion deposition in GISP2 ice core, Greenland	Strength of Icelandic Low pressure system
North Atlantic Holocene Drift Ice Proxy (Stack of MC52-V29191+MC21-GGC22)	Bond events	Percentage of ice-rafted debris in North Atlantic sediment cores	North Atlantic sea ice formation; Northern Hemisphere temperature
Global Sea Levels	GSL	Generalized observations of paleo-shorelines	Global sea level trends
SL21 *S. elongatus* (%)	SL21	Change in the prevalence of a cold-water species of dinoflagellate in the SL21 core, Aegean Sea	Aegean Sea surface temperature
LC21 Aegean warm-water foraminifera species (%)	LC21	Ratio of warm-water to cold-water forams in the LC21 core, Aegean Sea	Aegean Sea surface temperature
MD04-2788/2760 Black Sea XRF Ca intensity (total counts/1000)	BS XRF Ca	Variable rate of calcium deposition in a Black Sea sediment core	Sakarya River outflow strength; precipitation in NW Anatolia

Table 3: Explanation of climate proxy data relevant to RCC.

Data		Model phase				
Region(s) / Variables		*1*	*2*	*3*	*4*	*5*
SBDI	*p*	105	172	15,354	11,429	630
	a_t (modeled)	1,011	1,575	9,435	6,487	1,795
	y (modeled)	0.104	0.109	10627	1.762	0.351
	a_t (corrected)	227	354	2,118	1,456	403
	y (corrected)	0.463	0.486	7.249	7.847	1.563
All others	*p*	4,159	19,480	10,254	15,192	4,730
	a_t (modeled)	29,736	53,762	51,653	60,310	67,427
	y (modeled)	0.140	0.362	0.199	0.252	0.070
	a_t (corrected)	6,676	12,069	11,596	13,540	15,137
	y (corrected)	0.623	1.614	0.884	1.122	0.312
Combined	*p*	4,264	19,652	25,608	26,646	5,360
	a_t (modeled)	30,747	55,337	61,088	66,797	69,223
	y (modeled)	0.139	0.355	0.419	0.399	0.077
	a_t (corrected)	6,903	12,423	13,714	14,996	15,540
	y (corrected)	0.620	1.582	1.867	1.777	0.345

Table 4: Comparison of model output for population (*p*), settled territory (a_t), and population density (*y*). "Corrected" data is normalized according to the coefficient of disparity between modeled and empirical SBDI settlement observations.

Temporal reference (local settlement phases) *Phase*	*Range (B.C.E.)*	Major settlements	a_t	*p*	*y*
1	*c.* 4150-4100	Fedorovka	314	5,873	18.69
2	*c.* 4100-4050	Vladimirovka	628	3,380	5.38
3	*c.* 4050-4000	Nebelovka, Val'yava	2,422	17,662	7.29
4	*c.* 4000-3950	Glubochek, Khristinovka 1	2,745	15,362	5.60
5	*c.* 3950-3900	Shushkovka	2,333	11,354	4.87
6	*c.* 3900-3850	Chichirkozovka, Dobrovody	1,341	16,873	12.58
7	*c.* 3850-3800	Tal'yanki, Vasil'kov	942	14,776	15.68
8	*c.* 3800-3750	Maidanetskoe	789	9,521	12.07
9	*c.* 3750-3700	Tomashovka	1,591	6,710	4.22
"Mean" scenario			1,456	11,279	7.75

Table 5: Territory, population, and density estimates for each settlement phase of the SBDI during the Vladimirovskaya-Nebelovskaya-Tomashovskaya giant-settlement period, *c.* 4150-3700 B.C.E.

the model, which are situated in high-density clusters.

Comparison of modeled territory and density estimates with the empirical SBDI data showcases another obstacle of inferring a picture of population at a given time reference using temporally-indistinct data – territorial estimates far outweigh the population estimates, thus giving very low population densities in comparison to ethnographic observations of sedentary agriculturalists.[51] The close agreement between modeled and empirical population values for the SBDI lent some confidence to the model findings, and led to the calculation of a normalizing coefficient (0.2245) to correct for modeled densities. Tables 4 and 5 summarize findings related to the modeled and empirical data sets, respectively. These data are displayed graphically in Figure 4.

Plausible Peak Population Values

According to the final, compensated values, during its time of peak population (Cucuteni B / Tripolye CI period, *c.* 3750 B.C.E.) the Cucuteni-Tripolye complex as a whole was composed of 27,000 people inhabiting roughly 15,000 km^2, for an average density of 1.8 persons per km^2. The SBDI, while accounting for only 10% of total inhabited territory, was home to 43% of the population and boasted an average density of 7.8 persons per km^2 (see Fig. 5 for a visualization of these data).

