

Are we creating our past? Exploring theory building, geospatial statistics, and the reconstruction of the function of fortified Urnfield culture settlements

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ABSTRACT – *Urnfield Culture hilltop settlements are often associated with a predominant function in the settlement pattern. This study challenged the idea of centrality by means of density estimates and spatial inhomogeneous explanatory statistics. Reflecting on the differences in spatial trends and material culture, no conclusive evidence for a consolidation of power, economic, or cultic dominance was observed. The dataset strongly points towards the inapplicability of commonly used parametric and/or homogenous spatial algorithms in archaeology. Tracer variables as well as the methodological and theoretical limitations are critically reviewed and a methodological framework to increase the reproducibility and reusability of archaeological research is proposed.*

KEY WORDS – *social theory; methodology; central place; geospatial statistics; Urnfield culture*

Ali ustvarjamo svojo preteklost? Raziskovanje gradnje teorij, geoprostorskih statističnih podatkov in rekonstrukcije funkcije utrjenih naselij kulture žarnih grobišč

IZVLEČEK – *Višinska naselja kulture žarnih grobišč pogosto povezujemo z vodilnim položajem v vzorcu poselitve. V pričujoči študiji izpodbijamo idejo o centralnosti z uporabo ocen gostote poselitve in prostorskih nehomogenih pojasnjevalnih statističnih podatkov. Pri opazovanju razlik v prostorskih usmeritvah in materialni kulturi nismo našli nobenega prepričljivega dokaza o utrjevanju moči ter o gospodarski ali kulturni prevladi. Podatkovna baza kaže na neuporabnost parametričnih in/ali homogenih prostorskih algoritmov, ki se običajno uporabljajo v arheologiji. Nudimo kritičen razmislek o sledilnih spremenljivkah ter o metodoloških in teoretičnih omejitvah, hkrati pa ponudimo metodološki okvir, s pomočjo katerega lahko povečamo ponovljivost in ponovno uporabnost arheoloških raziskav.*

KLJUČNE BESEDE – *družbena teorija; metodologija; centralni prostor; geoprostorski statistični podatki; kultura žarnih grobišč*

Introduction

In pre- and protohistory the spheres of influence and functionalities of places are usually estimated and reconstructed based on a theoretical framework joined with spatial data. Whilst assumptions and approaches differ, this method predominantly connects a set of ideas of how economic and political power as well as cultic centres are reflected within

the archaeological and environmental record. These theories are usually based on the work of Georg Simmel (1903), who argued that social structures and power relations are projected to space. Further, the works of Walter Christaller concerning central places (Christaller 1933[2006]) and Eike Gringmuth-Dallmer's medieval centrality criteria (Gringmuth-

Dallmer 1999) have greatly influenced the interpretation of prehistoric hilltop settlements as places of centrality (e.g., Schauer 1993.62; Stegmaier 2017.265), dynastic seats (Winghart 1999.532), castles (Gersbach 2006.96–97), and even of proto-urban character (Ostermeier 2012.143). The adapted centrality criteria are usually described as the presence of fortifications, political power, specialised craftsmanship, and religious centres (e.g., Posluschny 2010.362). There is no unchallenged set of tracers, distinctive variables, and objective interpretative value. However, their existence is necessary – as anything in existence is somehow reflected on the system – and therefore is theoretically measurable (McCall 1939.15; Thorndike 1918.16). Most commonly, the presence of political power is substituted by the nearby presence of extraordinary rich graves, characterised by ‘class-specific’ objects (Jockenhövel 1990.224). These are associated with drinking and hospitality, especially if made out of bronze, along with weapons, wagons, riding accessories, amulets, objects made of precious metal, rich ornamental décor, and extraordinary mortuary constructions (Bockisch-Bräuer 1999; Clausing 1999; Falkenstein 2005; Fischer 1997; Jockenhövel 1971; Knöpke 2009; Kossack 1974). The connection of elites, economic power, and specialised craftsmanship is assumed to be indicated by the presence of advanced metallurgy as well as high-quality objects (Jockenhövel 1990.227). There is no archaeological evidence for the assumption that supposedly less prestigious craftsmanship, such as pottery or textile production, was solely conducted in lowland settlements (Jockenhövel 1994.25). Metal hoards are often associated with economic dominance in metal trade, but also with religious functions (Falkenstein, Ostermeier 2015.21; Roymans, Kortlang 1999.27–28).

The presence of a somehow stratified society in control of the aforementioned aspects has been summarised by various authors (e.g., Bockisch-Bräuer 1999; Clausing 1998; Falkenstein 2005; Knöpke 2009; Kristiansen 1982; 1998; Rowlands 1998; Sperber 1999; Tomedi 1999; Wirth 1999). Usually it is connected to the presence of a warrior-based elite, as the few extraordinary rich Urnfield culture graves have a higher proportion of weapons (Knöpke 2009.16). This has been named an ‘aristocratic warrior elite’ (Kristiansen, Larsson 2005.218), class of warlords (‘Kriegerherrenschicht’; Stary 1980.64), and sword bearing aristocracy (‘Schwertträgeradel’; Sperber 1999.643–644). For the latter, territories of 4–6km were reconstructed based on the distances of graves (Sperber 1999.629–635).

