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Waagen, J.

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CHAPTER 5.
SAMPLING SAMNITES: A STATISTICAL APPROACH FOR TESTING A HELLENISTIC / SAMNITE SETTLEMENT PATTERN HYPOTHESIS IN THE TAPPINO AREA, MOLISE, ITALY[4]

ABSTRACT

The Tappino Area Archaeological Project (2013-) investigates ancient society in the area surrounding the Tappino river in modern-day Molise, Italy, which from the Iron Age to the Roman period was inhabited by the Italic people called the Samnites. Using field survey and related methods, the project aims to reconstruct the ancient settlement pattern in the area. Until now, surveys mapped a higher concentration of rural settlements in the more elevated portions of the landscape, which resonates with the results from other projects in the wider Samnite area. Before using these results for interpreting the character of the settlement organization and for reconstructing the structure of Samnite society, we need to test carefully whether the documented concentration of sites is not the result of research biases, a notorious factor in landscape archaeology.

The project therefore tests various biases with the aid of new field methodologies and sampling strategies. For instance, areas that have escaped attention are mapped in more detail using point sampling in forested areas, drone aerials, LiDAR and other methods. In this paper, we aim to test whether settlement in the Samnite period is predominantly located in the more elevated portions of the landscape, e.g. hill-plateaus, by applying standard field survey methods in a proportionate stratified sampling scheme, representing also the less investigated areas. First, we look at the distribution of farm sites, the main rural sites in this area in this period, in a large area and test whether locally higher densities of farms are a recurring pattern, and whether this phenomenon is bound to hill-plateaus and similar geomorphological units. Since previous research in the Tappino area focused mainly on the higher portions of the landscape, it is important to check whether this has caused a research bias. It is also necessary to understand to what degree settlement responds to local variables that could distort our impression of the settlement pattern, such as archaeo-

[4] This chapter is based on the article "Sampling Samnites: a statistical approach for testing a Hellenistic/Samnite settlement pattern hypothesis in the Tappino Area, Molise, Italy" by Jitte Waagen and Tesse D. Stek, submitted 16 March 2022 to Archaeological and Anthropological Sciences.

The study in this chapter has been executed in the context of the Tappino Area Archaeological Project (TAAP), coordinated by Tesse D. Stek from the Royal Netherlands Institute in Rome (KNIR) and University of Groningen. The field work campaign oriented on the sampling issue that we present here was organized together with Rogier A.A. Kalkers, Jesús García Sánchez and Jitte Waagen, with the kind permission of the Soprintendenza Archeologia, Belle Arti e Paesaggio del Molise. Important support was provided by the Comune di Jelsi, especially by Michele Fratino, and our collaborative research center in Molise: the Centro Didattico di Studi Archeologici di Jelsi (CeDISA) , and the participants of the various fieldwork campaigns. Particular thanks go to readers of the first drafts, Jesús García Sánchez, Rogier A. A. Kalkers and Vladimir Stissi.

logical visibility, land use and geology, which are sub-hypotheses that will be explicitly assessed as well. Then, to be able to control for all these variables, we apply a proportionate stratified sampling scheme. To test the main hypothesis, we propose a statistically robust framework, intended at optimal strength and comparability of the analysis. This involves explicitly describing sampling design and statistical methods and specifying statistical significance of site densities.

5.1 INTRODUCTION

In antiquity, a large swathe of the mountainous area of the southern Apennines was inhabited by the Samnites, an Italic people known from the ancient sources mainly because of two aspects: their remarkable resistance to Roman expansion in the 4th to 1st centuries BC, and because they lived in a peculiar settlement organization with markedly less urbanization than in the surrounding coastal areas. The combination of these two elements is noteworthy, because military power is usually expected to be facilitated by a centralized (state) organization and a large population. Different organizational principles in the settlement of the Samnite community, or communities, have therefore been explored on the basis of excavations and geophysical research, but especially by archaeological field survey. However, the type of rural settlement organization we are dealing with is by its very character elusive, and the archaeology of mountainous areas is notoriously difficult to research. The benchmark landscape archaeological project in the area is the Biferno Valley Survey, which adopted a mostly extensive field survey method (Barker 1995). The distribution of the sites that the project mapped for the upper and middle valley seems to suggest that rural settlement concentrated on and around hilltops, but the survey method as well as the pottery chronology were still coarse, leaving important questions about the representativeness of the settlement pattern and the chronological development.

The highly intensive field survey project (Tappino Area Archaeological Project, TAAP) documented such a concentration of settlement, revolving around an Iron Age to Hellenistic hamlet site and a monumental cult site San Giovanni in Galdo (SGiG), that developed together with rural infill in the 3rd and 2nd centuries BC on a hilltop plateau (Pelgrom and Stek 2010). A similar higher density was noted by the same project on the other side of the valley, in the area of a cult site and the hillfort of Montagna di Gildone. The results of the project therefore seem to indicate that the Samnite landscape was characterized by the concentration of sites in the higher portions of the area, with high site densities as opposed to other portions of the landscape. However, these observations were obtained by intensive field survey only in the more accessible areas within these hilltop zones, and as such may be biased: it is possible that the image of a recurrently densely settled Samnite community is just a result of research intensity. Would we document a similarly high density of sites also in other areas of the Tappino Valley, on its lower hills, the valley floor, or in the heavily vegetated zones? The Tappino Area Archaeological Project has set the aim to investigate the robustness of the hypothesis that these settlement patterns are typical for the settlement organization in the area, and to map areas that have escaped attention in more detail, using different kinds of methodologies, such as point sampling in forested areas, LiDAR and other methods (e.g. Stek 2016, Stek and Hamel 2019, Stek and Waagen 2022).

In this paper, we aim to tackle one of the main questions: whether settlement in the Samnite period is predominantly located in more elevated portions of the landscape, e.g. hill-plateaus. In order to examine this, we look at the distribution of farm sites, the main rural sites in this area in this period. In contrast to the Roman period, the Hellenistic site hierarchy is relatively limited. Also, due to relatively late mechanization of agriculture, site 'haloes', i.e. the distribution of finds around the central site area (Attema et al. 2020: 15-17), are small in comparison to other Mediterranean areas (fig. 5.1). The material footprint of the main type of settlement unit, the farm, appears quite compact as well as uniform. Their distribution appears regularly dispersed (Pelgrom and Stek 2010) with on average ca. 300 m between them. Their uniform appearance and spatial distribution make the Hellenistic/Samnite farms ideal for testing the settlement hypothesis. We will test whether higher densities of farms form a recurring pattern, and whether this phenomenon is bound to hill-plateaus and similar geomorphological units. To exclude that the documented intensity of settlement is just a result of research design, such as systematic biases or research area definition (i.e. edge effect of spatial sampling, cf. Van Leusen 2002: 4-1), we defined a sizeable research area encompassing research areas of previous campaigns to collect more data. It is furthermore important