Compared to the estimates of Kruts,[52] these values are incredibly low. For the same period, Kruts estimates a total population of 330,000 over an area of 110,000 km^2, for a density of 3 persons per km^2. This is reduced from a peak of 410,000 during the middle Tripolye (BII) period, which is not present in the present model (it instead shows a plateau

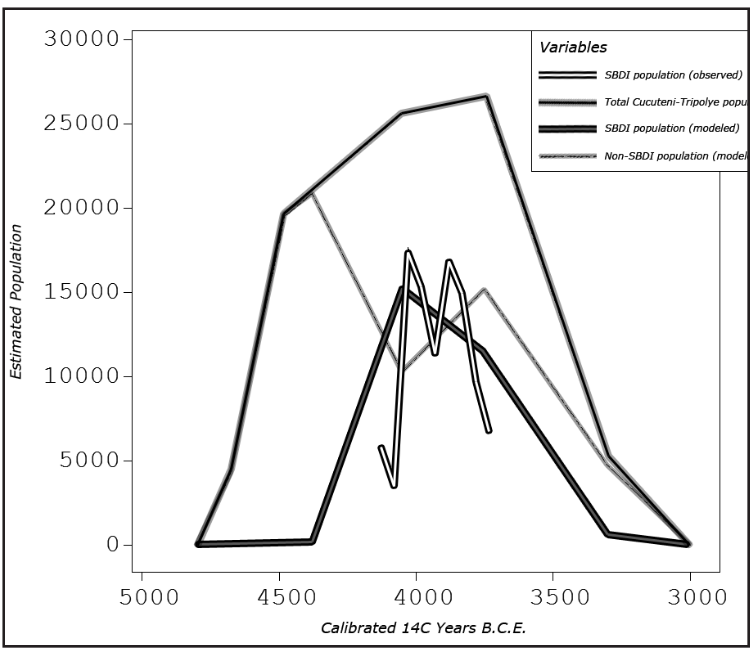

Figure 4: Comparison of spatially-distinct modeled population values against empirical SBDI settlement data. While modeled values for Tripolye CI correspond with an "average" scenario, it conceals considerable variability due to migrations, two peaks of which may be perceived here.

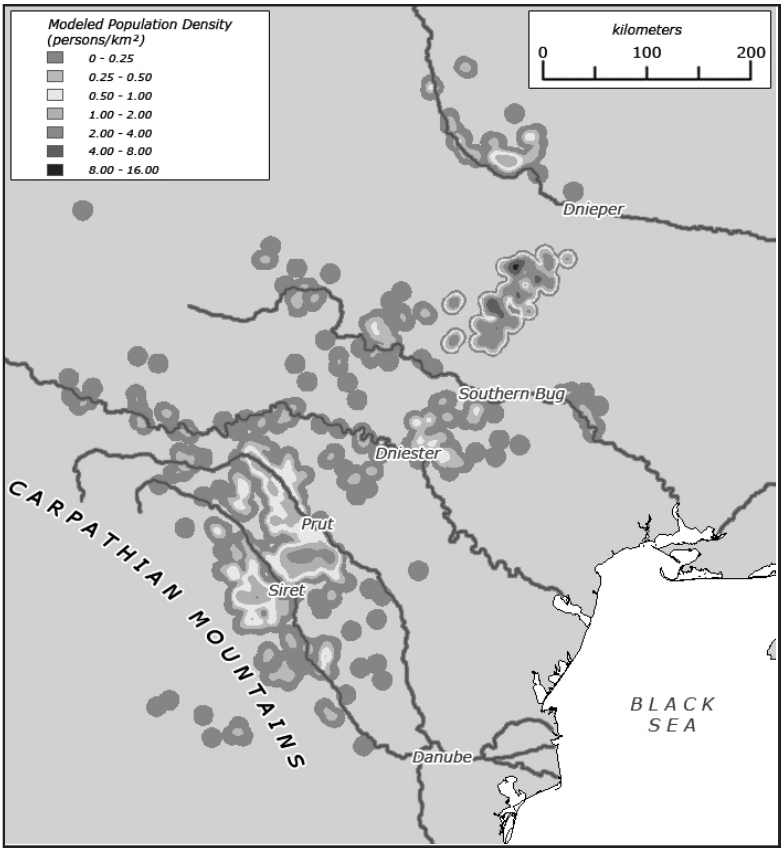

Figure 5: Modeled Cucuteni-Tripolye population densities during the middle of Cucuteni B/Tripolye CI (*c.* 3750 B.C.E.).

between both periods). Interestingly, despite large numerical differences, Kruts comes to a similar distribution of population, with ~39% (130,000) residing within the SBDI. While the model results here are affected by the sample size (in the case of the SBDI data, roughly 60% of known regional sites), compensating for this still does not approach the values proposed by Kruts. With liberal allowances for data limitation, a peak population of 50,000 individuals seems an upper limit.

To argue my case from the perspective of global population trends, let us examine the estimates of C. McEvedy and R. Jones,[53] as well as the growth rates calculated by M. Kremer based on these same data.[54] The values are: 7,000,000 for world population in 4000 B.C.E., 14,000,000 for 3000 B.C.E., and an annual growth rate of 0.000693. The overall trend of this model of global population growth is roughly hyperbolic until 1970 C.E., but the growth rates between each model state are abstracted to assume exponential growth. This allows for the interpolation of a value for 3750 B.C.E., given the formula for exponential growth:

$$x_t = x_0 (1+r)^t$$

where x_t is population at time t, x_0 is the starting value and r is the rate of growth, this generates an estimate of 8,325,000 in 3750 B.C.E. Since the Earth's land surface is approximately 1.4894 × 10^8 km^2, some simple arithmetic tells us that Kruts's scenario would place 4% of the world's population over an area of roughly seven ten-thousandths of its land surface. By contrast, our values account for 0.3% of the world's