While treating measurement as a state of uncertainty reduction this paper aims to investigate functional differences in the material record of Urnfield culture fortified hilltop settlements and lowland settlements in the Central Swabian Alb by comparing them among themselves and to other features, such as graves or hoards, based on an eclectic approach – both in method and theory. The reflection on similarities and differences in spatial location and categorical functional groups, as well as a critical assessment of the variables’ symbolism and statistical methods, will complement the interpretation of fortified hill-top settlements and their function. Finally, it will provide ideas for a framework to overcome current problems in the application of geospatial algorithms.

Material and methods

The data used was originally published by Rainer Kreutle (2007). As he collected the majority of the data himself during a relatively short period of time (1986/1987; Kreutle 2007.15) a low intra-observer error rate, especially concerning colour and tempering descriptions, is to be expected. Therefore sites should be comparable to each other and differences do not arise based on different description styles, terminologies or categories. However, as the landscape of the Swabian Alb is predominantly characterized by valley systems, reaching up to 1000m asl in the central parts, the archaeological knowledge is influenced by local collectors and modern settlement areas. Nonetheless, a statistical correlation between construction activity and the discovery of sites was not observed.

The dataset consists of 283 sites of seven types (i.e. hilltop settlement, lowland settlement, cave finds, graves, hoards, single finds, and objects of unknown contexts). Although the central part of the Swabian Alb is not favourable to agriculture, due to its climate and lack of water resources, 27 hilltop and 37 lowland settlements were observed in the area, producing 1023 and 432 recorded pottery units, respectively. A total of 2088 ceramic objects, including 296 units originating from 61 burial sites were included. In general, pottery from settlement sites is coarser and more broken than those recovered from graves. Most vessels are from settlement sites and served as urns, the most characteristic finds are bowls with creased sides and beakers. In order to simplify the data and include as many objects as possible, the pottery was categorised as beakers, bowls, cups, pans, pots, and special shapes.

Furthermore, 1089 metal objects (tools, jewellery, weapons, indicators of metallurgy, indicators of other craftsmanship, harnesses or wagon parts, special objects and unidentified items) were included in the analysis. The collection represents a typical Urnfield culture assemblage. Most of the items were recovered from graves (581) and hoards (232). The majority consisted of knives, needles, and various kinds of rings and bracelets, whilst tools (sickles and axes) predominantly originate from settlements or hoards. It is notable that most weapons, especially spears, were single finds or parts of grave inventories.

The data is supposed to serve as an example dataset of Urnfield culture sites, to not only allow for functional reconstruction, but also a critical assessment of the statistical algorithms.

Quadrant counts on a 10km pattern and kernel density estimates based on optimised likelihood cross validation bandwidth with edge correction were calculated to compare the spatial intensity distributions of the different site types. Theoretical territories were constructed based on Dirichlet tessellations and Delaunay triangulations. Spatial distance trends were visualised by Stienen diagrams. Correlations of site types and specific objects were analysed through an inhomogeneous L-function and evaluated through Monte Carlo envelopes (19 runs). The similarity of site assemblages was graphically compared. All statistical analyses were based on the method and algorithm recommendations by Adrian Baddeley *et al.* (2015) and computed in R with the relevant packages (Arnold 2018; Bivand *et al.* 2013a; 2013b; 2018; Bivand, Lewin-Koh 2017; Bowman *et al.* 2007; Pebesma, Bivand 2005; R Core Team 2016; Urbanec 2013; Wickham 2009; Wickham *et al.* 2017; 2018a; 2018b; Wickham, Henry 2018).

Results

Spatial data

The data displayed varying spatial intensities, not only presenting regional trends but also differing among site types (Fig. 1). The trend corresponds to the central plateau of the Swabian Alb and its associated passes.

Dirichlet tessellation centred on hilltop settlements and its associated Delaunay triangulation indicate slight hexagonal trends (Fig. 2a), and Stienen distance measures indicate preferable spheres of influence of around 6km (Fig. 2b).

The explanatory power of the association of all site types was correlation stationary ($T = 0.06$, $p = 0.001$) and had a constant scale of spatial interaction ($T = < 0.01$, $p = 0.001$). This suggested weak explanatory