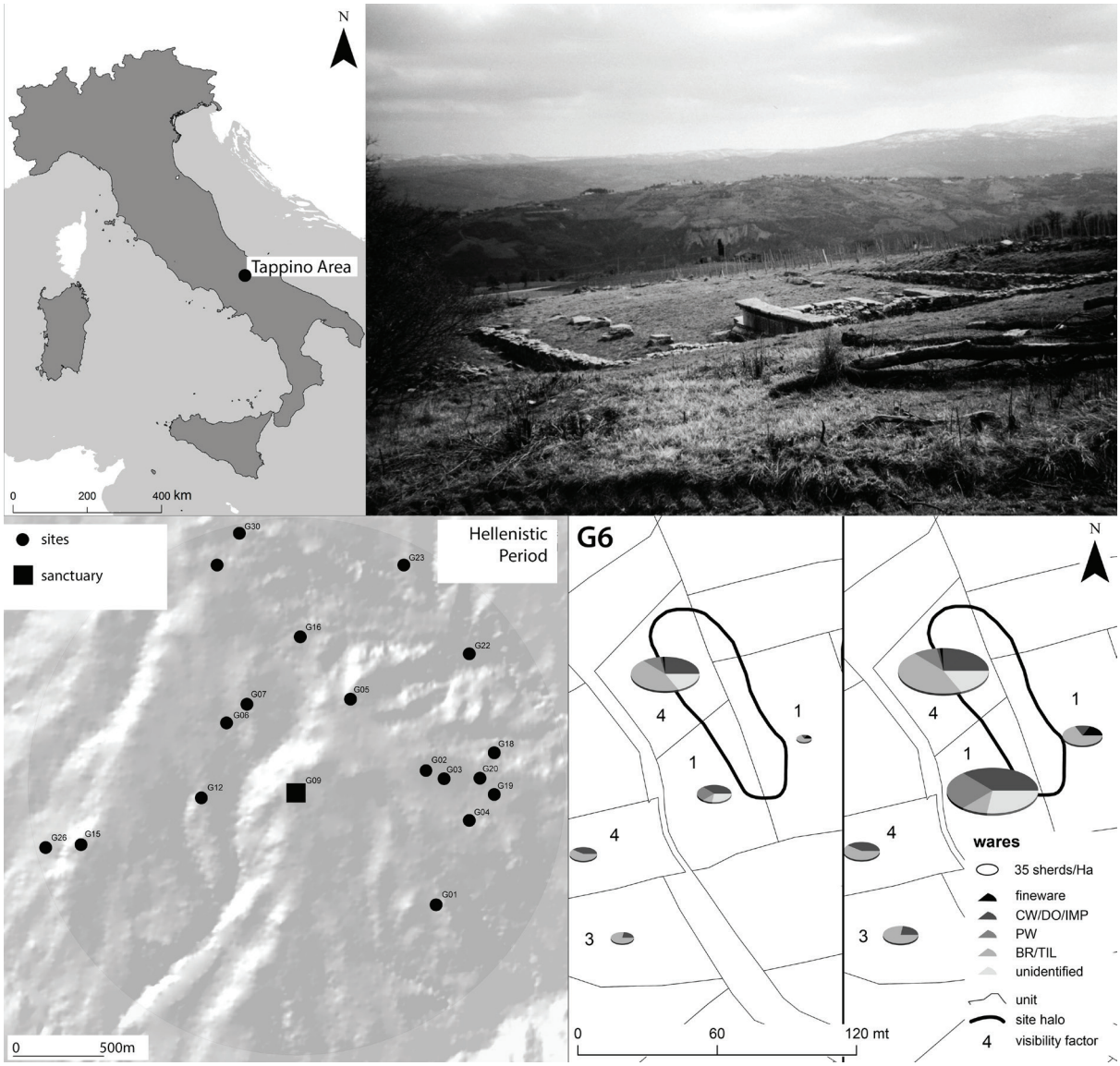

Figure 5.1. Above: location of the SGiG survey area (l), the sanctuary San Giovanni in Galdo, Colle Rimontato (r). Below: distribution of Hellenistic/Samnite sites as encountered (l), typical example of a Hellenistic/Samnite site G6 raw collected data (c) and hypothetical distribution based on finds-, bias- and spatial analysis (r).

to understand to what degree our current impression of the settlement pattern may be affected by e.g. archaeological visibility and land use (cf. Terrenato 2000), as these are significantly different in the lower parts of the Tappino area, as well as by geology. This is also important to reduce the effect of, for instance, including only fertile soils in the sample, as is often the case in archaeological field survey due to current agricultural practice. As a result, one might find higher densities of sites because of this effect (Pelgrom 2012: 78, Stek and Waagen 2022). In order for these sub-hypotheses to be tested (i.e. are lower densities in lower parts of the Tappino an effect of different visibility conditions), these variables will be included in a proportionate stratified sampling scheme.

For the evaluation of the hypotheses, we propose a statistically robust framework, intended at optimal strength and comparability of the analysis. This involves explicitly describing sampling design and quantitative methods, and specifying statistical significance of site densities.

5.2 THE FIELDWORK RESEARCH DESIGN

5.2.1 INTENSIVE ARCHAEOLOGICAL FIELD SURVEY

The field work projects that produced the data with which we work in this paper used a so-called offsite intensive survey method, also called transect sampling (Stek and Pelgrom 2005, Pelgrom and Stek 2010, Waagen 2014, Stek 2018, Stek and Waagen 2022). In short, this amounts to systematically line walking a batch of sample units with an average size of .25 ha, collecting all detected finds in a 2 m wide swathe, as well as recording find conditions that potentially affect retrieval probabilities such as ground visibility, land use, etc. Whereas the method results in relatively good quality data, its pace is relatively slow, and the methodological particularities have raised considerable debate (cf. Fenntress 2000, Blanton 2001, Terrenato 2004). Indeed, a good case can be made to apply a form of large-scale extensive site-oriented survey where full collection and fine spatial resolution is relinquished with the benefit of allowing a far more extensive terrain to be covered (cf. Stek et al. 2015) making it e.g. easier to study the possibility of multiscalar clustering (cf. Casarotto et al. 2016). However, for this research, the intensive offsite method has been preferred as the main investigative instrument. The main reason with regards to the hypothesis to test is that it ensures backwards compatibility with the previous surveys and avoids introducing a fieldwork methodology bias (cf. e.g. Attema et al. 2020: 3). The intensive approach however has also been demonstrated to have particular benefits. Various studies demonstrate that the intensity of sampling correlates with the number of retrieved artifacts (Wandsnider and Camilli 1992: 177, Schon 2002: 136), as well their size (Stek and Waagen 2022), i.e. more intense means a higher number of smaller objects. This results in a much more detailed image of surface distributions, and gives on the whole higher densities and larger samples, with more variability in the retrieved sample collections. This in turn offers a better grip on small-scale patterning and concentrations that are often thought to easily escape notice (Flannery 1976, Cherry 1983, Barker 1995, Stissi 2011). Indeed, this has been attested in in this very research project in the Tappino area (Waagen 2014). For example, studying variability in low density surface collections can lead to new insights into their spatial patterning related to human activity in the past, and even to the definition of new sites (Stek and Waagen 2022, Waagen 2014) and such an approach is now part of TAAP standard field survey procedures. Finally, although it must be mentioned that the merits of bias assessment have been contested by some (cf. Terrenato 2004), the intensive survey method allows a high level of control of recording and examining possible biasing factors and thus estimates of their potential effect on the outcomes.

5.2.2 DEFINING SAMPLE UNITS AND POPULATION

As in most other survey projects, complete coverage of an entire research area with the intensive method is not only impracticable but also unattractive. It would cost far too much, and the level of resources that are required to generate extra information is unlikely to be justified by the actual returns (Attema et al. 2020: 5). Therefore, a sampling design is necessary. The main challenge in general for archaeological survey projects is how to arrive at a statistically useful sample (Attema et al. 2020: 13), especially in case of a parameter estimation, such as establishing site density (Banning 2021: 44, Burger and Todd 2006: 239). After all, we need to establish our sample size n in order to perform robust statistics. This means that we have to consider what we define as sample units, sample elements and population (Banning 2021: 44), i.e. the units available for collecting, the units of analysis which are the sites, and what is actually sampled, i.e. the settlement patterns related to the Italic people we wish to investigate.

The main focus of the analyses will be the density of both sites, i.e. Hellenistic/Samnite farms, and offsite material. In general, whether offsite finds are direct material correlates of human activity (i.e. haphazard loss or manuring) or indirect in the form of destroyed and eroded sites (small sites, huts, special purpose sites), they can be used as a proxy for the intensity of past use of a landscape, and as such are relevant for the question of past spatial organization of subsistence. Therefore, the main body of data will consist of the field survey sample units that are the basic recording sample units for find densities. It should be clear though, that the actual analytical sample unit is space (Banning 2021: 44); we sample the area using defined units of which we establish, through collection, their properties in terms of densities and the presence/absence of sites.

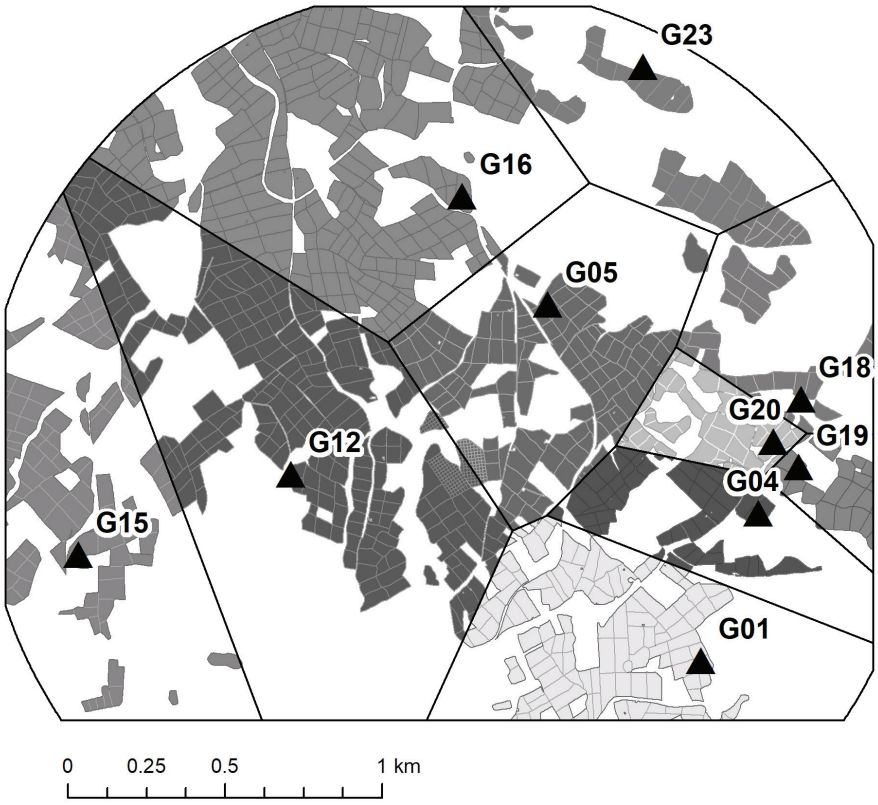

Figure 5.2. Extents of Samnite farms (triangles) as a proxy for site density; shades of gray demarcate area defined by Thiessen polygons.