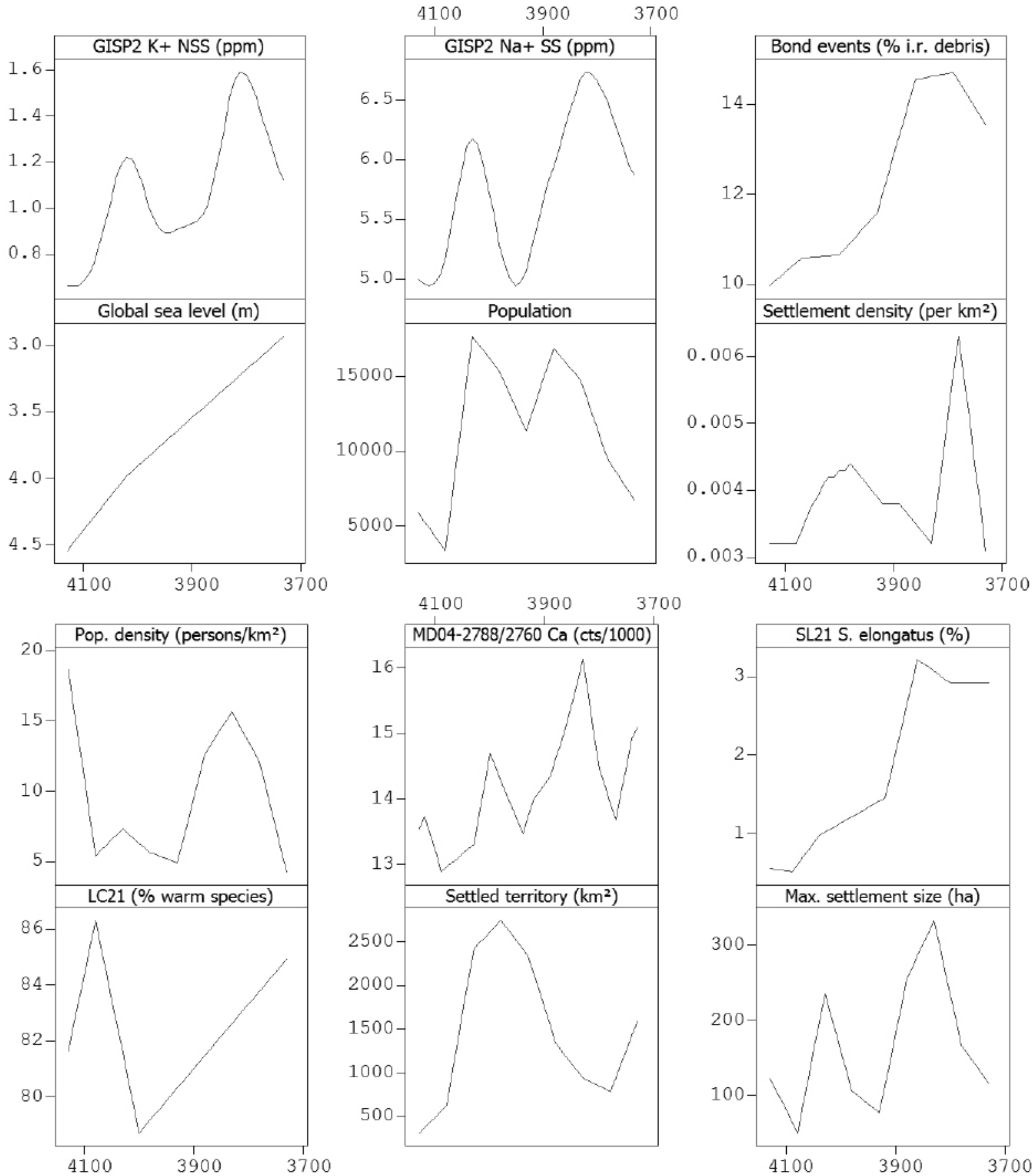

Figure 6: Trends in metrics of SBDI settlement development displayed alongside a variety of paleoclimate proxies. The chief indicator of RCC in the context of this study is the GISP2 K+ data, which measures the strength of the Siberian High pressure system.

population over the same area, of which only one-seventh is actively exploited at this time.

The divergence in values here is due to Kruts's methodology for extrapolating population based on land area. While the settlement data show extensive "no man's land" between local settlement groups, Kruts determines local densities and uniformly extrapolates for entire regions. This leads to inflated values which do not accurately reflect observed settlement patterns. It should also be noted that Kruts's model has a different temporal resolution, and utilizes an older scheme of relative dating without reference to calibrated absolute chronology. Contextualized against the total world population, it is asserted that a peak population value of ~30,000-50,000 for the entire Cucuteni-Tripolye complex *c.* 3750 B.C.E. is a more plausible scenario.

Assessing Statistical Correlations

The core of the climate analysis lies in the calculation of statistical correlations between climate proxies and data from the model of SBDI settlement development (Fig. 6). The following correlation matrix (Table 6) therefore makes the distinction between correlations between like classes and correlations between unlike classes of data. We are chiefly concerned with the latter.