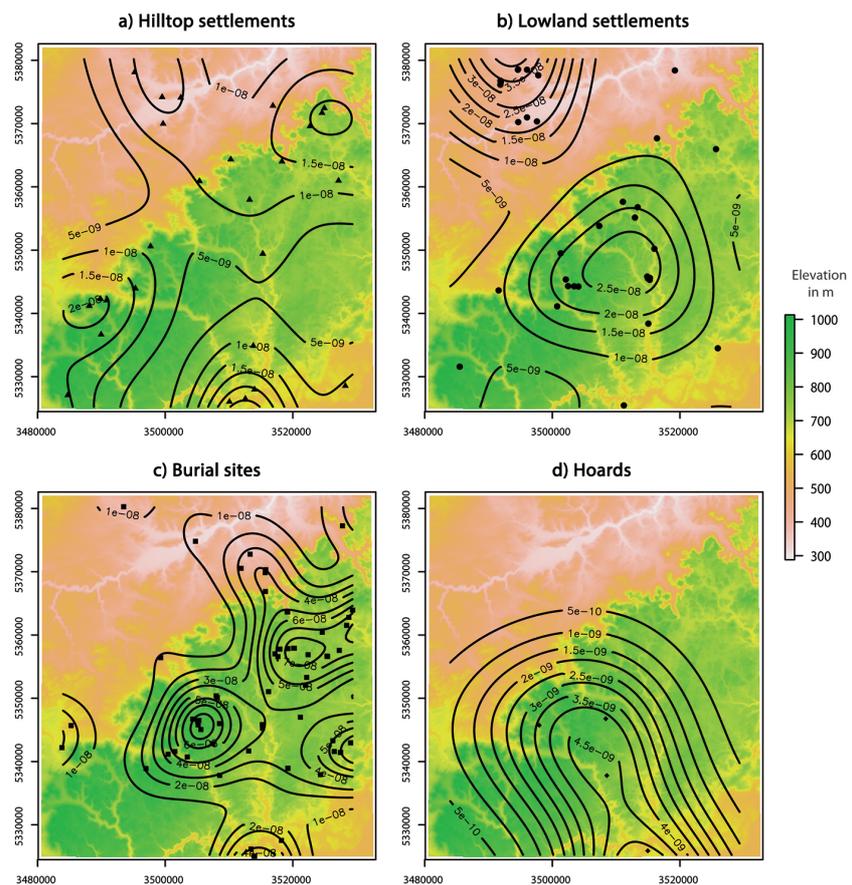


Fig. 1. Distribution of sites and their associated density estimates based on a Gaussian kernel with optimised bandwidth (likelihood cross validation) with edge correction. (a) $\sigma = 6.2\text{km}$, (b) $\sigma = 7.1\text{km}$, (c) $\sigma = 4.2\text{km}$ (d) $\sigma = 9.0\text{km}$. Digital terrain model by the University of Heidelberg, based on an SRTM dataset projected on EPSG:5683, Gauss-Kruger zone 3. One step on the x-axis corresponds to 20km. The symbols on each map correspond to the same site types on every other map in the paper: a triangle = hilltop settlement, dot = lowland settlement, square = burial sites, and diamond = hoards.

power, and Monte Carlo envelope validation of the centred inhomogeneous L -function indicated evidence against an inhomogeneous Poisson point process (Fig. 3).

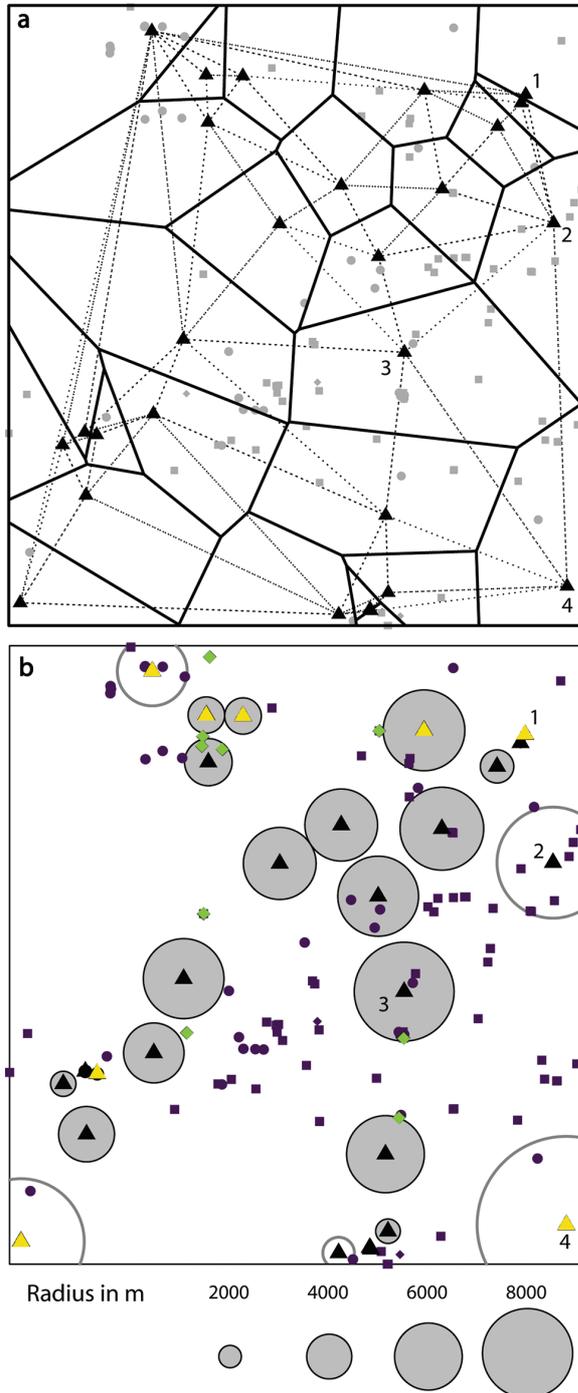


Fig. 2. (a) Dirichlet tessellation (black line) with associated Delaunay triangulation (dotted line) of the hilltop settlements. Lowland settlements, burial sites and hoards are shown in dark grey. (b) Stienen diagram of the hilltop settlements with the other site types shown in dark purple. Urnfield culture dated fortifications highlighted in yellow, burials with swords in green.