Therefore, an important question is, in addition to our collection sample units, how do we test sample element (site) spatial density in a continuous population? For statistical assessment, we need an enumerator that provides us with a value for total sample size n, i.e. the amount of space that has been examined. And this should be done carefully because a large n usually produces statistically significant results. If we would take the collection sample units for n, it would be easy to generate a large sample for which we can make statistically significant statements, by making the units very small (Hole 1980: 226, Banning 2020: 44). Clearly, statistical scrutiny should not be sensitive to arbitrary manipulation. Take the sample elements (sites) for n doesn't work because it is actually their presence we want to measure within a defined space. How to establish whether one has a statistically significant sample of space devoid of sites? This particularity of sampling space is a problem that is surprisingly rarely discussed in archaeological field survey literature. One solution is to create a spatial unit that is not artificial but related to the phenomenon we wish to measure. A Hellenistic/Samnite farm as attested in the SGiG surveys 'occupies' a minimum area in a spatial point pattern distribution. This defines a spatial 'magnitude' that comes out of the data, instead of a unit that can be made larger and smaller at will. We will call this spatial magnitude 'extent', representing a size unit. By dividing the total area of investigated surface by that extent size we can establish an n consisting of extents, representing sample size. If we compare that to the attested number of sites, we will then be able to establish whether the sampled n extents show on average less, equal or more sites per extent than the SGiG surveys. It is important to emphasize that we are comparing data patterns as a simple abstract spatial description. The extent we contemplate is a theoretical construct, to be able to establish a unit of measurement that is rooted in archaeological observation. There is no claim to establish a site catchment area or something similar, which is quite another debate (e.g. Vita-Finzi Higgs 1970).

It seems reasonable to use the data that we have for SGiG to establish at least a rough idea of the extent of a typical Hellenistic/Samnite farm, and establish a size for the sample element. The Thiessen polygons algorithm can define borders based on points halfway the mutual distances between the farms, and create a bounding box for the individual sites (fig. 5.2). Formally, a Thiessen algorithm is used for continuous point distributions, i.e. all sites in the analysis should be attested using a continuous survey, without the risk of

omitting sites. Such conditions are however unfortunately extremely rare, if not inexistent, in archaeological field survey. In addition, we do need to be aware of the coarseness of the chronological time-frame and that sites may not have been exactly contemporaneous, a potential bias that is unfortunately difficult to mitigate at the current state of knowledge. Therefore, acknowledging some possible inaccuracy, we argue that this is the best approximation that we have for measuring an extent. Of the eight Hellenistic/Samnite farms that have been identified in the SGiG surveys, site G20 may be the best case; it is one of the few farms that is completely surrounded by other farms (i.e. no edge effects) and almost all fields in the area are covered in the surveys (i.e. it is unlikely that there is an obvious visibility bias here). Comparable settlement patterns around the aforementioned hillfort and in the area of Colle Sparanise (C36, Barker 1995: 49-50), Biferno valley, direct parallels to this study, show similar extents, ca. 200 m average distance between farms, approximately 12.5 ha (cf. Stek 2015). It seems fair to take the 12.5 ha as the size of an extent and use that for further statistical analysis.

Now that we established both the collection sample units that we can use for examining the offsite data and analytical sample elements for assessing site densities, we must define a population, again, a spatial unit. Because of a set of problems inherent in landscape archaeology, the validity of statistical populations is often not dealt with explicitly. A population is defined as a group of objects, events or concepts, and demarcates the level at which one wants their conclusions to be true (Chenhall 1975: 5, Cherry et al. 1978, Drennan 2009: 80). In landscape archaeology this is often the territory of a community of people, in our case the historically known (Pentrian) Samnites. To use this as a statistical population we need to establish the extent of the associated territory in the late 4th to 2nd centuries BC. Understandably however, identifying the geographical boundaries for a community known from literary sources for this period is impossible, and are likely to have been fuzzy. Alternatively, we could follow river-valley projects such as the Biferno Valley or the Sangro valley (Barker 1995, Bell et al. 2002), assuming that a geomorphological unit is likely to represent a cultural ecosystem. This is, however, not necessarily the case – especially not in mountainous and non-urbanised areas. In other words, strictly defining a population that directly corresponds to the community of interest is nigh impossible and not productive to pursue. What we will do is define a heuristic population consisting of an area large enough to encompass the total variety of geomorphological units in the area. The transect that we set out contains a river valley and plains, undulating slopes, hill-plateaus, and hilltops, as well as a mountain. Measuring (10 x 20 km, totaling to 20.000 ha), it is large enough to demonstrate repetition of the key constellations in land use and settlement density we can expect in this type of landscape. It is worth repeating that the pattern we discerned in our dataset for the Tappino fits quite well with e.g. Colle Sparanise in the Biferno valley. This suggests that the research so far in the larger area identifies a pattern, and that the transect for testing this pattern lies within that larger area.

5.2.3 A STRATIFIED SAMPLING APPROACH

The hypothesis that we will test is that of higher densities of sites on undulating slopes, plateaus, or hilltops, than in other parts of the landscape. To engage with the main hypothesis and the sub hypotheses, i.e. cover sufficiently the geomorphological and other variables such as geology and land-use, we applied a proportionate stratified sampling design. A stratified sampling design refers to a sample collection organized by allocating sample units over subdivisions, i.e. strata (Orton 2000, Drennan 2009, Banning 2020). The advantage of a stratified sample is that we have control over the inclusion and exclusion of variables. Furthermore, the proportional allocation of sample units over the separate strata, or self-weighted sample (Cochran 1977: 91) means control over bias caused by underrepresentation of larger strata and overrepresentation of smaller strata. In addition, because the sampling fraction remains constant, it allows regarding the complete dataset still as a simple random sample (Orton 2000: 30). The final major advantage is the improved statistical efficiency of a proportionate stratified sample since one ultimately reduces eventual effects of vagaries of sampling, i.e. minor variability in a sample due to 'random' selection processes (Shennan 1998: 377, Orton 2000: 30, Drennan 2009: 236-237).

Sample areas of 1 km^2 have been proportionally distributed over the transect targeting the different defined strata, after which all sample units within them have been surveyed. The strata have been established on a general scale using landscape classifications as well as basic orographic data; hilltops/high ridges (ca.

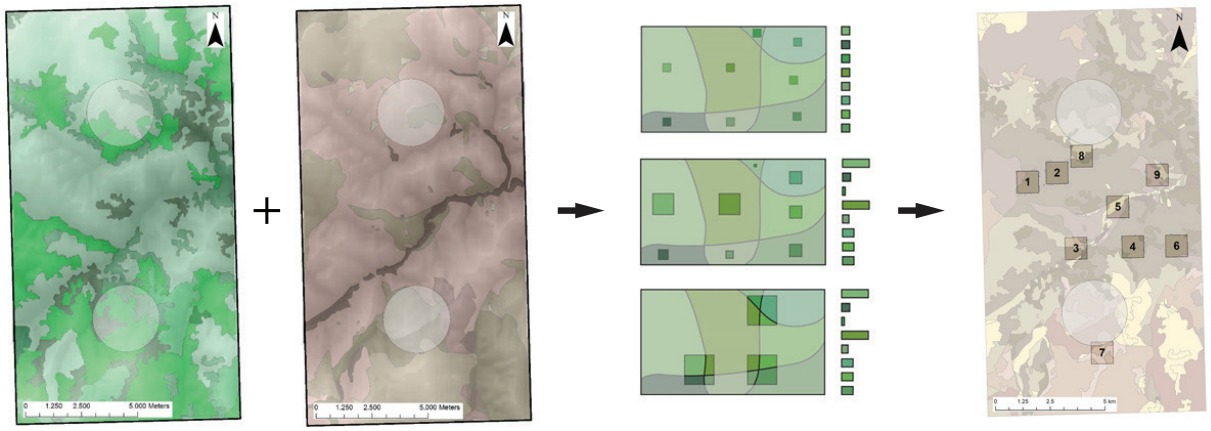

Figure 5.3. Spatial positioning of sample areas in TAAP transect (round spheres represent survey areas around the sanctuaries). Aggregation of land use and lithology maps to produce a spatial layer of unique combinations (l), sequence of proportional allocation of contiguous control areas over LU-Litho strata (c), eventual placement of sample areas (r).

between 500-650 m), lower river valley (ca. between 350-450 m), the undulating sloping landscape in between (ca. 450-650 m), and mountains (>700 m). Embedded within this primary geomorphologic stratification are the most prominently present environmental variables. There is neither a soil map or a geophysical map available for the area, so we use a combination of a lithological and a land use map (Carta Lithologica, Corine Land Use 2012, both 1:100.000, Geoportale Nazionale 2019). Lithological formations are indicative for soil properties such as structure and susceptibility to erosion, which in their turn can affect suitability for agriculture. The land use map adds more value, as it provides information on current vegetation ground cover, which is useful for testing the influence of differential ground visibility. It should be emphasized that we are just evaluating archaeological field survey data patterns in the light of possible biases; we are not presupposing any geophysical determinant to be responsible for settlement per se. The sample areas were placed in the various geomorphological areas while respecting as much as possible a proportional allocation of sample units over various spatial variables, based on the relative size of these strata (fig. 5.3). For geomorphological units it approximates distributing ca. 44% of sample units in the lower river valley, 33% on undulating sloping landscape 11% on hilltops/high ridges, and 11% in a mountainous area. Within the geomorphological areas, sample units are allocated based on strata created from the intersection of lithology types and land use types, which we will call LU-Litho strata. For example, if the LU-Litho stratum A, a combination of lithology type X and land use type Y covered 50% of the total area of the transect, the proportional allocation ensured that at least half of the sample units were collected in defined geomorphological areas with LU-Litho stratum A. To avoid very small substrata, i.e. the rarest combination of lithology and land use amounts to .7% of the landscape under research, a 3% threshold of proportional presence as a lower limit has been respected; statistical theory suggests maximum 6 strata (Cochran 1977: 134). In addition, the various LU-Litho strata have not been allocated proportionally over the geomorphological strata themselves, as that would have caused extreme fragmentation.