Aside from calculation of the correlation coefficient to determine the strength of a relationship and interpretation of the p-value to determine the significance of a relationship, results may be weighed on the basis of how many mutually-correlated variables exist within a class. For example, we can see that the measure of maximum settlement size (a_m) is well-correlated with nearly all of climatic measurements – RCC weather systems, North Atlantic ice rafting, Anatolian precipitation, and Aegean sea surface temperature. Taking this variable as a proxy for migratory strength, these correlations provide the strongest support for the idea that giant-settlement development was contingent on climatic variability.

Strong correlations also exist between settlement density (y_s) and the climate proxies. A negative correlation during periods of peak migration (as indicated by a_m) is to be expected, as population concentrates in solitary giant-settlements. The highly positive correlation seen here is likely due to the periodic emergence of agglomerated settlement systems among the settlements of the Tomashovskaya local group during periods of particularly poor climate. While small-scale migrations are occurring constantly, these organizations may be considered a largely non-migratory climate response. As an example, the second exaggerated peak in the trend line of settlement density corresponds with the development of a dendritic *K*=2 settlement system based around the giant-settlement of Maidanetskoe.[55]

Care must be taken to not ascribe too much confidence to some of the results of the correlation analysis. The variable of global sea level (GSL) was included largely as a control, since these data describe (at this time) simply a near-linear positive increase. The correlation coefficients for a_m and y_s versus GSL (0.468 and 0.484, respectively) should be taken as a baseline for interpreting the strength of correlations between these and other variables. Therefore it is more difficult to assess the meaning of received relationships between, for example, y_s and Bond Events.

Sea surface temperature data from Aegean cores LC21 and SL21 are also not considered important from the perspective of correlations. They instead are a verification tool for assumptions regarding GISP2 data. On a centennial time scale, high K+ and Na+ values are correlated with the "cold poles" variety of RCC, but it cannot be assumed that they are accurate predictors of this on a finer time scale. Taken together, they show that the GISP2 peaks relevant to this analysis are indeed periods of relative cold.

The XRF Ca intensity measurements from core MD04-2788/2760 are particularly interesting,

	GISP2 K+ NSS	**GISP2 Na+ SS**	**Bond events**	**G.s.l.**	**p**	**y_s**	**y_p**	**BS XRF Ca**	**SL21 SST**	**LC21**	**a_t**
GISP2 Na+ SS	0.920 0.000										
Bond events	0.743 0.000	0.775 0.000									
G.s.l.	0.747 0.000	0.678 0.000	0.914 0.000								
p	0.374 0.016	0.381 0.014	0.216 0.174	0.251 0.113							
y_s	0.608 0.000	0.407 0.008	0.359 0.021	0.484 0.001	0.157 0.326						
y_p	0.253 0.111	0.412 0.008	0.453 0.003	0.112 0.487	-0.012 0.942	-0.068 0.671					
BS XRF Ca	0.598 0.000	0.615 0.000	0.741 0.000	0.684 0.000	0.460 0.002	-0.025 0.875	0.433 0.005				
SL21	0.747 0.000	0.777 0.000	0.988 0.000	0.939 0.000	0.269 0.089	0.345 0.027	0.399 0.010	0.786 0.000			
LC21	0.080 0.617	0.225 0.158	0.216 0.174	0.087 0.587	-0.735 0.000	-0.089 0.578	0.169 0.289	-0.172 0.283	0.161 0.315		
a_t	-0.034 0.834	-0.209 0.189	-0.310 0.048	-0.009 0.957	0.641 0.000	0.149 0.351	-0.705 0.000	-0.036 0.824	-0.226 0.155	-0.774 0.000	
a_m	0.669 0.000	0.833 0.000	0.671 0.000	0.468 0.002	0.620 0.000	0.043 0.791	0.617 0.000	0.736 0.000	0.676 0.000	-0.068 0.671	-0.154 0.335

Table 6: Correlation matrix of SBDI settlement data and climate modeling proxies. Dark grey - significant relationships between disparate classes of data; white – significant correlations between like classes of data; grey – uncorrelated data; black – correlation rejected due to poor data quality.

as they illustrate regional variation in weather responses to the RCC mechanism. In this case, since Ca intensity is correlated with the GISP K+ data, we may infer that it behaves similarly to modern weather patterns – in the winter, cold winds from the Siberian High blow southwest along the steppe corridor, at times forming a cyclonic system over the Black Sea that may spawn severe weather. The confluence of cold air and comparatively warm water prompts condensation and precipitation, which is primarily contained within the Black Sea basin. It should be stressed that, despite the proximity of these regions, comparatively wet conditions in northwestern Anatolia do not preclude (and may actually indicate) dry conditions in the forest-steppe of Ukraine.

Conclusion

The presented results add substance to the hypothesis that climate played a key role in influencing the Western Tripolye migrations. While the data show only two of five major migrations identified in the archaeological materials,[56] they do not contraindicate the assessment that constant micro-waves of migration continually brought new population into the SBDI. The correlations between

SBDI population observations and climatic proxy data gives us confidence enough to suggest a general relationship – that Manzura's demographic "steppe valve," at least during the interval of *c*. 4150-3700 B.C.E. in the Southern Bug-Dnieper region, was determined by trends in the super-regional climate. We focus on these climatic trends due to their influential position at the beginning of a postulated causal chain, which necessarily leads to social and political stresses that prompt migratory episodes. Unfortunately, however, these stresses are inferential and not measurable at this time. Perhaps the results presented here may guide speculation in this area.

