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# Chapter 2. A method for modeling dispersed settlements: visualizing an early Roman colonial landscape as expected by conventional theory[9]

*Abstract*

This paper proposes a GIS quantitative method for simulating dispersed distributions of sites in a landscape. A number of sites might have escaped archaeological detection due to adverse surface visibility conditions during field survey (the so-called 'missing sites'). For the early Roman colonial landscapes of central-southern Italy, these surface visibility factors are traditionally seen to be so dramatic as to have allegedly hampered the detection of the conventionally expected dispersed and densely-settled colonial farm landscape. In this paper, the regional and site-oriented field survey conducted in Venosa (Basilicata, Italy) is used as a case-study to simulate hypothetical early colonial sites. The aim of this theoretical exercise is to show how the rural dispersed settlement pattern expected by the conventional theory could appear on a map, and to visually highlight the divergence between survey data and conventional spatial expectancies.

## 2.1 INTRODUCTION

In the debate on ancient settlement organization of Roman colonies, the extent to which rural colonial settlements have been detected by modern archaeologists in the field plays an important role. A loss in recovery of sites as a result of the limitations of field survey methodology (*i.e.* visibility biasing factors) is generally known (see discussion in De Guio 1985; 1995; Francovich *et al.* 2000), but its precise scale is seldom clearly connected to historical interpretation. In the conventional reconstruction of Roman colonial landscapes, this notion of a low site recovery rate is crucial to the argumentation. In this paper, the colonial landscape projected by the conventional view, and by extension the related levels of site 'loss' between the Roman period and modern day field observations, is calculated and visualized by means of a GIS simulation. This not only reveals the scale of modern correction needed to sustain the conventional view of early Roman landscapes, but also introduces a useful visualization method.

Numerous studies have addressed the impact of factors that could prevent object detection in the plough-soil (*i.e.* artifact taphonomy). Several methods have been proposed for the correction of artifact density recorded in intensive, off-site field survey (*e.g.* Haselgrove *et al.* 1985; Shennan *et al.* 1985; Allen 1991; Gaffney *et al.* 1991; Schofield 1991; Verhoeven 1991; Van de Velde 1996; 2001; van Leusen 1996; 2002; Gillings & Sbonias 1999; Fentress 2000; Ebert & Singer 2004; Given 2004a and b; De Haas 2012; Feiken 2014; Waagen 2014). In contrast, the development of methods to "correct" site recovery rates in site-based field surveys has seen less research (discussion in Cambi 1999; Witcher 2006; 2011; Wilson 2008; Fentress 2009). For

9 This Chapter corresponds to the article "A method for modeling dispersed settlements: visualizing an early Roman colonial landscape as expected by conventional theory" by Anita Casarotto, originally published (22 December 2017) in *Archeologia e Calcolatori*, volume 28.1 (publisher Edizioni all'Insegna del Giglio) as an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives License (https://creativecommons.org/licenses/by-nc-nd/3.0/). This article is accessible through this link: https://doi.org/10.19282/AC.28.1.2017.09
I would like to express my gratitude to my supervisors, Dr. Jeremia Pelgrom and Dr. Tesse D. Stek for their comments throughout the writing process of the article. I would also like to thank Prof. Maria Luisa Marchi for the methodological information about the visibility map of the territory of Venusia. Limited changes to the original publication have been included in this Chapter 2.

surveys in Italy, only a few studies have proposed concrete methods for simulating the sites that may have not been detected due to poor ground visibility conditions in which site-based surveys were carried out (*e.g.* Terrenato & Ammerman 1996; Terrenato 2000; see also Nance 1983 for a methodological discussion and Fokkens 1998 for a north-western European case-study). In this paper these previous methods as well as new ones are taken into account to simulate the possible effect of surface visibility on site detection in survey.