A caveat here is that not all combinations of geomorphological units and LU-Litho strata have been covered. For the same reason, we must be cautious aggregating all instances of a specific stratum over all the different areas. However, this was a small sacrifice for being able to preserve spatial contiguity, which was a practical necessity. In conclusion, the distribution of the sample areas over the geomorphological units allows comparisons between those areas, and the allocation of sample units over the LU-Litho strata allows comparisons of their possible effects and combinations of those, as laid out previously.

5.2.4 THE PROBLEM OF SAMPLE SIZE

To establish an adequate total sample size (Orton 2000: 21-23, Drennan 2009: 127, Banning 2020: 49) in archaeological field survey, there are two possibilities. First, to apply a formula rooted in statistical theory on sample size or second, to continue sampling until some sort of stopping rule is applied, e.g. the emergence of a repeating pattern. The latter, also known as sequential sampling, although solid and often

leading to fewer sample units, was considered to be potentially too costly in terms of effort-investment. Therefore, we opted for a fixed sample size based on a-priori calculations. This means that we need to understand how many extents we should survey to be able to test whether the proportion of extents with a site as opposed to extents without a site is greater, equal or less than those of the SGiG sample. This is very much like an average number of sites per extent but expressing it in proportions makes it viable to calculate with. We need to determine a minimal feasible amount of terrain to cover resulting in a statistical spatial sample with a confidence level (*CL*) specification, which allows to make a statement such as:

'we can be [confidence level] confident that the proportion of extents with one or more sites is between [*x*] and [*y*] in our research area'

Such a confidence statement is the result of an assessment of the standard error *SE* in your sample results, which is the standard deviation in the measurements *s* (values of a property), divided by a root square of the number of measurements *n* (the number of cases). It follows from the formula below that the expected error in the measurements gets smaller when n increases. It relates to the confidence statement in determining the error range (*ER*) 'between [*x*] and [*y*]', where *x* and *y* are determined by comparing the *SE* with a normal probability distribution. By choosing a *CL* you can manipulate the outcome, i.e. a high *CL* will enlarge the *ER* of the expected value, and vice versa. Reworking this procedure, it is possible to set the *CL*, estimate an *s* and determine the number of cases you would need to arrive at a statement with such a degree of confidence.

$SE = s$ / sqrt (n) equals n = sq (s x t / ER)

The number of cases *n* can be counted by dividing the total surveyed ha by the 12.5 ha size of a single extent, our sample element. If we take the SGiG sample with a total coverage of 262 ha divided by 12.5 ha, we have an *n* of 20.96. With a total of 8 identified sites, we arrive at a proportion of extents with a site of 38.2%, which leaves 12.96 extents without a site, 61.8%. We can then apply the significance calculations for categorical data (Drennan 2009: 139):

SE = sqrt (p x q) / sqrt (n)

There are 8 extents with a site (*p*) and 12.96 (*q*) without a site. Thus s = sqrt (.382 x .618) = .49 and SE = .49 / sqrt 20.96 = .49 / 4.58 = .107; comparison with the probability distribution where the degrees of freedom ($n - 1$) are 20, shows that for SGiG we are 95% confident that the proportion of extents with sites is 38.2% +/- 22.3%. Although this appears a considerable error range, please note that the +/- 22.3% indicates a distance of two standard deviations within a normal distribution of probabilities, i.e. a curve, with probability decreasing towards the extremes, and the mean being the most probable value. For a more precise indication with a bit less confidence, for example a *CL* of 80%, and arrive at an error range of 38.2% +/- 14.1%.

In order to establish how much terrain we must cover to arrive at which confidence level in our results, we can use the converted formula for sample size calculation (Drennan 2009: 142):

n = sq (s ⋆ t / ER)

Here, *s* is sqrt (p ⋆ q), and t is the desired confidence level. For a *CL* 95% (so 1.96 with infinite degrees of freedom) and *ER* 5% (so .05) this amounts to an estimated sample size of n = sq ((.49 ⋆ 1.96) / .05) = 368.9, translated to ha is 368.9 ⋆ 12.5 = 4,611.25 ha, back to km^2 is 46.1 km^2. In other words, a sample of 46.1 km^2 is required for a statement with a *CL* 95% and *ER* 5%. This is impossible within the confines of our resources, and therefore we have to reduce the *CL* and *ER*. Lowering the quality criteria, we could arrive at 493.3 ha, translating to an area of 4.93 km^2 for a *CL* of 80%, *ER* 10%. This was considered a realistic amount of terrain to cover for the resources available. Whereas confidence levels of 80% may be a bit less than what is often considered as a standard for decision making in inferential statistics, they do nonetheless provide a firm quantitative base for subsequent comparisons of site densities.

5.3 ANALYSES

5.3.1 RESULTS OF THE 2013 AND 2014 CAMPAIGNS

A full report on the archaeological findings of the TAAP will be published elsewhere (for further contextualization, see Stek 2018). The results relevant for assessing the main hypothesis of this paper will be dealt with here. The proportionate stratified design has resulted in 9 SAs (fig. 5.4, tab. 5.1), thus 9 km^2, containing a total of 1380 sampled units, an average coverage per SA of 46%, a total of 17.292 artifacts, and a total of 20 sites as identified in the field. In total, the sample units have been distributed over 7 different strata (tab. 5.2).

For the site density analysis, we used sites that show activity in the Samnite period (fig. 5.4), being TAP02, TAP03, TAP05, TAP06, TAP07, TAP08, TAP09, TAP13, TAP15, TAP16, TAP25, TAP27 and TAP29 (the last two are likely the same site and will be treated as such).

5.3.2 SITE DENSITY ANALYSIS

As a general pattern, almost all sites have been found on the undulating slopes, plateaus, and hilltops of our research area. More in particular, the sites that produce black gloss ceramics (BG) are all located on the higher plateaus, above 500 m altitude.

If we group the SAs based on this mean altitude threshold in a group of low and high situated (tab.5.1, bold is high), we recognize a considerably different site density between the two groups, which we will from now call Low. group and Elev. group (tab. 5.3). However, this is due to the gravitation of sites towards larger settlement centres on Colle San Martino, a site with a sanctuary, and on the slopes of the hillfort on the Montagna di Gildone. A multiscalar spatial organization is possible, where the spread of farms could follow a different configuration than these larger nuclei. Excluding the clusters around CSM and MdG and looking only at the sites interpreted as farms, makes the difference much less pronounced (tab. 5.3).

Based on the statistical estimations made earlier, we can make a model of the number of extents containing a site in our survey area. Dividing the total surveyed area by the extent size, for Low group we have sampled 10.48 extents, and for Elev. group we have sampled 22.64 extents. Applying the formula, we are 95% confident that the proportion of extents with sites is 9.6% +/- 19% for Low group and 13.3% +/- 14.9% for Elev. group. With a lower *CL*, e.g. 80%, we reduce error margins; 9.6% +/- 12% for the lower situated SAs and 13.3% +/- 9.5% for the higher situated SAs.

In comparison, the percentages of extents with sites in Elev. group is lower than those of the SGiG survey area, but still higher than those in Low group, which could tentatively corroborate the hypothesis of higher site densities in higher positioned parts of the landscape. As expected, due to the limitations in the amount of terrain that could be covered, a relatively low number of sample elements have been covered, and therefore error ranges are still considerable. Although the statistics appear to sustain the hypothesis of dissimilar site densities between the two groups, it must be observed that the averages of Low group and Elev. group still lie within their mutual error ranges (fig. 5.5), and the apparent difference will not pass a test of statistical significance.