Aside from proposed corrections to the population research of Kruts, the findings of this study compliment the extensive body of analytical research into the developmental processes of Cucuteni-Tripolye settlements, as exemplified by the recent modeling of Diachenko.[57] As archaeologists work to assess and improve upon existing hypotheses of Cucuteni-Tripolye cultural development, we should seek to extend the high-quality analysis of the Southern Bug-Dnieper interfluve to other regions, while developing a coherent vision of populations at a variety of scales beyond individual regions and local groups. It is hoped that, despite its limitations, the analysis presented here constitutes a step in this direction.

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Endnotes:

1 Recent volumes include Korvin-Piotrovskiy et al. 2003; Ciuk 2008; Korvin-Piotrovskiy and Menotti 2008; Anthony and Chi 2010.
2 All dates rendered in "B.C.E." notation are based on determinations of calibrated radiocarbon years.
3 Manzura 2005, Ryzhov 2007, Kruts 2008, Diachenko 2010b.
4. Manzura 2005, 325.
5. e.g. Mantu 2000, Manzura 2005.
6. Bibikov 1965; Masson 1980; Shmagliy 1980; Kolesnikov 1993; Videiko 2002.
7. Kruts 1993.
8. Ryzhov 2007; et al.
9. Rassamakin and Menotti 2011.
10. Diachenko 2010a.
11. Most recently, Diachenko and Menotti 2012.
12. Diachenko 2010b.
13. Previously discussed by many climate authors; see Dolukhanov and Shilik 2007 for a recent example focusing on human responses.
14. Fouache et al. 2011.
15. Fouache et al. 2011, 9.
16. Zbenovich 1996, 205; Manzura 2005, 318.
17. Hassan 1981, 161.
18. Depending on whether one applies Neo-Malthusian (e.g. Zubrow 1975; Hassan 1981) or Boserupian theory of population dynamics in relation to economic "intensification" (e.g. Boserup 1981), or a compromise between the two (e.g. Wood 1998), carrying capacity values are open to debate, as are mechanisms of population regulation. However, few – if any – demographic specialists would accept a general assumption of unchecked growth in preindustrial societies.
19. Hassan 1981, 167.
20. Mayewski et al. 2004.
21. Weninger et al. 2009.
22. Weninger and Harper, forthcoming.
23. Bond et al. 1997, 1260.
24. For more general information on the properties of the RCC mechanism, see Mayewski et al. 2004 and Weninger et al. 2009.
25. Discussed in Weninger and Harper, in press.
26. cf. Diachenko 2010b, 41 (table 3); Rassamakin and Menotti 2011, 646(table 1).
27. Manzura 2005.
28. Diachenko and Menotti 2012, 2814.
29. Rassamakin 2012, 24-29.
30. Rassamakin and Menotti 2011, 650-651 (table 2).
31. This nomenclature for settlement phases is derived from Diachenko and Menotti 2012.
32. Manzura 2005, 317-333 (figs. 2, 3, 6, 7, 12).
33. Diachenko 2010a, 20 (table 1); Diachenko 2012, 2812 (table 1).
34. Zbenovich 1996, 202; Mantu 1998, 246-295; Telegin et al. 2003, 461-462; Rassamakin 2004, 8-9; Palaguta 2007, 97-164; Kruts 2008, 234-236; Lazarovici et al. 2009, 85-166; Diachenko 2010a:20-21.

35. Kruts 2008.
36. Diachenko 2008, 14; Diachenko 2010c, 120-121.
37. A similar value was independently arrived at for another context – the settlement Bernashovka II in the Dniester region (Kolesnikov and Tkachuk 1993).
38. Kruts 1989, 117-126; Videiko 1992, 9-11; Kolesnikov 1993, 36-41; Diachenko 2010c, 114-120.
39. Weninger and Jöris 2008.
40. O'Brien et al. 1995; Mayewski et al. 1997; Meeker and Mayewski 2002; Mayewski et al. 2004.
41. O'Brien et al. 1995; Mayewski et al. 1997; Meeker and Mayewski 2002; Mayewski et al. 2004.
42. Bond et al. 2001; Bond et al. 2008.
43. Brückner et al. 2010, fig. 7.
44. Marino et al. 2009, 3256 (fig. 6).
45. Marino et al. 2009, 3254 (fig. 5).
46. Kwiecien et al. 2008, 113 (fig. 7).
47. Specifically, this study uses the quadratic kernel density function included with ArcGIS 10.0, which is in turn modeled after that of B.W. Silverman (1986, 76 [equation 4.5]). ArcGIS formed the primary environment for manipulation of spatial data, with terrain constructed from the data of Wessel and Smith 1996 and Danielson and Gesch 2011.
48. Hassan 1981.
49. Harper 2012.
50. Formulated by E.S. Higgs and C. Vita-Finzi and mentioned in many sources (e.g. Higgs and Vita-Finzi 1972, 31).
51. cf. Hassan 1981, 41 (table 4.2).
52. Kruts 1993, 235.
53. McEvedy and Jones 1978.
54. Kremer 1993, 683 (table 1).
55. Links between climatic variation and these specific phenomena are discussed at length in Diachenko 2010b; Diachenko 2010c; see also Diachenko 2012, 132.
56. According to Ryzhov 2007, 445-453.
57. Diachenko 2012.