Archaeological data

As no significant indicators for interaction could be generated from the spatial data, the artefact assemblages were analysed for their similarity. No significant differences in the pottery firing technique were observed (Girotto 2018). The differences in the proportion of drinking vessels were insignificant (Fig. 4).

Discussion

An extensive discussion of all possible elements and factors of the dataset is not only beyond the scope of this study, it is also impossible based on the current state of knowledge. The presented results are a regional study and are foremost a tactile explanatory vehicle to highlight the problems of settlement interpretation in prehistory. The inability to detect why certain settlement sites are exceptional within a certain cluster is most often based on qualitative approaches and theoretical interpretation. A notable exception being Oliver Nakoinz (2013a), as the lack of statistical significance of explorative analyses requires either a descriptive approach or holistic models. However, most interpretations are based on the *a priori* selection of ‘prestigious’ factors, such as the universal perception of gold as of utmost value (e.g., Gersbach 2006.97) or their rarity is ‘proof’ of their special functions in society. For this study, the main theoretical contribution to select the traditional markers is provided by Albrecht Jockenhövel (Jockenhövel 1990.220): “Fortified settlements protected large and small settlement clusters. They can be considered their economic, power and possibly cultic centre” (author’s own translation).

Hilltop settlements as centres of protection and power

The pattern of the hilltop settlements is reminiscent of the passes allowing passage through the central plateau of the Swabian Alb (Fig. 2a), thus possibly indicating gateway functions (e.g., Nakoinz 2013b.96). Nonetheless it should not be considered as evidence for the control of trade or routes as their location is heavily influenced by the landscape. None of the sites offers causal archaeological evidence to assume more than a correlation of site type and topology.

This is further implied as in a only few cases were lowland settlements observed close to hilltop settlements. Nearest-neighbour distances of the hilltop settlements (Fig. 2b) suggest a preferred distance of approx. 6km on the Alb, however there was no cor-

relation with Urnfield culture dated fortifications. Therefore no conclusive evidence could be gained concerning their protective function for settlement clusters.

Whilst graves occur at higher rates within the Swabian Alb, the location of graves of sword bearing individuals is interesting. Comparatively often such a grave is located at the border of a Stienen circle (Fig. 2b). Whether this is a representation of the territories of sword bearers ('*Schwerträgerterritorien*'; Sperber 1999.629–635) remains questionable. The additional association of elites with wagons and harnesses cannot be supported by the sites of the Runder Berg, Bad Urach (1) and the Hackberg, Gomadingen (2). Both present additional evidence for management of horses, however the findings from the Runder Berg were recovered from the settlement and might also be representative of agriculture. Bronze parts of a harness were found in a grave near the Hackberg, but the possibly associated hilltop settlement is supposed to have only had space for a singular building (Biel 1987.78–79). Only a necropolis near the Plettenberg (4) had evidence that could be conclusive. A wagon and sword were recovered from a double burial, and lowland settlements as well as other graves are present in the Stienen radius of the Plettenberg. However, due to the insignificance of the explanatory analyses no direct causality can be deduced from the findings. Theoretical territories should only be interpreted, if at all, with great caution as they might be a result of random fluctuation present in the sample or the dataset due to its lack of large scale excavations.

This study highlights how the archaeological search for centrality is driven very much by current understandings of where it should occur, and not which underlying processes might have created it (e.g., Green, Perlman 1985.5; Hen-

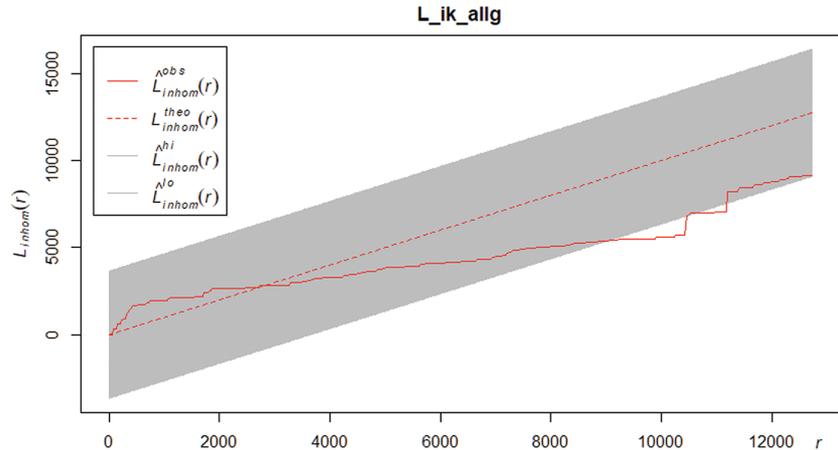


Fig. 3. Centred inhomogeneous L-function and Monte Carlo envelope of all recorded sites indicating divergence from an inhomogeneous Poisson process. Range r in metres.

ning, Lucianu 2000.533; Maise 1996). A terrific example of this would be the Heuneburg, Herbertingen Hunderingen (5). Based on early works (e.g., Kurz 2012.449–450, Gersbach, 2006.96–97) and the data published in Kreutle (2007) a much less prominent position in the Urnfield settlement structure was proposed. However, current research attributes almost urban characteristics to the site (Stegmaier 2017.264). This illustrates not only the importance of large scale excavations, but also how much an *a priori* idea of the characteristics of a central place influence the interpretation.