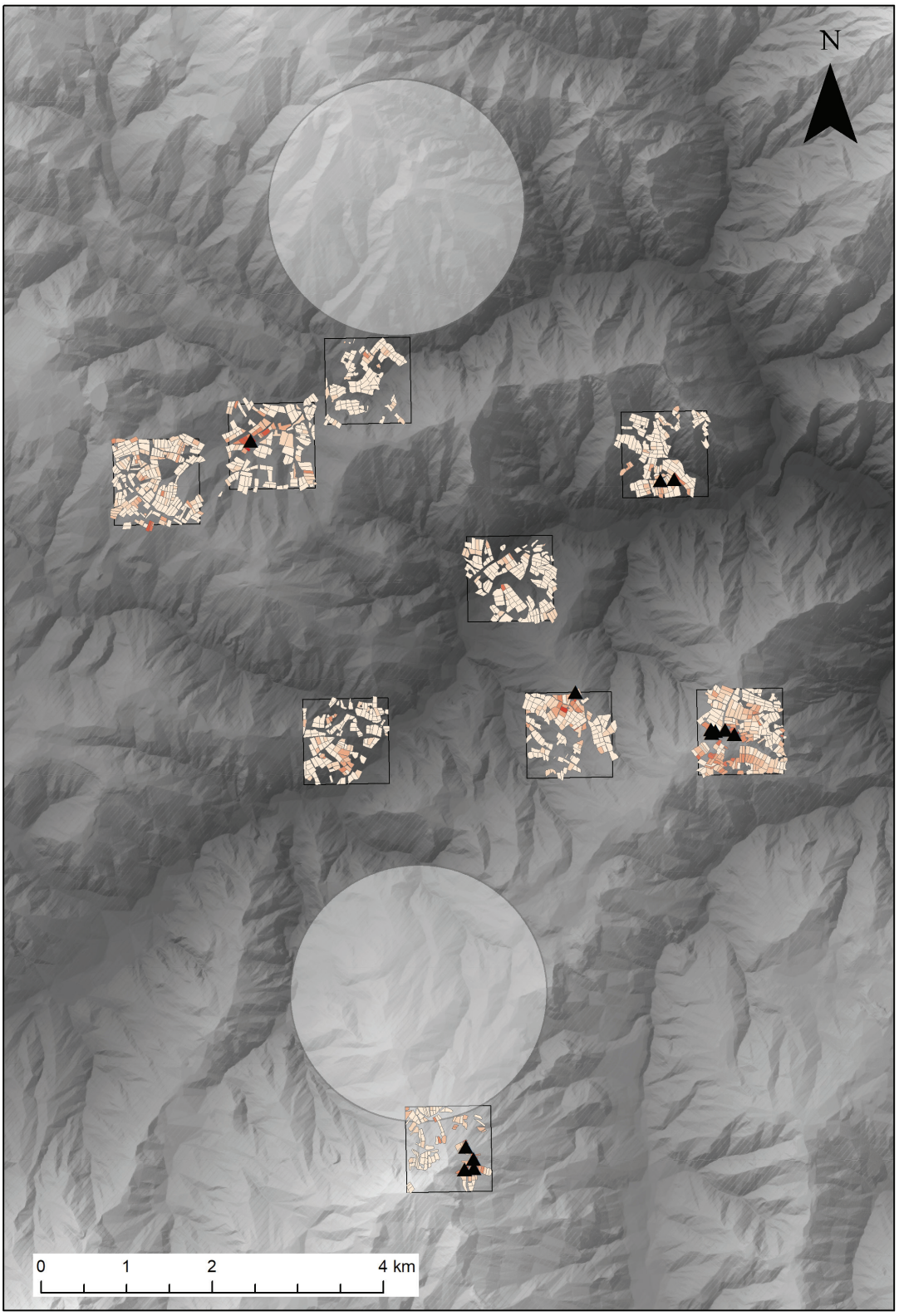

Figure 5.4. Research area transect; circles are original sample areas, squares are TAAP sample areas 1-9, triangles are sites with a Hellenistic/Samnite chronology, sample unit shade represents total finds weight densities, within a range from 0-20 g/m2.

Sample area	*min*	*max*	*mean*
1 (hilltop)	521	633	577
2 (undulating slopes)	474	537	500
3 (low river valley)	376	490	418
4 (undulating slopes)	427	601	519
5 (river valley floor)	339	435	370
6 (undulating slopes)	510	662	604
7 (mountainside)	733	892	805
8 (low river valley)	444	555	485
9 (low river valley, some slopes)	350	550	437

Table 5.1. SA geomorphology with minimum, maximum and mean elevation (m).

Stratum	*land use/ lithology*	*HA*	*%*
7	hom. / langh, limestone	585	3.1
8	woodland / olig, limestone, microc.	614	3.3
9	het. / langh, limestone	1.019	5.5
10	woodland / tort, marl, mica	1.812	9.8
11	het. / olig., limestone, microc.	2.141	11.6
12	hom. / olig., limestone, microc.	2.635	14.3
13	het. / tort, marl, mica	2.842	15.4
14	hom. / tort, marl, mica	5.296	28.7

Table 5.2. LU-Litho stratum definition. Abbreviations: hom. = homogeneous agriculture, het. = heterogeneous agriculture, olig = Oligocene, langh = Langhian, tort = Tortonian, microc. = microcrystals.

5.3.3 OFFSITE DENSITY ANALYSES: A NON-PARAMETRIC APPROACH

The offsite densities provide an option for more robust and complementary analyses. The finds used for this are coarse ware (CW) and plain ware (PW) densities, material dating from the Archaic to the Late Roman period, but of which the majority in the survey dataset is found on sites with 4th and 3rd centuries BC black gloss pottery (Waagen 2021). This material provides us with a large batch of data with a good geographical spread and they are a good proxy for offsite find densities related to the Hellenistic/Samnite period. Although these ware classes also include finds from other periods, a large share of them are indeed Hellenistic and are consistently found in association with Hellenistic/Samnite domestic sites, amounting to around 60% of all PW and CW sherds. The majority of PW feature sherds from offsite assemblages are dated to the Hellenistic/Samnite period as well, and there is no reason to suspect a big difference between onsite and offsite PW and CW sherds. All sample units overlapping with sites or higher densities clearly connected to sites, are left out of the analyses, to avoid those having a large effect on the tests. This amounts to excluding all sample units intersecting a buffer with a 50 m radius around the geometrical centre of the site boundaries, usually reaching far over the actual site haloes, if any. Consequently, what remains are the finds that can be related to activities like land-use, pastoral activity, etc., as well as the remains of badly visible, eroded and destroyed sites (cf. Bintliff and Snodgrass 1988, Wilkinson 1989, Alcock et al. 1994, Bintliff et al. 2007, De Haas 2012, Waagen 2014). As such, if higher densities of PW and CW finds in the higher parts if the landscape could be attested, this would strengthen the conclusions of more intense use of the area in the period under study, as well as the existence of potentially destroyed sites, and thus the central hypothesis under investigation.

Group	# sites total	# sites per SA	Covered area
Low (1)	1	.33	131 ha
Elev. (2)	12	2	283 ha

Group	# sites total	# sites per SA	Covered area
Low (1)	1	.33	131 ha
Elev. (2)	3	.5	283 ha

Table 5.3. Low and Elev. groups with all sites (above) and without larger settlement centres (below).

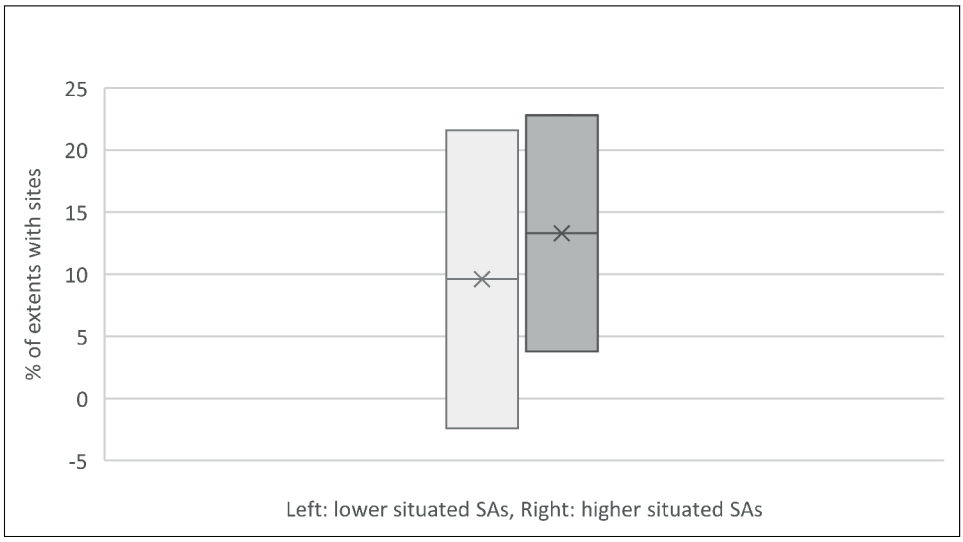

Figure 5.5. Graph visualizing the average proportion, and attached error range, of extents with sites; light bar represents Low group, with an average extent with sites of 9.6% +/- 12%, dark bar represents Elev. group, with an average extent with sites of 13.3 +/- 9.5%, both CL 80% (based on the assumption of 12.5 ha extent size).

Standard parametric statistics are less suited to compare sample batches of archaeological field survey field collections, because these presume that the distribution of frequencies follow a normal form. Evidently, archaeological field survey frequencies usually are heavily right skewed, resulting in asymmetry with a large sample variance and an unstable mean. This can cause parametric tests to result in unreliable estimates. Therefore, we will apply non-parametric statistical tests for the density comparisons.

Here, we used the Kruskall-Wallis (KW) and the Kolmogorov-Smirnov tests (KS), which are designed specifically for non-parametric data (Salkind 2007). The KW is in fact an alternative to an Analyses of Variance (ANOVA) test, in which, based on the variance occurring in a grouped set of sample units, it is determined whether a set of three or more independent samples are taken from the same distribution. Instead of the parameters of a normal distribution that ANOVA uses, KW uses rank sums. In case KW test results are significant, post-hoc tests determine which samples are deviant. The KS test then is the non-parametric alternative to the two-sample t-test, where differences between two samples are used to determine whether they are drawn from the same distribution. Another option here is to use the Mann-Whitney U test, but the KS is considered less powerful, i.e. is more conservative in attributing significant differences, because it takes more information into account. This means differences identified through KS are less susceptible to biases, which is why it is used in this analysis.