Works Cited

Anthony, D.W., and J.Y. Chi, eds. 2010. The Lost World of Old Europe: The Danube Valley 5000-3500 BC. Princeton: Princeton University Press.

Bibikov, S.N. 1965. (in Russian) "Khozyaystvenno-ekonomicheskiy kompleks razvitogo Tripol'ya" [The Middle Tripol'ye household-economic complex]. Sovetskaya Arkheologiya 1965(1):48–62.

Bond, G., W. Showers, M. Cheseby, R. Lotti, P. Almasi, P. deMenocal, P. Priore, H. Cullen, I. Hajdas, and G. Bonani. 1997. "A Pervasive Millennial-Scale Cycle in North Atlantic Holocene and Glacial Climates." Science 278:1257–1266.

Bond, G., B. Kromer, J. Beer, R. Muscheler, M.N. Evans, W. Showers, S. Hoffmann, R. Lotti-Bond, I. Hajdas, and G. Bonani. 2001. "Persistent Solar Influence on North Atlantic Climate During the Holocene." Science 294:2130–2136.

Bond, G., et al. 2008. "North Atlantic Holocene Drift Ice Proxy Data." IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series #2008-018. NOAA/NCDC Paleoclimatology Program, Boulder CO, USA.

Brückner, H., D. Kelterbaum, O. Marunchak, A. Porotov, and A. Vött. 2010. "The Holocene sea level story since 7500 BP - Lessons from the Eastern Mediterranean, the Black and the Azov Seas." Quaternary International 225(2):160–179.

Ciuk, K., ed. 2008. Mysteries of Ancient Ukraine: The Remarkable Trypilian Culture 5400-2700 BC. Toronto: Royal Ontario Museum.

Danielson, J.J., and D.B. Gesch. 2011. "Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010)." U.S. Geological Survey Open-File Report 2011:1073–1099.

Diachenko, O.V. 2008. (in Ukrainian) "Dynamika zmin chysel'nosti naselennya volodymyrivs'ko tomashivs'koyi liniyi rozvytku zakhidnotripil's'koyi kul'tury" [The dynamics of population change in the Vladimirovka-Tomaskovskaya line of development of the Western Tripolye culture]. Arkheologiya 2008(4):9–17.

--------- 2010a. (in Ukrainian) "Do problemy systematyzatsiyi poselen' zakhidnotrypil's'koyi kul'tury u mezhyrichchi pivdennoho Buhu ta Dnipra" [The systematization of Western Tripolye settlements in the Southern Bug-Dnieper interfluve]. Arkheolohiya i davnya istoriya Ukrayiny 2010(2):17–22.

Diachenko, A.V. 2010b. (in Russian) “Evstaticheskie kolebaniya urovnya Chernogo morya i dinamika razvitiya naseleniya kukuten’-tripol’skoy obshchnosti” [Eustatic fluctuations of the Black Sea level and the dynamics of the development of the Cucuteni-Tripolye population]. Stratum Plus 2010(2):37–48.

--------- 2010c. (in Russian) “Tripol’skoe naselenie Bugo-Dneprovskogo mezhdurech’ya: prostranstvenno-vremennoy analiz” [Tripolian populations of the Bug-Dneiper interfluve: spatial-temporal analysis]. Kandidat Nauk dissertation, Institut Arkheologii NAN Ukrainy, Kiev.

--------- 2012. “Settlement System of West Tripolye Culture in the Southern Bug and Dnieper Interfluve: Formation Problems.” In The Tripolye Culture Giant-Settlements in Ukraine: Formation, Development and Decline, edited by F. Menotti and A.G. Korvin-Piotrovskiy, 116–138. Oxford: Oxbow Books.

Diachenko, A.V., and F. Menotti. 2012. “The gravity model: monitoring the formation and development of the Tripolye culture giant-settlements in Ukraine.” Journal of Archaeological Science 39:2810–2817.

Dolukhanov, P.M., and K.K. Shilik. 2007. “Environment, sea-level changes, and human migrations in the Northern Pontic area during late Pleisocene and Holocene times.” In The Black Sea Flood Question: Changes in Coastline, Climate and Human Settlement, edited by V. Yanko-Hombach, A.S. Gilbert, N. Panin, and P.M. Dolukhanov, 297–318. Dordrecht: Springer.

Fouache, E., D. Kelterbaum, H. Brückner, G. Lericolais, A. Porotov, V. Dikarev. 2011. “The Late Holocene evolution of the Black Sea - a critical view on the so-called Phanagorian regression.” Quaternary International 30:1–13.

Harper, T.K. 2012. “Sustaining Tal’yanki: a model of Eneolithic subsistence economics at a giant-settlement of the Tripolye culture, Ukraine.” M.A. thesis, Department of Anthropology, SUNY at Buffalo.

Hassan, F.A. 1981. Demographic Archaeology. New York: Academic Press.