Hilltop settlements as centres of economy and hospitality

No causality for the location of the different site types could be established. However, artefact analy-

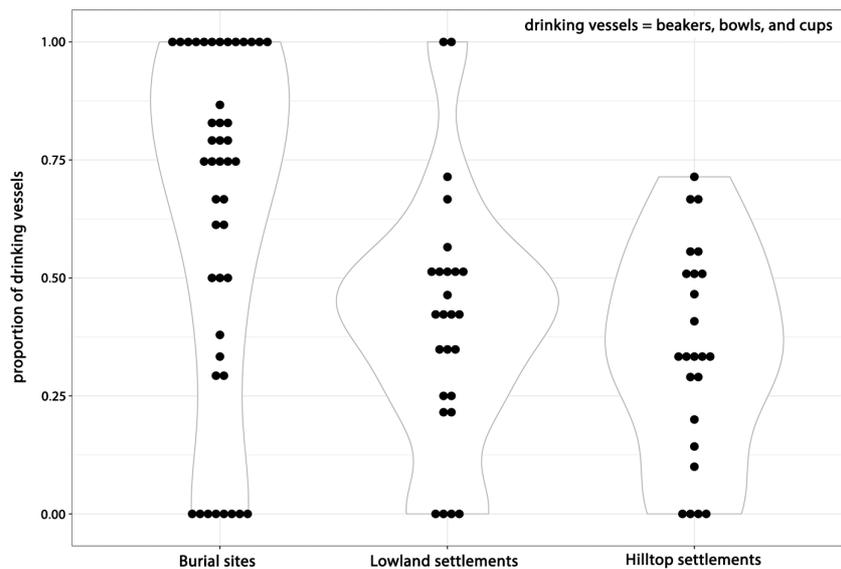


Fig. 4. Violin plot of the proportion of drinking vessels among the site types.

sis can still offer insights with regard to their functional differences. The data was characterised in its original publication (*Kreutle 2007*) using the traditional approach, and therefore this paper will focus on two specific aspects: Indications for the control of craftsmanship and metallurgy, and the connections of elites and hospitality.

As mentioned before the control of advanced metallurgy is generally assumed to be a feature of (fortified) hilltop settlements, but there is no conclusive evidence for this. However, this idea perfectly fits in a hierarchical and evolutionary mindset with regard to Bronze Age societies. Metal is often considered a driving factor of individualisation, increasing wealth, complexity, and the consolidation of power (e.g., *Kuijpers 2012:418*). Further, it requires that people valued metal objects more than any other kind. In the study region no grave associated with metallurgical craftsmanship has yet been discovered, however these are usually associated with slightly richer graves than the average (*Nessel 2012*). In general their heterogeneity is more likely a remnant of the organizational and functional aspects of the related

person in a social system, and not an indicator of a high social status.

The indicators of metallurgy are distributed among hilltop and lowland settlements as well as hoards (Fig. 5).

The presence of the finds suggest areas of general increased productivity, as around the Runder Berg (1). Interesting is the optimized bandwidth of *c.* 37km, which indicates that its distribution is a superregional phenomenon that cannot be analysed on the small scale of the study region. This complements archaeological ideas on metal production during the Urnfield period, and highlights once more the problem of insignificant point process associations.

General increased productivity and economic dominance is often connected to elites participating in superregional exchanges to acquire prestigious objects and resources, like metal. However, these functional aspects require the theoretical base of the presence of an elite or otherwise dominant group of people.

Usually a connection of warriors, elites, and hospitality is postulated. This is based on the idea of the organisation of power in decentralised communities where feasting plays a major role in the consolidation of alliances, as well as in the display of power and economic dominance (*Dietler 2001:77*). Following the idea of hypothesis falsification and measurable outputs of significant variables to this connection, the increased presence of sword bearing individuals should also generate higher proportions of drinking vessels at hilltop sites. However, the plot mainly distinguishes burials and settlement sites (Fig. 4). The increased rates in graves indicate a focus on drinking during the funerary ritual or for the afterlife, regardless of whether the pots or their contents were originally considered as burial gifts. The slightly higher portion of