Following the conventional theory on colonial settlement (see below), hypothetically "corrected" site recovery rates and "complete" site distributions are, by way of experiment, proposed for the Roman colonial landscape of the Latin colony of Venusia (founded in 291 B.C. in southern Italy). The field surveys conducted in the territory of Venusia, and in many other rural colonial landscapes around the Italian peninsula, identified only a fraction of the early colonial sites (and specifically only a small portion of the 3rd century B.C. farms) expected based on the demographic information reported in ancient literary sources (see the discussion in Rathbone 1981; 2008; Pelgrom 2008; 2013). The generally accepted explanation for this *conundrum* of missing colonial sites is that they have not been identified because of the difficulty to detect simple, poor colonists' rural dwellings in pedestrian surveys, especially when the surface visibility conditions are not optimal for site detection (Rathbone 1981; 2008; Millett 1991; Cambi 1999; Witcher 2011). According to this conventional idea, this obstacle to site discovery would explain why the expected densely populated and regularly settled colonial landscape is not visible through field survey.

Using a quantitative method for correcting possible survey visibility distortions in settlement patterns, this study shows how the territory around the colonial center of Venusia may have appeared if the conventional model is correct (for this model of dispersed Roman colonial settlements see *e.g.* Salmon 1969; Brown 1980; Rathbone 1981; 2008; Celuzza & Regoli 1982; Settis 1984; Bussi & Vandelli 1985; for a critique of this model see Pelgrom 2008; 2013; Stek & Pelgrom 2013). This was achieved by means of computer-based simulations that uniformly allocated a large amount of hypothetical missing sites (in other words, sites that might not have been registered by previous field surveys because of the less than ideal ground visibility conditions). The result is a hypothetical reconstruction of the expected "complete" site distribution (supposedly the distribution that, according to the conventional model, should have been observed during the survey if surface visibility was constantly, not variably, optimal across the entire landscape). The assumption underlying such simulations of landscapes with dispersed settlements is that there is a strong association between surface visibility and the number of colonial sites discovered in field surveys; an idea that, as previously mentioned, is widely accepted by the conventional theory on colonial settlement.

Prior calculations of site recovery rates for colonial landscapes have been based upon preconceptions about rural colonial landscapes, and which recovery rates we would end up with when following certain established assumptions on density and distribution (*e.g.* Rathbone 1981; Cambi 1999). This analysis further explores this line of thought by offering a visual, concrete picture of how the envisaged dispersed colonial settlement pattern would have been recorded, if it existed and was visible, on a site-based survey map. This theoretical exercise serves as an important first step to gaining a better understanding of the quantitative and spatial implications of this conventional theory. However, the alleged direct relationship between object of study (*i.e.* distribution and density of sites in colonial landscapes) and methodological survey limitations (*i.e.* visibility biasing factors) cannot be taken at face value but needs to be tested (see Chapter 5).

Recently, several scholars have started to question the conventional Roman colonial settlement theory, which predicts a colonial countryside settled regularly and densely. By noting that, instead, irregular patterns underlie the settlement sites registered in surveys, the question is now raised as to whether these patterns reflect another, alternative settlement model (Pelgrom 2008; Stek 2009) rather than being the result of visibility biasing factors (Rathbone 2008). The current paper aims to contribute to this