Higgs, E.S., and C. Vita-Finzi 1972. “Prehistoric Economies: A Territorial Approach.” In Papers in Economic Prehistory, edited by E.S. Higgs, 27–36. London and New York: Cambridge University Press.

Kolesnikov, A.G. 1993. (in Russian) Tripol’skoe obshestvo Srednego Podneprov’ya (opyt sotsial’nykh rekonstruktsiy v arkheologii) [Tripolian society in the Middle Dnieper region (the practice of social reconstruction in archaeology)]. Kiev: Naukova Dumka.

Kolesnikov, O.G., and T.M. Tkachuk. 1993. (in Ukrainian) “Do pytannya mikrokhronologiyi trypil’s’kykh poselen’ (na materialakh Bernashivs’kogo poselennya etapu B/II – C/I)” [On Tripolian settlement microchronology (based on materials from the Bernashivka settlement, phases BII to CI)]. In Podil’s’ka starovyna, 44–48. Vinnytsya.

Korvin-Piotrovskiy, O.G., V.A. Kruts, and S.M. Ryzhov, eds. 2003. Tripolye settlements-giants: The international symposium materials. Kiev: Korvin Press.

Korvin-Piotrovskiy, A.G., and F. Menotti, eds. 2008. Tripolye Culture in Ukraine: the Giant-settlement of Talianki. Kiev: Korvin Press.

Kremer, M. 1993. “Population Growth and Technological Change: One Million B.C. To 1990.” Quarterly Journal of Economics, August 1993:681–716.

Kruts, V.A. 1989. (in Russian) “K istorii naseleniya tripol’skoy kul’tury v mezhdurech’e Yuzhnogo Buga i Dnepra” [On the history of the Tripolye culture population in the Southern Bug-Dnieper interfluve]. In Pervobytnaya arkheologiya: Materialy i issledovaniya, 117–132. Kiev: Naukova Dumka.

--------- 1993. (in Ukrainian) “Pytannya demografiyi Trypil’skoyi kul’tury” [The question of the demographics of the Tripolye culture]. Arkheologiya 1993(3):30–36.

--------- 2008. “Giant-settlements of the Tripolian Culture.” In Tripolye Culture in Ukraine: the Giant-settlement of Talianki, edited by A.G. Korvin-Piotrovskiy and F. Menotti, 42–48. Kiev: Korvin Press.

Kwiecien, O., H.W. Arz, F. Lamy, S. Wulf, A. Bahr, U. Röhl, and H. Haug. 2008. “Estimated reservoir ages of the Black Sea since the Last Glacial.” Radiocarbon 50(1):99–118.

Lazarovici, C.-M., Lazarovici, G.-C., and S. Țurcanu. 2009. Cucuteni: a Great Civilization of the Prehistoric World. Iași: Palatul Culturii.

McEvedy, C., and R. Jones. 1978. Atlas of World Population History. New York: Penguin.

Mantu, C.-M. 1998. (in Romanian) Cultura Cucuteni: Evoluție, Cronologie, Legături [Cucuteni Culture: Evolution, Chronology, Linkages]. Piatra Neamț: Muzeul de Istorie.

--------- 2000. "Cucuteni-Tripolye Cultural Complex: Relations and Synchronisms with Other Contemporaneous Cultures from the Black Sea Area." Studia Antiqua et Archaeologica 7:11–28.

Manzura, I.V. 2005. "Steps to the Steppe: or, how the North Pontic Region was Colonised." Oxford Journal of Archaeology 24(4):313–338.

Marino, G., E.J. Rohling, F. Sangiorgi, A. Hayes, J.L. Casford, A.F. Lotter, M. Kucera, and H. Brinkhuis. 2009. "Early and middle Holocene in the Aegean Sea: interplay between high and low latitude climate variability." Quaternary Science Reviews 28:3246–3262.

Masson, V.M. 1980. (in Russian) "Dinamika razvitiya tripol'skogo obshchestva v svete paleodemograficheskikh otsenok" [Dynamics of Tripolye society in light of paleodemographic estimates]. In Pervobytnaya arkheologiya. Poiski i nakhodki, 204–212. Kiev: Naukova Dumka.

Meeker, L.D., and P.A. Mayewski. 2002. "A 1400-year high-resolution record of atmospheric circulation over the North Atlantic and Asia." The Holocene 12(3):257–266.

Mayewski, P.A., L.D. Meeker, M.S. Twickler, S. Whitlow, Q. Yang, W.B. Lyons, and M. Prentice. 1997. "Major features and forcing of high-latitude northern hemisphere atmospheric circulation using a 110,000-year long glaciochemical series." Journal of Geophysical Research 102:26345–26366.

Mayewski, P.A., E.E. Rohling, J.C. Stager, W. Karlen, K.A. Maascha, L.D. Meeker, E.A. Meyerson, F. Gasse, S. van Kreveld, K. Holmgrend, J. Lee-Thorph, G. Rosqvist, F. Racki, M. Staubwasser, R.R. Schneider, and E.J. Steig. 2004. "Holocene climate variability." Quaternary Research 62:243–255.

O'Brien, S.R., P.A Mayewski, L.D. Meeker, D.A. Meese, M.S. Twickler, and S.I. Whitlow. 1995. "Complexity of Holocene climate as reconstructed from a Greenland ice core." Science 270:1962–1964.