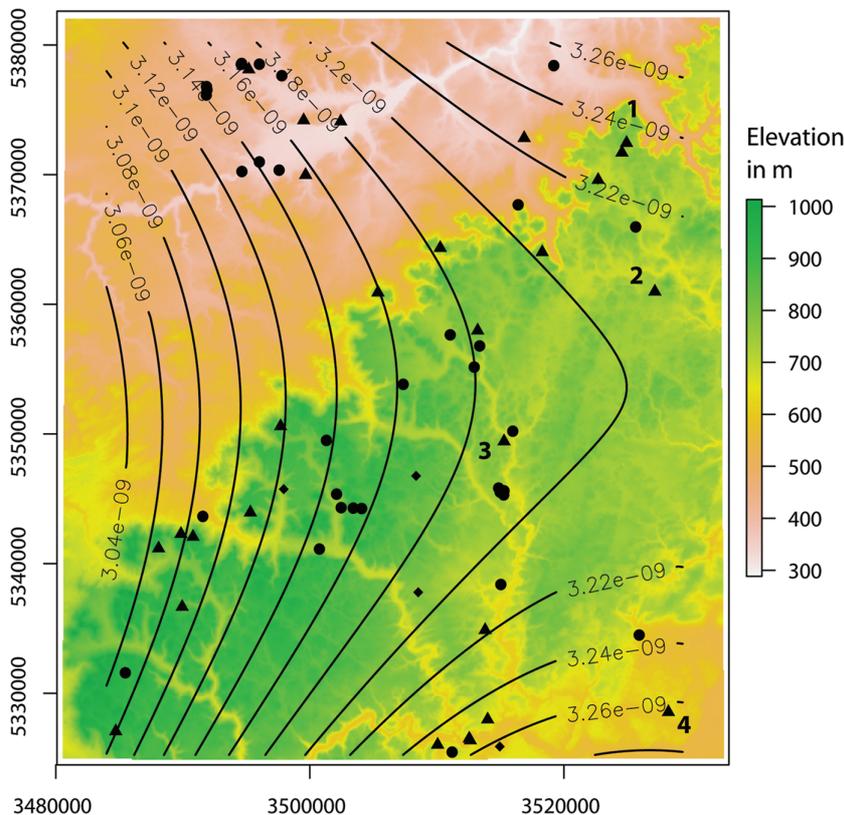


Fig. 5. Density estimates of metallurgical indicators (ingots, metallurgical by-products, moulds, and associated tools) and distribution of the hilltop settlements, lowland settlements, and hoards. Based on a Gaussian kernel with optimized bandwidth (likelihood cross validation) with edge correction, $\sigma = 37.6\text{km}$. Digital terrain model as in Figure 1.

dinking vessels at lowland settlements is insignificant, as all confidence intervals overlap. The dataset did not strengthen the argument of hilltop settlements as places of increased hospitality or feasting. However, the pottery assemblages across all contexts were very variable. Potentially slight changes in proportion were hidden due to the high variance. The connection of sword bearing individuals and hilltop settlements could not be reinforced. Maybe the often quoted “[...] all civilisations owe their origin to warriors” (Keegan 1993, vi) should be questioned as too often “elite positions are taken as a given where their existence needs to be proven from contextual information” (Kienlin 2012, 21).

Summary

The analyses do not comprehensively support the idea of hilltop settlements as early central places, seats of the elites, and economic centres. Even the presence of an elite group, due or because of the occurrence of hilltop settlements could not be conclusively evidenced. The strongest connections are sword bearing individuals at the borders of Stienen nearest-neighbour circles which might indicate some territorial differentiation.

A priori selection of high status indicators merely projects modern assumptions on the society of the Urnfield culture. Therefore, the presented maps do not necessarily reflect aspects of a past social reality but might also represent the underlying research concepts. It allows the observer to critically evaluate commonly used indicators and methods, as any meaningful variable should produce a significant result. However, if the original populations’ ideas differed significantly, it is possible that the currently tested variables simply do not have explanatory power, because they were not relevant in the past.

Implications for future research – Are we narrating our past?

Statistical limitations

Aside from theoretical considerations many of today’s limitations are critically linked to the archaeological geostatistical approach. A complex system, like human interaction, social organization, and the symbolism of places, cannot be seen as one solvable by simple spatial statistics (e.g., Hacigüzeller 2012, 246; Herzog 2009). Questions concerning social interactions and structures are cognitive features, often subjective, seemingly irrational, and symbolic. They are, by their very nature, post-processual but our use

of ostensibly objective environmental and spatial data rightfully faces the same critique Daniel Miller and Christopher Tilley made of the processual theory school in 1984: “A belief by some in mathematization as the goal of archaeology; the attempt to reduce past social systems to a suitable equation” (Miller, Tilley 1984, 3). Furthermore, it implies the “reduction of the analysis of social change to the elucidation of external factors impinging on the social system” (Miller, Tilley 1984, 3). However, any of the classical statistical approaches is reasonable if it can actually answer the posed research question. Following the concept of maximum parsimony the least complex method with the least amount of required *a priori* interpretation should always be chosen. Creating a null hypothesis that can be investigated is often difficult, as most archaeological questions ask why certain events happen/assemblages occur as they desire causal explanations. However, statistical methods investigate correlations, and causality can only be derived from interpretation or made likely through modelling. The most prominent difference in today’s research is the use of other scientific methods and theories in a more holistic way (Müller-Scheeßel 1998, 265). If one chooses not to model a complex system and/or non-linear dynamics, the algorithms and methods, even if they are spatial and deal with complex phenomena like in epidemiology and ecology, cannot be simply adapted for archaeological purposes. Among the most critical differences are the ones required for a scientifically acceptable research design, such as a lack of reproducibility or a controlled environment. Most important of all though are the questions as to whether archaeological data can be considered a representative sample of the original population, or if any past dataset is truly independent (Buccellati 2017, 344). Further, most algorithms require certain assumptions, like homogeneity and stationarity. In return they themselves impose specific behaviours on the founding populations, like specific probability distributions and parametric behaviour. Whilst usually not even addressed at all in archaeological papers, inhomogeneous functions, Bayesian probability approaches, and the validation of explanatory analysis allow for a sounder interpretatory basis than homogeneous estimators and Gaussian or Poisson distributions for point processes. Overall the inhomogeneous counterparts of well-known methods, like the K-function, tend to perform much better. Even the few requirements of inhomogeneous methods are often not met in archaeological applications, as illustrated in the example data. This also holds true for the disciplines that originally devel-

oped these methods, as Jose A. F. Diniz-Filho *et al.* (2007.850) neatly summarized: “[w]hen multiple assumptions are not being met, as in the case of virtually all geographical analyses, can a result from any single method (whether spatial or non-spatial) be claimed to be better? [...] If different methods themselves are unstable and generate conflicting results in real data, it makes no sense to claim that any particular method is always superior to any other.”