Test	*Description*	*Stat.*	*Sig.*	*Decision*
1	CW weight dens between SA	KW	.000	***reject***
2	CW weight dens between Low group & Elev. group	KS	.000	***reject***
3	CW weight dens within Low group	KW	.088	***accept***
4	CW weight dens within Elev. Group	KW	.142	***accept***
5	CW number dens within Low group	KW	.012	***reject***
6	CW weight dens between LU-Litho strata	KW	.000	***reject***
7	+36% CW weight dens between Low group & Elev. group	KS	.000	***reject***
8	+36% CW weight dens between LU-Litho strata	KW	.000	***reject***
9	+36% and 0 fields adj. CW weight dens between Low group & Elev. group	KS	.000	***reject***
10	+36% and 0 fields adj. CW weight dens between LU-Litho strata	KW	.000	***reject***

Table 5.4. Hypothesis test summaries, reject 0-hypotesis means statistically significant variability in distribution, accept 0-hypothesis means no statistically significant variability in distribution, $\alpha = .05$*, KW = Kruskal-Wallis, KS = Kolmogorov-Smirnov.*

5.3.4 COMPARING SAMPLE AREAS

Tests have been performed on fragmentation, weight density and numeric density of coarse ware and plain ware sherds. The first comparison is between SAs, to assess the influence of geomorphology. We will use the KW and KS tests to establish whether characteristics of sample collections (per SA group or per stratum) are similar, i.e. accept the 0-hypothesis, or dissimilar, i.e. reject the 0-hypothesis. The inferential analysis of CW weight densities, using a KW comparison of distributions of CW densities in units where CW has been found (so no 0 scores), already shows a statistically significant variability between SAs (tab. 5.4, test 1).

The boxplots (based on the median, clearly showing the skewed distribution of find densities) of the SAs confirm the division in two main groups (fig. 5.6): SAs that lie in the lower parts of the riverbed valley and/or on steep sloping areas in the landscape are clearly less dense in finds (Low group), as opposed to those in higher undulating plateaus and hilltops (Elev. group). This division follows the 500 m average elevation threshold. A comparison of the slightly changed groups as two individual samples with the KS test (tab. 5.4, test 2), rejects the 0-hypothesis. The boxplots illustrate the difference clearly (fig. 5.7).

The variability in CW weight densities within the aggregated SAs tested with the KW is only just insignificant (tab. 5.4, test 3-4). This is a result of variation between unit densities, which is considerable, only there is no statistically significant variability in densities between the units within those groups. Nevertheless, overall, the statistics point tentatively to a confirmation of the hypothesis that there are consistently higher CW weight densities in the higher situated SAs.

The difference between the groups of SAs is 72 g/ha for the lower situated area, with an *s* of 198 g/ha and a maximum of 2030 g, against 154 g/ha for the higher situated area, an *s* of 230 g/ha and a maximum of 1358 g per ha. Evidently, the latter is on average about twice as dense. Unit 1699 is a clear outlier in the boxplots of the lower area, due to a large piece of dolium retrieved from that field (652 g). Without that outlier, the low-density area plummets to 57 g/ha, with an SD of 99 g per ha, and a maximum of 810 g per ha. This is less variability than in the higher situated areas. Although the *s* is an unstable indicator of spread in skewed distributions, they describe relative deviations from the mean and follow the expected pattern.

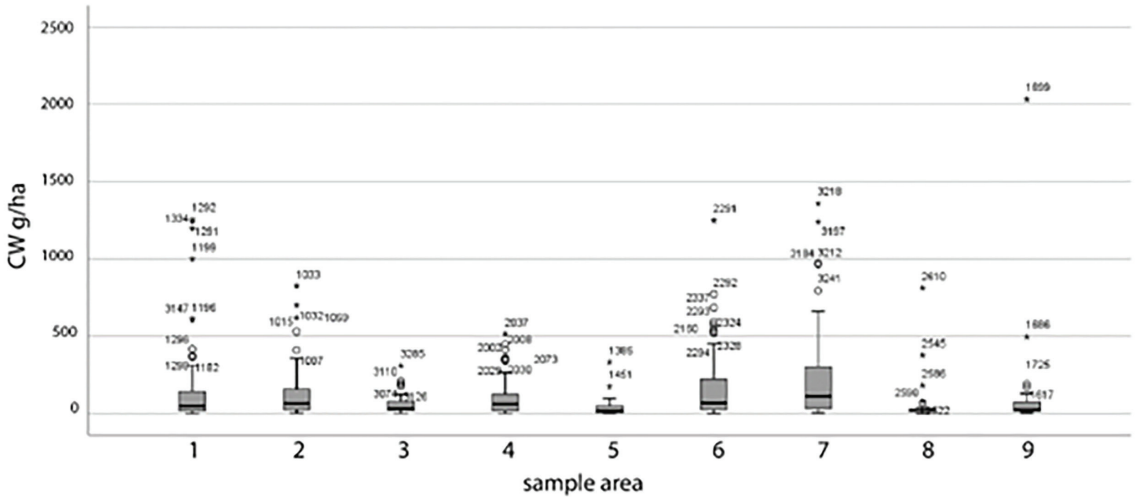

Figure 5.6. Boxplot showing variability of CW weight density between SAs. X-axis represents control areas,Y-axis represents CW weight densities, labels represent individual sample unit numbers.

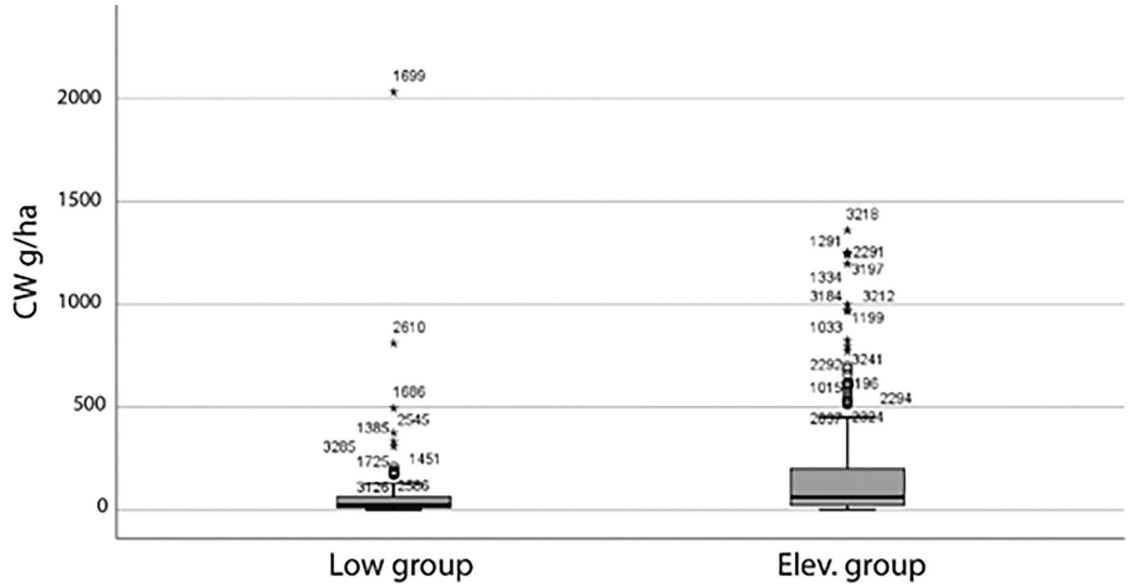

Figure 5.7. Boxplot showing variability of CW weight density between Low and Elev. groups. X-axis represents groups,Y-axis represents CW weight densities, labels represent individual sample unit numbers.

Calculating a simple Coefficient of Variation (*CV*), i.e. render them proportional to the mean (Waagen 2021, Stek and Waagen 2022), shows that the relative variability in the higher situated areas, $CV = 1.5$, is lower than for the lower areas, $CV = 1.7$. In conclusion, the lower situated SAs show lower CW weight densities that exhibit more variability in density than higher densities, which likely is a reflection of a more dispersed and irregular pattern of CW material distribution. The same pattern is visible in numeric CW densities, with again a statistically significant differentiation between groups of SAs (fig. 5.8).

Similar to the CW weight densities, the variation in numeric density in the lower areas is considerable; the KW test even rejects the 0-hypothesis (tab. 5.4, test 4-5), as a result of the earlier mentioned more irregular spread of finds in the lower densities. The likely reason that the 0-hypothesis is rejected for numeric densities, is that weight densities are on average less biased as quantity estimators due to breakage effects, and show a more balanced patterning (Waagen 2021).

Overall, however, the tests show little variation in fragmentation of CW material, which is to be expected since fragmentation metrics are derived from averages per field and thus are very generalized (Stek and

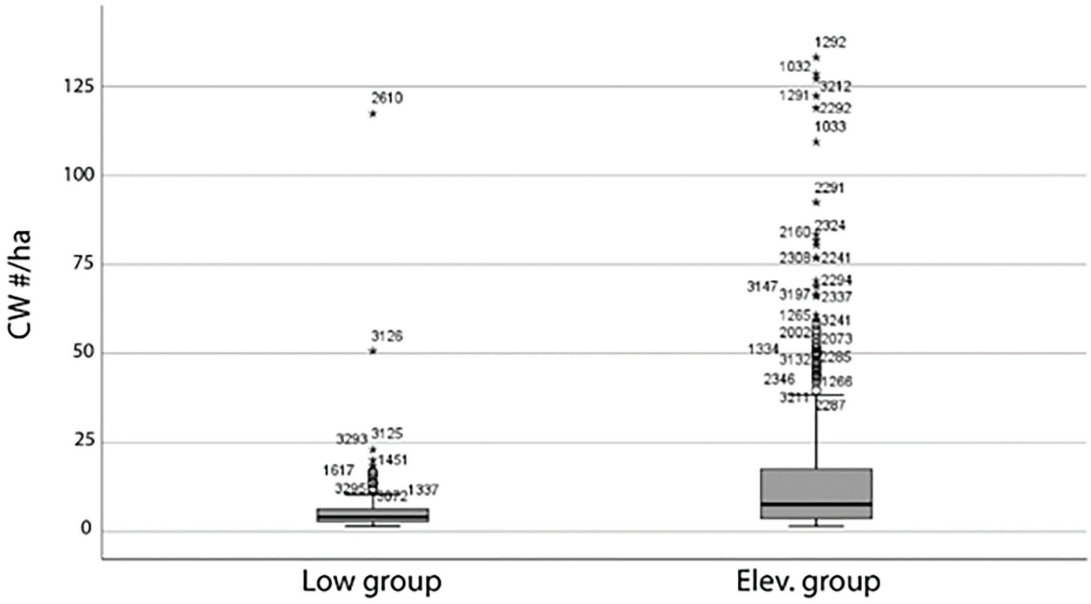

Figure 5.8. Boxplot showing variability of CW number densities between Low and Elev. groups. X-axis represents groups, Y-axis represents CW number densities, labels represent individual sample unit numbers.