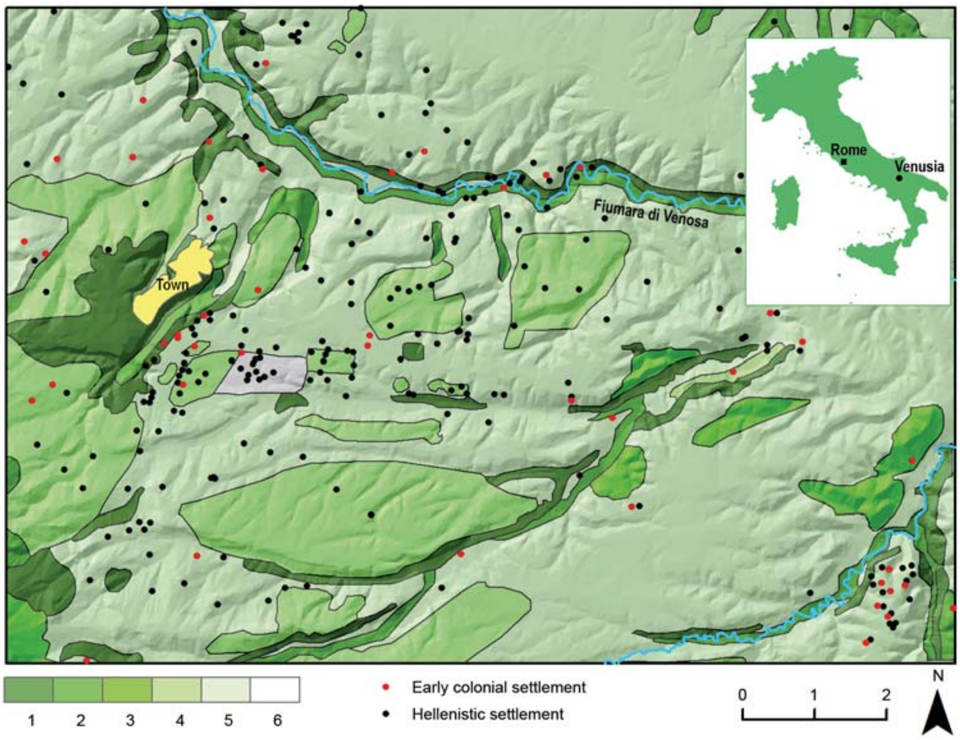


**Fig. 2.1** Hellenistic settlement site distribution and visibility map (based on Marchi & Sabbatini 1996, 107; graphic elaboration by author). The raster base map is the shaded relief calculated from the 10 m-resolution DEM named TINITALY/01 (Tarquini *et al.* 2007; 2012; Tarquini & Nannipieri 2017).

debate by offering a tool that enables a visual, direct assessment of the substantial spatial discrepancy that exists between the conventional settlement theory and survey data (see discussion in Pelgrom 2012). This, in turn, can be used to evaluate the validity of this model for the settlement organization of the colonial countryside.

## 2.2 DATA

The regional, site-oriented field survey in north-eastern Basilicata was conducted between 1989 and 2000 within the context of the *Forma Italiae* project (Azzena & Tascio 1996; Sommella 2009; Marchi 2016a and b; Marchi & Forte 2016), and represents one of the richest datasets of this type for central-southern Italy (Marchi & Sabbatini 1996; Sabbatini 2001; Marchi 2010)[10]. The first data published were collected in the area around the ancient urban center of the Latin colony of Venusia (*c.* 120 sq km) (Marchi & Sabbatini 1996). In total 604 sites were detected here, of which 262 are settlement sites dating to the Hellenistic period. Of these 262 sites, there are 44 settlement sites dated with certainty to the early colonial period, given that 3rd century black gloss pottery was attested at these sites (Fig. 2.1).

In this paper, all Hellenistic settlement sites are taken into consideration as possible early colonial settlements. This is because sites possibly occupied in the 3rd century B.C. but lacking datable diagnostic

10 Fields were systematically walked by surveyors spaced five to ten m apart who recorded all visible material concentrations (*i.e.* sites) with a material density equal to or higher than five shards per sq m (see Pelgrom *et al*. 2014, 31-35; Marchi 2016a for more details on the survey method). IGM (Istituto Geografico Militare) maps (1:25,000) were used as a support to register the position and the extension of sites, in combination with CTRs maps (Carta Tecnica Regionale 1:5000; 1:10,000), and GPS technologies (Azzena & Tascio 1996).

archaeological evidence (*e.g.* 3rd century B.C. black gloss pottery) can be dated only to a broader chronological range (namely the Hellenistic period) (for further argumentation of this choice see also Chapter 3, section 3.2). In the current simulation, settlement sites are treated as simple and homogenous dots[11].

The survey team paid attention to the relationship between ground visibility and site discovery. After noting that different land uses and the plow status of the fields offered suitable visibility for survey especially in certain seasons (*e.g.* olive and vineyard orchards in winter and spring), repeated coverage of the same surface was planned and executed in order to retrieve the necessary information. For the territory around the ancient town of Venusia, a visibility map was produced by the team and published in Marchi & Sabbatini 1996, 107. A graphic elaboration of this map (by author) is offered in Fig. 2.1.