Whilst one should not believe that “anything could be recovered from the archaeological record, if you only searched hard enough” (Chippindale 1987.515), new approaches and methods have highlighted the potential of statistical algorithms and models. Besides promising results in the field of agent-based modelling and exploring concepts of non-linear dynamics in archaeology, the inclusion of mathematical chaos, sensitivity analysis and ascendance (e.g., Arias-González, Morand 2006; Deman *et al.* 2016) as well as the reconstruction of centrality based on parabolic fractal distributions (Henning, Lucianu 2000; Müller-Scheeßel 2007) have moved and will continue to move the discipline forward.

Tracer variables

The discussion presented above offered highlighted some of the most common factors and methods used to investigate settlement hierarchy. Alongside a rather classical methodological approach this serves as a basis to evaluate such a scientific approach. Conceptual and theoretical assumptions merged with spatial and archaeological data form – directly or indirectly – the basis for the reconstruction of societal structures in illiterate societies. Apart from complex self-learning algorithms, like neural networks or chaotic deterministic autocatalytic cycles, factors of interest need to be chosen and weighted. Whether that be the association of swords as symbol of rank or power (e.g., Egg 1986.203; Kristiansen, Larsson 2005.213; Roymans, Kortlang 1999.310–311), the association of elites and fortification (Jockenhövel 1990), or hoards as a reflection of cultic practices (e.g., Hansen 1994.309). The connection of elites and metallurgy is presumably based on a similar context. Promising results for the identification of prestigious artefacts were presented by Robert Schumann (2015), who not only differentiated between status and prestige but also added much to the debate on the explanatory power of artefacts in relation to different assemblages. Therefore, whether classical statistical methods or more

complex modelling will provide new ideas or are even useful depends largely on the research question. Standard approaches, e.g., those exploring a certain set of factors, mainly focus on equilibrium-related methods, while many questions in social archaeology are actually about processes. Whilst these approaches certainly have their place in research they are not ideal to investigate societal structures, because their emergence is a process, constantly fluctuating between entropy and equilibrium. These cycles (e.g., Zimmermann 2012) are the driving process – the behavioural patterns and events – that once generated the material culture record.

It is obvious how a traditional understanding of society as a dichotomous, static phenomenon restricts the interpretative power of the material record. A society can be decentralised, have cooperative systems of power, or a high level of horizontal stratification. Even the presence of multiple vertical organisational structures in close regional proximity or the domain of an archaeological culture cannot and should not be ruled out (e.g., McIntosh 1999.1). To develop new pathways in the interpretation of prehistoric societies the assumptions of ideal, static types of societal organisation should be left aside in favour of processes and strategies associated with the constitution and maintenance of political power (Blanton *et al.* 1996.2; Kienlin 2012). Usually they can be described as cooperative and exclusionary patterns of behaviour in variable combinations, and do not require evolutionary logic or follow a systemic logic (Bossen 2006.89; Jung 2011; 2006). Similarly it is important to acknowledge that their material indicators and symbolism and meaning cannot be easily identified. However, they form an integral part of the supposedly subjective statistical analysis. Nonetheless the results do not speak for themselves, but are rather an outcome of our own limited culturally specific symbolic understanding, as a symbol “connotes a certain meaning as semantic unit of an ideological code [...], which] prevents us from seeing the semantic systems in the totality of their mutual relationships” (Eco 1970. 553–554).

Humanity, the prime example of a complex non-linear system, thrives on its two main characteristics: emergence over scale and self-organisation over time. People interact with their environment, and their spontaneous interactions create unforeseen changes that amplify over time in new structures and social systems (Lam 1998.37–38). Therefore, especially with equilibrium-based approaches, the

choice of tracer variables rooted in the perceived universality of modern day values indeed creates a past. In this case, any model is not a tool to heuristically understand processes, context, and possibilities but rather, as Alfred Tarski (1933) stated, a realisation of a theory. However, in prehistoric archaeology, this cannot be the way forward to reconstruct society, as it restricts its greatest asset: the view on the *longue durée* (Braudel 1977) of social change. Archaeology might be “*the discipline with the theory and practice for the recovery of unobservable hominid behavior patterns from indirect traces in bad samples*” (Clarke 1973.17), but embracing new theories and concepts such as complex, non-linear models will bring the discipline forward to a more holistic understanding of objects and their value for the people that used them. Gaining these insights and the inclusion of variables will reduce the amount of narration fed into the reconstruction of past societies.