Waagen 2022). However, breakage levels in the high densities are statistically significant variables between themselves, i.e. there is more variability in size of CW material in the higher situated areas, which is something that may be related to larger sherds being present as a result of ploughed up deposits (Stek and Waagen 2022). Finally, PW weight and number distributions show roughly similar trends confirming the general pattern (fig. 5.9).

Concluding the analysis of densities per CA, we can infer from the statistical analysis that the higher situated SAs show significantly higher densities than the lower situated SAs in their offsite densities.

5.3.5 COMPARING STRATA

The apparent geomorphological distinction must be tested against the LU-Litho strata to investigate whether this general pattern may be affected by correlations with specific types of geology and land use. The comparison of the CW weight densities over all LU-Litho strata using Kruskall-Wallis shows a statistically significant difference between them (tab. 5.4, test 6).

The variability again indicates two groups (fig. 5.10); LU-Litho strata 8, 11 and 14 on one side, and the other LU-Litho strata on the other side. LU-Litho stratum 10 also indicates somewhat higher densities, but this is a very under-sampled LU-Litho stratum (woodland), so the results there should be treated with caution. These LU-Litho strata do not share a specific geological or land use category, but their geomorphological distribution shows a familiar pattern. LU-Litho stratum 8 is only sampled in SA 7, a higher situated CA, and 78% of the units sampled both in LU-Litho stratum 11 and 14 are located in the higher situated SAs. The LU-Litho strata analysis therefore does not produce any reason to doubt the general pattern. As for fragmentation, the analysis does not indicate any big differences between the LU-Litho strata.

5.3.6 GROUND VISIBILITY BIAS?

An important potential bias though, may be the relative ground visibility between the various areas. Almost half of the sample units collected in SA 3 and SA 8, both low density areas, are allocated to LU-Litho stratum 13, which is the 2nd largest LU-Litho stratum and makes up ca. 16% of the total sample. This LU-Litho stratum consists of fields with a heterogeneous land use; horticulture, viticulture and gardens,

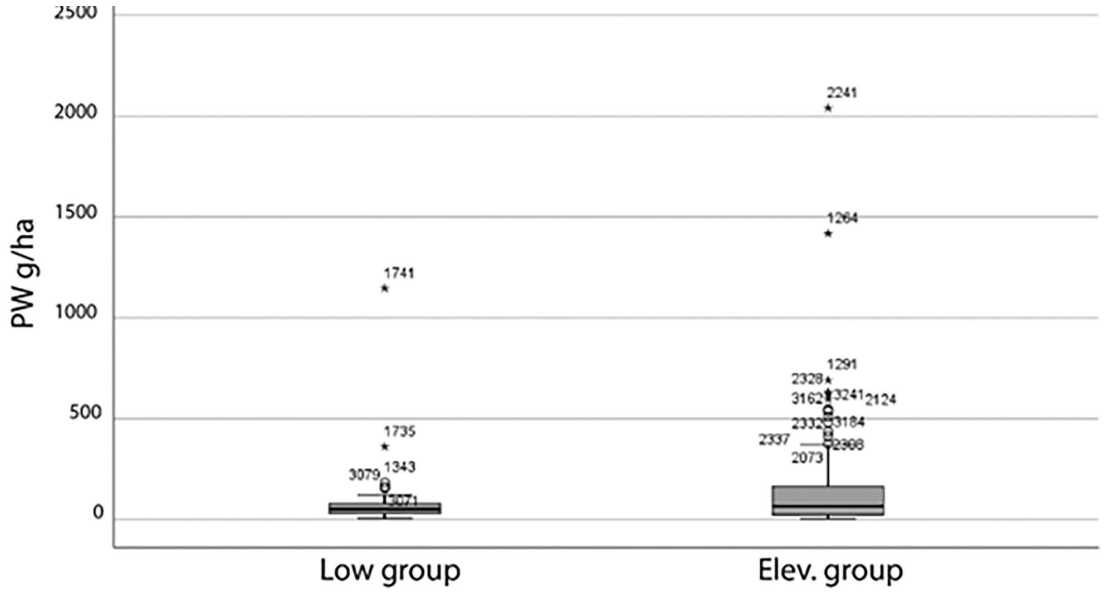

Figure 5.9. Boxplot showing variability of PW weight densities between Low and Elev. groups. X-axis represents groups, Y-axis represents PW weight densities, labels represent individual sample unit numbers.

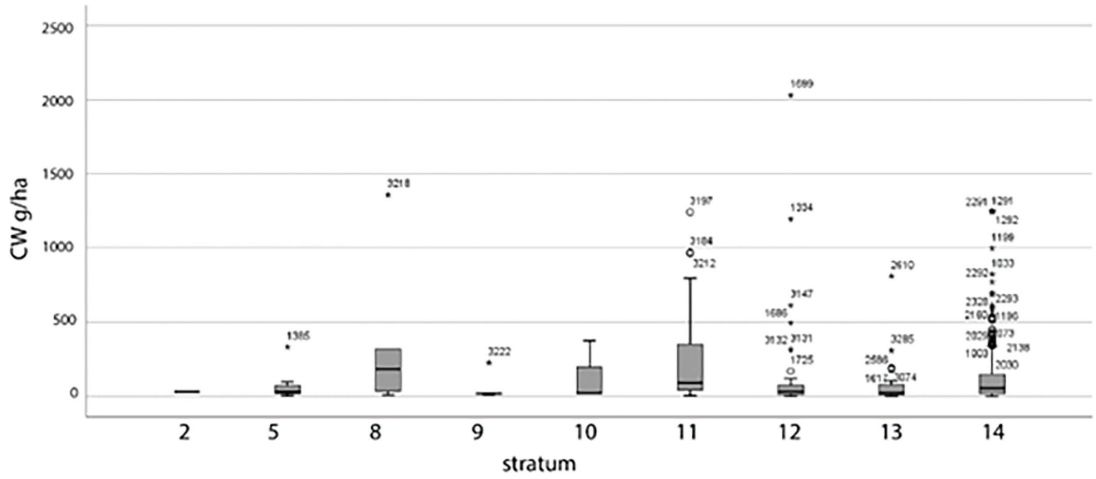

Figure 5.10. Boxplot showing variability of CW weight densities between LU-Litho strata. X-axis represents LU-Litho strata, Y-axis represents CW weight densities, labels represent individual sample unit numbers.

not recently ploughed and with a dense cover of small weeds and grass. Therefore, low densities sampled in LU-Litho stratum 13 could be the result of unfavorable visibility conditions, which can be of considerable effect (cf. Schiffer et al. 1978, Terrenato and Ammerman 1996, Banning 2002, Van Leusen 2002, Waagen 2014, Stek and Waagen 2022). The cross table of visibility scores (1 = low, 4 = high, see Attema et al. 2010: 19-20, on how these scores are established) per LU-Litho stratum shows a very different pattern for LU-Litho stratum 13 with a lower overall visibility (tab. 5.5).

A statistical test can be applied to understand whether the difference in visibility scores is significantly different, and how strong the difference is. A chi-square test compares the distributions of visibility scores to see whether they follow roughly the same pattern, or whether they can be regarded as stemming from different 'visibility-populations'. It is specifically designed for categorical data; although visibility scores appear to follow a quantified interval scale, they are in fact ordinal as the differences between the visibility scores (i.e. between 3-4) is not a consistent quantity. A direct comparison between the cumulative visibility score distribution of the four largest LU-Litho strata, i.e. LU-Litho stratum 11, 12 and 14 in one group (together 54,7% of the sample collection, excluding strata 8-10), and 13 in the other, gives up a propor-

LU-Litho stratum	1	2	3	4	total
8	5	7	7	2	21
9	9	3	11	1	24
10	2	1	2	1	6
11	19	26	18	10	73
13	45	54	8	7	114
12	**48**	**82**	**60**	**18**	**208**
14	182	281	241	185	889
Total	310	454	347	224	1335

Table 5.5. Cross table with distribution of visibility scores across LU-Litho strata.

tional difference of 27%. Although statistical significance is usually more easily achieved with large sample sizes such as these, the pattern is clear and supports our impression.