Such a map integrates the land use information[12] and the land cover conditions registered by field walkers in the season of optimal visibility for survey, and classifies the land surfaces on a visibility scale from one (null or very low visibility) to six (optimal visibility) (Azzena & Tascio1996, 292-296). With this map, surveyors wanted to test if there is a link between the low number of archaeological sites recorded in wide portions of the landscape and surface visibility. The archaeological site points displayed in their distribution maps had a particular pattern: very densely populated zones constantly alternated with much less dense site areas and large vacuums (Marchi & Sabbatini 1996, 103-104, 111-130). The visibility map can help to evaluate whether such a configuration of sites is the result of visibility biasing factors or, rather, the result of ancient settlement rationales.

## 2.3 VISUALIZING THE CONVENTIONALLY EXPECTED EARLY COLONIAL LANDSCAPE

In this section, a quantitative method is proposed to correct possible visibility distortions in site density and distribution. A similar method has been presented by Terrenato (2000). His approach also aimed at measuring the probability of a site being present in a certain location, even though it had not been identified by surveyors due to limited visibility. The relation between local variations in ground visibility and site discovery is complex; the variable effect of visibility on site recovery rates must be taken into account when constructing a simulation of missing sites. Additionally, the simulation of a dense and dispersed early colonial landscape is based on the assumption of uniformity in the original settlement distribution. Therefore, hypothetical colonial missing sites should be allocated across the landscape in a way that is calibrated in accordance with the relationship between visibility and the recorded site density and pattern at each landscape location. This simulation was conducted in three steps.

As a first step, a probability surface for the allocation of hypothetical missing sites was constructed. This surface must indicate the likelihood that a missing colonial site existed in each location of the landscape, but was not recorded by surveyors. This probability thus depends on both ground visibility conditions experienced during the survey, and site density recorded at each landscape location. The calculation of this surface was implemented in ArcGIS 10.2.2 using three GIS tools:

1) First, a kernel density estimation of Hellenistic sites was carried out (Fig. 2.2). The kernel density tool of ArcGIS calculates “a smooth estimate of a probability density from an observed sample of observations” (Bailey & Gatrell 1995, 84). The probability density is highest at the location of points and diminishes gradually with increasing distance from the points

11 A majority of these sites was occupied during several phases. Therefore, their size is not necessarily indicative of an early colonial occupation and may likely be related to those archaeologically “more visible” periods characterized by the abundant consumption of non-perishable material. As a consequence, it would be incorrect to use the documented size as a parameter for distinguishing different settlement categories (*e.g.* farm, villa, village) for individual periods. The aim here is not to perform analyses of visibility for correcting the number of different settlement categories. The fact that there exists a well-acknowledged problematic relationship between material concentrations recorded at the surface during surveys and the reliability of site classifications based on this type of data (*e.g.* Barker & Lloyd 1991; Alcock & Cherry 2004) justifies here the methodological choice of disregarding categories in favor of a more neutral definition of surface material scatters.