Olson, D.M., E. Dinerstein, E.D. Wikramanayake, N.D. Burgess, G.V.N. Powell, E.C. Underwood, J.A. D'Amico, I. Itoua, H.E. Strand, J.C. Morrison, C.J. Loucks, T.F. Allnutt, T.H. Ricketts, Y. Kura, J.F. Lamoreux, W.W. Wettengel, P. Hedao, and K.R. Kassem. 2001. "Terrestrial Ecoregions of the World: A New Map of Life on Earth." BioScience 51:933–938.

Palaguta, I. 2007. Tripolye Culture during the Beginning of the Middle Period (BI): The Relative Chronology and Local Grouping of Sites. BAR International Series 1666. Oxford: Hadrian Books.

Rassamakin, Yu.Ya. 2004. (in Ukrainian) "Stepy prychornomor'ya v konteksty rozvitku pershykh zemlerobs'kikh suspil'stv" [The steppe of the Black Sea region in the context of the development of the first agricultural societies]. Arkheologiya 2004(2):3–26.

--------- 2012. "Absolute chronology of the Ukrainian Tripolian settlements." In The Trypolye Culture Settlements-Giants in Ukraine: Formation, Development and Decline, edited by F. Menotti and A.G. Korvin-Piotrovskiy, 19–69. Oxford: Oxbow Books.

Rassamakin, Yu.Ya., and F. Menotti. 2011. "Chronological Development of the Tripolye Culture Giant-settlement of Talianki (Ukraine): ^{14}C Dating vs. Pottery Typology." Radiocarbon 53(4):645–657.

Ryzhov, S.M. 2007. (in Ukrainian) "Suchasniy stan vyvchennya kul'turno-istorychnoyi spil'nosti Kukuten'-Trypillya na teritoriyi Ukrayiny" [Recent understanding of the Cucuteni-Tripol'ye cultural complex in the territory of Ukraine]. In O. Ol'zhych. Arkheologiya, edited by S.M. Ryzhov and Yu.Ya. Rassamakin, 437–477. Kiev: Publishing House "Olena Teliga."

Shmagliy, N.M. 1980. (in Russian) "Krupnye tripol'skie poseleniya v mezhdurech'e Dnepra i Yuzhnogo Buga" [Large Tripolye settlements in the interfluve of the Dnieper and Southern Bug]. In Pervobytnaya arkheologiya: poiski i nakhodki, 198–204. Kiev.

Silverman, B.W. 1986. Density Estimation for Statistics and Data Analysis. New York: Chapman and Hall.

Telegin, D.Ya., M. Lillie, I.D. Potekhina and M.M. Kovaliukh. 2003. "Settlement and Economy in Neolithic Ukraine: a New Chronology." Antiquity 77:456–471.

Videiko, M.Yu. 1992. (in Ukrainian) "Ekonomika ta suspil'nyj lad trypil's'kogo naselennya Pivdennogo Pobuzhzhya (etapy BII-CI)" [The economy and social system of the Tripolye population in the Southern Bug region (stages BII to CI)]. Kandidat Nauk dissertation, Institut Arkheologii NAN Ukrainy, Kiev.

--------- 2002. (in Ukrainian) Trypil's'ki protomista. Istoriya doslidzhen' [Tripolye proto-cities: a history of investigations]. Kiev: Akademperiodyka.

Weninger, B., and O. Jöris. 2008. "A ^{14}C age calibration curve for the last 60 ka: the Greenland-Hulu U/Th timescale and its impact on understanding the Middle to Upper Paleolithic transition in Western Eurasia." Journal of Human Evolution 55:772–781.

Weninger, B., L. Clare, E. J. Rohling, O. Bar-Yosef, U. Böhner, M. Budja, M. Bundschuh, A. Feurdean, H-G Gebel, O. Jöris, J. Linstädter, P. Mayewski, T. Mühlenbruch, A. Reingruber, G. Rollefson, D. Schyle, L. Thissen, H. Todorova, and C. Zielhofer. 2009. "The Impact of Rapid Climate Change on prehistoric societies during the Holocene in the Eastern Mediterranean." Documenta Praehistorica 36:7–59.

Weninger, B., and T. Harper. Forthcoming. "The Geographic Corridor for Rapid Climate Change in Southeast Europe and Ukraine." In Chronologies, Lithics and Metals: Late Neolithic and Copper Age in the Eastern Part of the Carpathian Basin and in the Balkans. Berlin: Deutsches Archäologisches Institut.

Wessel, P., and W.H.F. Smith. 1996. "A global, self-consistent, hierarchical, high-resolution shoreline database." Journal of Geophysical Research 101(B4):8741–8743.

Wood, J.W., 1998. "A Theory of Preindustrial Population Dynamics: Demography, Economy, and Well-Being in Malthusian Systems." Current Anthropology 39(1):99-135.

Zbenovich, V.G. 1996. "The Tripolye Culture: Centenary of Research." Journal of World Prehistory 10(2):199–241.

Zubrow, E.B.W., 1975. Prehistoric Carrying Capacity: a Model. Cummings Archaeology Series, edited by C.C. Lamberg-Karlovsky and J.A. Sabloff. Menlo Park (CA): Cummings.