A way forward

Synthesising the remarks on the chosen tracer variables it becomes obvious that is not only the choice of methods which influences the result. The findings can also be interpreted in different ways, because science is never truly objective, and will always be

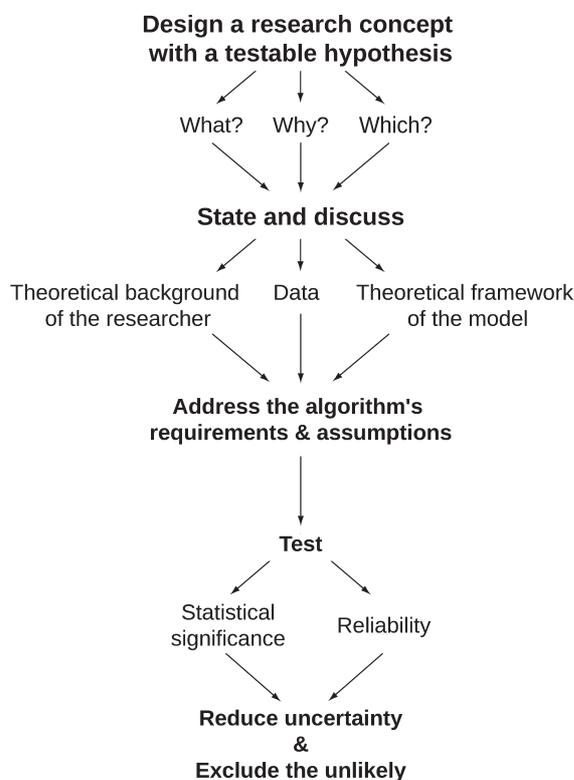


Fig. 6. Proposed general procedure to increase the reproducibility and reusability of statistical research and interpretation in archaeology.

influenced by the world and culture we live in today. Further, any statistical finding is only a statement of probability how well the data used fits a hypothesis, never proof of reality. Therefore, the results should much more be seen as a reduction of uncertainty. As in information theory, new knowledge is produced by the exclusion of unlikely events or processes, following the idea of falsification. Further, the reconstruction of function clearly requires us to accept that, as in the Bayesian school of statistics, this uncertainty is a feature of the observer and the data itself (see Bolstad 2007). The hope that one day the patterns left by past societies can be understood comes from the fact that things that exist have some quality, and that this can be measured (McCall 1939.15; Thorndike 1918.16). The search for such meaningful variables should continue in the current eclectic school of thought (e.g., Chippindale 1987.515; Pearce 2011.87), choosing the most suitable methods, approaches, and algorithms. Creativity and new ideas should not be hindered by a lack of implementation of inhomogeneous functions or Bayesian functionalities in easily accessible statistical applications, but rather should aim to produce new methods and concepts to implement them.

Considering the limits imposed on the interpretability of archaeological investigations, both reproducibility and a documented approach should be the prime criteria of any methodological or statistical paper. Whilst readily applied in modelling and more complex strategies, this is often overlooked in more classical archaeological approaches.

It is therefore proposed to include an adapted version of the ODD protocol, devised by Volker Grimm *et al.* (2006), as a supplement to any statistical approach in archaeology (Fig. 6).

Concisely stating the project overview, design concepts, and details will force the researcher to not only arrive at a statistically testable hypothesis, but also specify what the prime research questions are, by which factors those are supposedly influenced and why these specific factors were chosen. Furthermore, as clearly outlined in the previous sections it is of great importance to state and discuss not only the theoretical background and framework of the researcher and model, but also the data itself.

Whilst the theoretical background of the model might already impose prior assumptions, it is critical to address the requirements and assumptions of the

algorithms as this will further influence the outcome. In particular because it is common that they are not met (*Diniz-Filho et al. 2007*), they need to be accounted for in the interpretation. Furthermore, any results should be tested not only for statistical significance, but for reliability and logic as well.

Statistical results can never prove a hypothesis, but if the underlying factors and methods are clearly outlined any result can not only be reproduced and reused by other researchers, but itself be considered a reduction of uncertainty and an exclusion of the unlikely.

Conclusion

This paper presented a statistical analysis and its critical evaluation concerning the function of Urnfield culture hilltop settlements as power, economic and cultic centres. For the study region, the Central Swabian Alb, the hilltop settlements were approximately regularly spaced at around 4km linear distance and followed the natural topology of the region. Density and distance measures were the foundation of the study, as the requirements for most explanatory functions were not met. Solely based on descriptive statistics and theoretical considerations, the spheres of influence of hilltop settlements sometimes had graves with swords and rarely chariots at their borders. If one is willing to accept the semantic attribution of sword bearing individuals to territories and power, there are indications of the power functions of hilltop settlements. However, no reliable indications connected to economic and cultic dominance were observed.

The study highlighted the importance of critically discussing commonly used statistical algorithms and how they influence the results of research. Depending on the choice of factors the researcher is indeed narrating a past in accordance with perceived 'universal' ideas of value or status. Although archaeological data does not meet the requirements for inhomogeneous, non-parametric point processes, this suggests that these pathways should be explored deeper and probability functions as well as the validation of explanatory analyses should not remain scarce phenomena in geospatial archaeological applications, in order to better understand intangible variables. It also suggests that researchers should use non-linear methods to reconstruct society more holistically. Further, it means that researcher should adhere to a methodological framework to increase the reproducibility and reusability of the research they conduct.

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