Evidently, this difference in visibility circumstances has the potential to seriously skew attested find densities, and negatively bias the low-density SAs. If the 27% difference in ground visibility would mean that almost one-third of the finds have been blocked from the field walker's view, the lower densities in LU-Litho stratum 13 could be misleading. Probability modeling can be applied to attest whether a big shift in the analysis outcomes is likely to occur. We simulate the potential effect of an overall 27% proportional difference by modeling a correction for 27% less finds in LU-Litho stratum 13, i.e. multiplying CW and PW densities by 1.36, and only for finds in LU-Litho stratum 13. Repeating all variability tests, the results show that the overall correlation of high-density SAs and geomorphology is still clearly present (tab. 5.4, test 7, fig. 5.11), and also the density comparison per LU-Litho stratum gives up a similar pattern of variability (tab. 5.4, test 8, fig. 5.12). A problem here is that many units in LU-Litho stratum 13 produced 0 finds, which is probably not representative of the true find density because of the bad visibility conditions. Ploughzone dynamics can have a substantial effect on archaeological finds, and fallow, unploughed fields appear to systematically underrepresent find densities present in the subsoil (Stek and Waagen 2022). To adapt the test in an attempt to cope with this effect, we attributed an average find density to these fields of based on the mean corrected CW densities in LU-Litho stratum 13 (101 gram and 11 sherds). Again, the variability tests the 0-hypothesis are rejected and the pattern of variability remains stable (tab.5.4, test 9 and 10).

To conclude, although there may be well effects of the low visibility of certain areas of the SAs, based on the current tests and insights, there is no reason to suspect a considerable deviation from the overall pattern. In our hypothetical scenario, the densities do not increase enough to cast doubts on the earlier analysis and interpretations. We can therefore safely infer from the analyses that all data, after rigorous statistical analysis, confirm the expected pattern, namely a significant trend of higher offsite densities in CW and PW distributions in the higher situated SAs, associated with the hypothesis of hilltop/plateau concentrations of settlements.

5.4 CONCLUSIONS

In this paper, we evaluated the hypothesis of higher densities of Hellenistic/Samnite settlement in the more elevated geomorphological units in the Tappino area, i.e. undulating slopes, plateaus and hilltops. One of the main goals has been to do so with a statistically robust method, warranting optimal strength and comparability of the results, which is unfortunately often lacking in the analyses of archaeological field survey data. We developed an analytical framework with explicitly described sampling schemes and statistical methods. This framework allowed us to study two variables that we deem suitable proxies for differentiating between a concentration of settlement in elevated areas: farm sites, i.e. farm site density in the Hellenistic/Samnite period; and offsite finds, i.e. offsite CW and PW densities. In order to be able to statistically specify site densities, we proposed a method to define a size unit, the extent approach, and testing site presence/absence with the formula for categorical data. A proportionate spatial stratified sampling

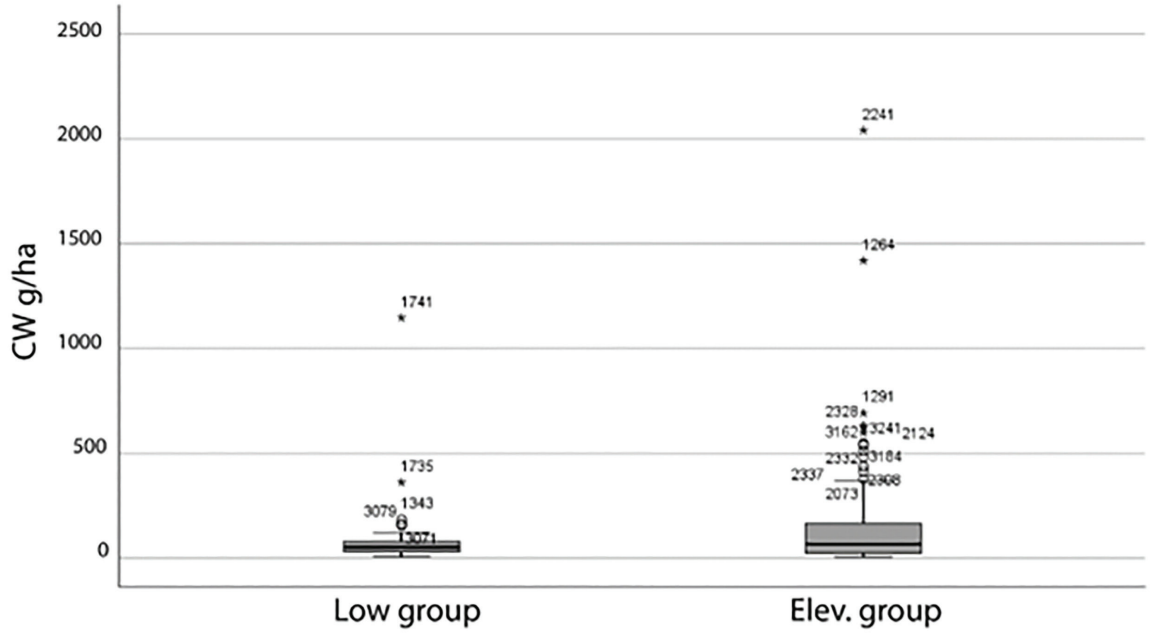

Figure 5.11. Boxplot showing variability of CW weight densities between Low and Elev. groups when multiplied with a factor 1.36. X-axis represents groups,Y-axis represents CW weight densities, labels represent individual sample unit numbers.

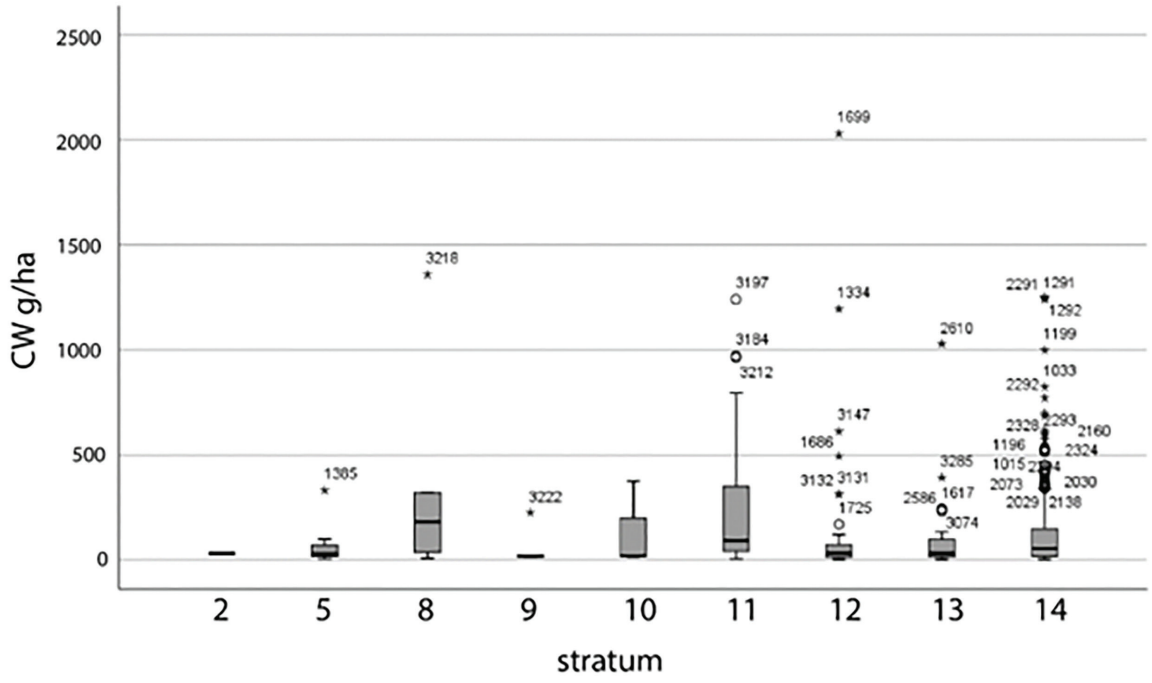

Figure 5.12. Boxplot showing variability of CW weight densities between LU-Litho strata when multiplied with a factor 1.36. X-axis represents LU-Litho strata,Y-axis represents CW weight densities, labels represent individual sample unit numbers.

approach has been applied to include the geomorphological variety in the Tappino area in our sample, as well as various situations of archaeological visibility, modern land use and lithology, to assess the degree to which they may bias the outcomes. A valuable methodological outcome of this paper is that it shows how we can improve the robustness of archaeological field survey for reconstructing ancient settlement organization. We demonstrated the value of a procedure for a systematic bias assessment, and developed a method that tells us how much terrain must be surveyed before well-founded statements about ancient settlement patterns can be made. These methods can be applied to other field surveys in other landscapes, and therefore hold a value beyond this specific research area; it must be mentioned though that their exact application is dependent on landscape characteristics and site typologies, which should be carefully considered.

Thus, we can tentatively confirm the initial hypothesis of a Hellenistic/Samnite settlement concentration on the elevated portions of the terrain. The site densities appear to be higher on hilltops and plateaus. In addition, the offsite finds, taken to represent a whole range of human activity in the landscape, as well as probably destroyed sites, show a statistically significant patterning too, which leads to the same conclusion. Based on the stratified analysis of potential biases we can discount the probability that factors, such as land use, skews our view on the spatial distributions of finds in any problematic way. As a final demonstration of this type of testing, we performed an exercise in scenario modeling on the potential bias factor of ground visibility. We maximized the potential effect of a LU-Litho stratum with very bad ground visibility and tested whether this had any notable influence on the tests, which it did not. Taken together, we can therefore state with confidence that Hellenistic/Samnite site and find densities in the Tappino area are clearly in support of the hypothesis of a concentration of settlement in the more elevated parts of the terrain.

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