12 For more details see Azzena & Tascio 1996, 292 – 296 (especially footnote 18).

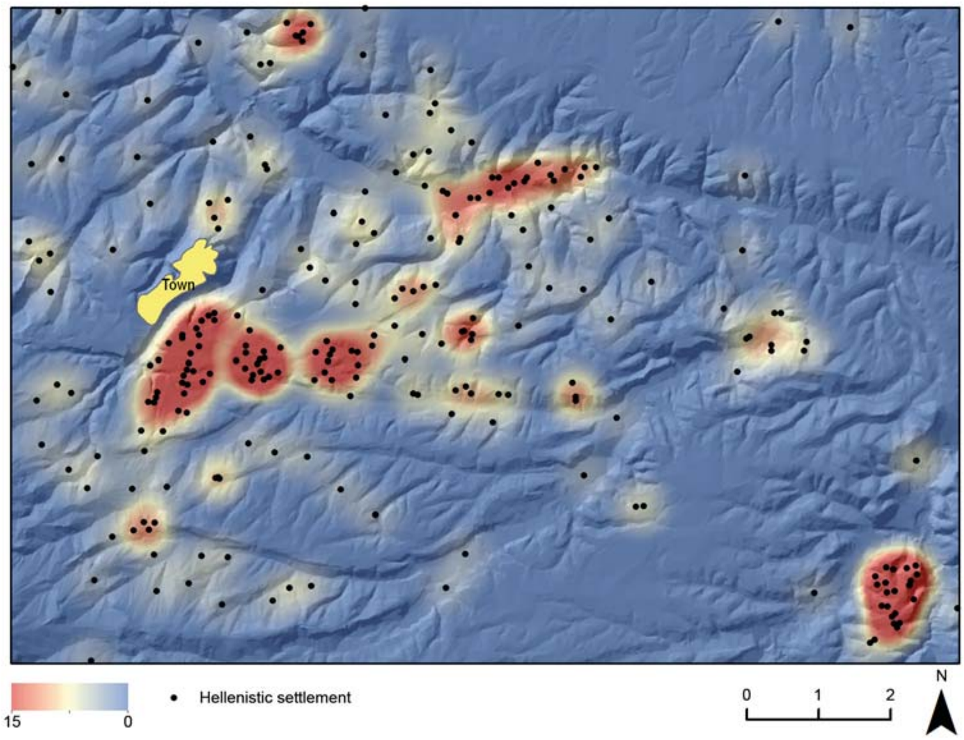


**Fig. 2.2** Kernel density surface calculated for the Hellenistic settlements. The legend indicates the number of estimated sites in a circle of one square km from each location (cell resolution 10 x 10 m). The raster base map is the shaded relief calculated from the 10 m-resolution DEM named TINITALY/01 (Tarquini *et al*. 2007; 2012; Tarquini & Nannipieri 2017).

(Esri 2014a). The site probabilities were calculated in a circle of one sq km from each recorded point, and then were summed up in each location (cell size set at ten by ten m). The resulting density surface displayed the probable intensity for a particular distributional phenomenon in each location and over the entire landscape, and is based on the density of recorded Hellenistic sites.

2) Afterwards, the fuzzy tool of ArcGIS was used to linearly and inversely transform the kernel density estimate (Fig. 2.2) and the visibility map (Fig. 2.1) into probability surfaces, with values that range from zero to one (Esri 2014b). The traditional model for the organization of the colonial countryside expects high and homogeneous site density; following this idea, landscape locations with a low recorded site density received a high probability value for missing colonial sites; conversely, landscape locations with a high recorded site density received a low probability value for missing sites. This means that, for instance, the maximum site density value had the lowest probability (*i.e.* zero) and the minimum density value had the highest probability (*i.e.* one) for missing sites. The same operation was performed for the ground visibility map: high probability values for missing colonial sites were given to low values of visibility, and low probability values for missing sites were assigned to high values of visibility. Again, this means that the maximum and the minimum visibility values (*i.e.* six and one, see Fig. 2.1) received respectively the lowest and the highest probability for missing sites (*i.e.* zero and one).

3) The reclassification of these two variables (*i.e.* site density and ground visibility) on the same probability scale (from zero to one) made them unitless, and allowed for direct comparison and integration. Fig. 2.3 shows the result of the integration of these two variables. In order to correct the estimated site density for possible visibility biases, the reclassified density map was multiplied by the reclassified visibility map

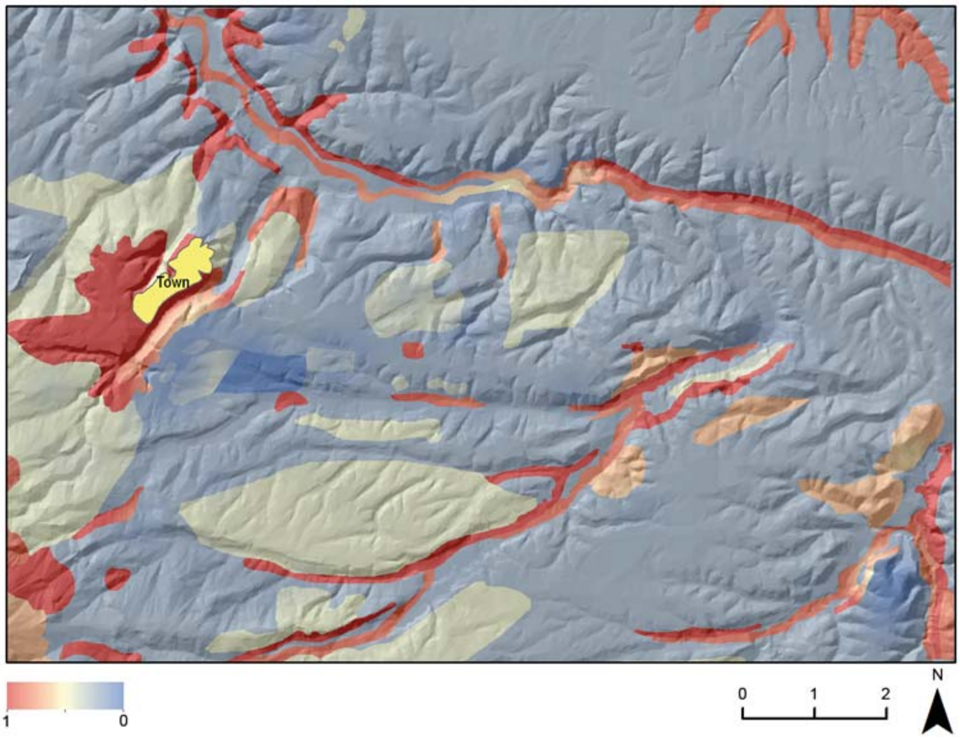


**Fig. 2.3** Trend surface created for missing site allocation. The legend indicates the probability for the allocation of missing sites and ranges from a minimum of 0 to a maximum of 1. The raster base map is the shaded relief calculated from the 10 m-resolution DEM named TINITALY/01 (Tarquini *et al*. 2007; 2012; Tarquini & Nannipieri 2017).

through a raster overlay operation. In this way, a trend surface for the allocation of missing sites was created. This trend surface takes into consideration the possible visibility distortions involved in the recording of sites and can be used as a base to allocate hypothetical missing sites across the landscape.

As a second step, it was necessary to calculate the hypothetical number of missing sites, before implementing the allocation of points on the trend surface. There are already figures for missing sites in colonial landscapes that were calculated by scholars following a demographic method (see below). In this analysis, however, these previously-proposed numbers were not used; instead, new thresholds for missing sites were calculated using a GIS-based spatial and statistical method. Specifically, the number of sites necessary to recreate a dispersed pattern was calculated through several tests: increasingly larger numbers of missing sites were simulated until the site distribution clearly started to exhibit a statistically significant regular pattern. The pattern of the simulated distributions was evaluated by means of the nearest neighbor tool[13] of ArcGIS (for other methods see *e.g.* Orton 2004; Ducke 2015).

As a third step, the trend surface was used as a base for the allocation of simulated sites. The allocation of

13 This tool allows researchers to categorize the dominant pattern displayed by the simulated dots (either clustered, random, or dispersed) (Clark & Evans 1954). The nearest neighbor analysis calculates the distances from each point to its nearest neighbor and then averages all these inter-distances (Hodder & Orton 1976, 30-52; Kintigh & Ammerman 1982; see the discussion in Orton 2004). If this average is higher than that obtained from a random distribution of dots, the site distribution exhibits regularity (*i.e.* dispersed distribution). This tool also calculates the nearest neighbor ratio by dividing the observed average distance by the expected average distance: a ratio less than 1 indicates clustering, equal to 1 randomness, and more than 1 indicates uniformity (Esri 2014c). The z-score and the p-value resulting from using this tool, then, reveal whether the detected pattern is significant: in other words, a significant pattern is identified if very high or very small z-scores exist in association with very small p-values (see Esri 2014c for the mathematical details on this procedure).

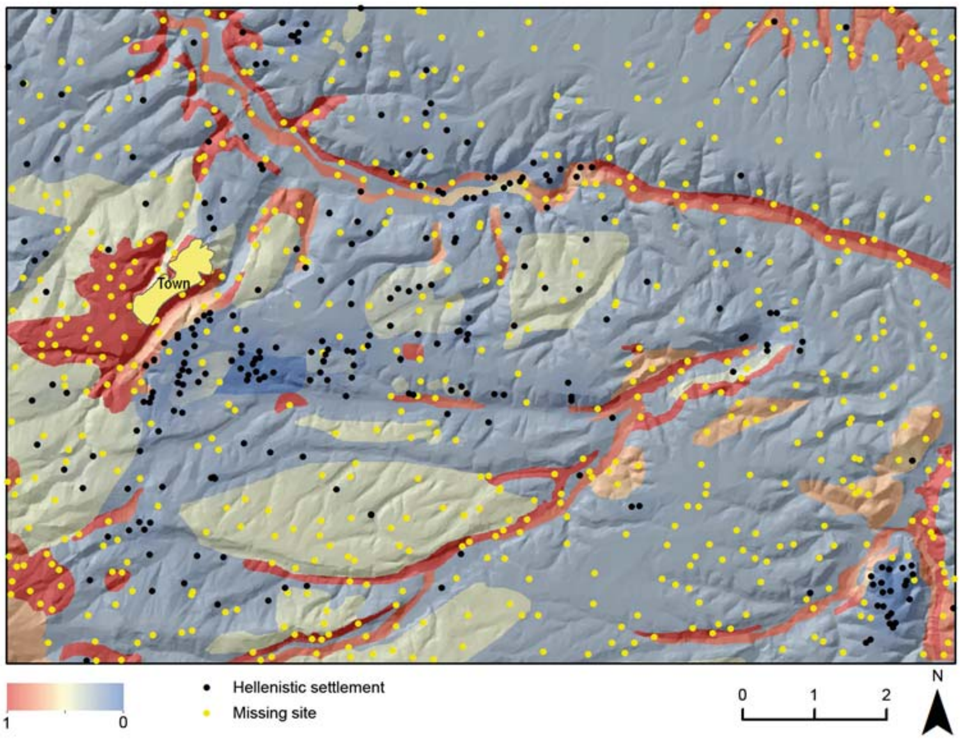


**Fig. 2.4** Trend surface created for the allocation of missing sites (probability from 0 to 1), and the simulated "complete" early colonial settlement distribution (262 recorded settlements plus 600 missing sites, therefore 862 sites in total). The raster base map is the shaded relief calculated from the 10 m-resolution DEM named TINITALY/01 (Tarquini *et al*. 2007; 2012; Tarquini & Nannipieri 2017).

missing sites on the trend map (Fig. 2.4) is based on the conventional assumption of homogeneous site density and pattern for the colonial countryside. Only few sites (or none) were thus allocated in those landscape locations where the recorded site density was high and the ground visibility was good, since the probability for missing sites there was low. As the density and visibility decreased, more sites were allocated: in the zones where both the recorded site density and visibility were low, many sites were spread out because of the high probability for missing sites in these locations. In other words, those landscape locations characterized by both low visibility and low recorded site density were more likely to receive missing sites than locations with a high recorded site density in good visibility conditions. In ArcGIS there is a tool precisely suited for this operation: it is called 'create spatially balanced points'. By using this GIS tool, points representing missing sites were scattered across the study area in a balanced way (*i.e.* in proportional accordance with the trend surface probability values, see above) to create a uniformly dotted landscape. As a future step to improve this simulation, it would be interesting to consider other constraints for the allocation of sites (*e.g.* the relief), and to note to what extent the exclusion of, for instance, steep slopes changes the simulated site configuration.

By using the nearest neighbor tool, the pattern type characterizing the simulated distributions was assessed (see footnote 13, p. 35). Thus, the number of missing sites required to create a dispersed early colonial settlement distribution was established. For our case-study, the originally recorded Hellenistic distribution (262 sites in total) exhibited clustering in its pattern (neighbor ratio: 0.707420; z-score: -9.059943; p-value: 0.00). In order to transform this clustered distribution into a regularly dense distribution of early colonial sites, a total number of (at least) 600 missing sites had

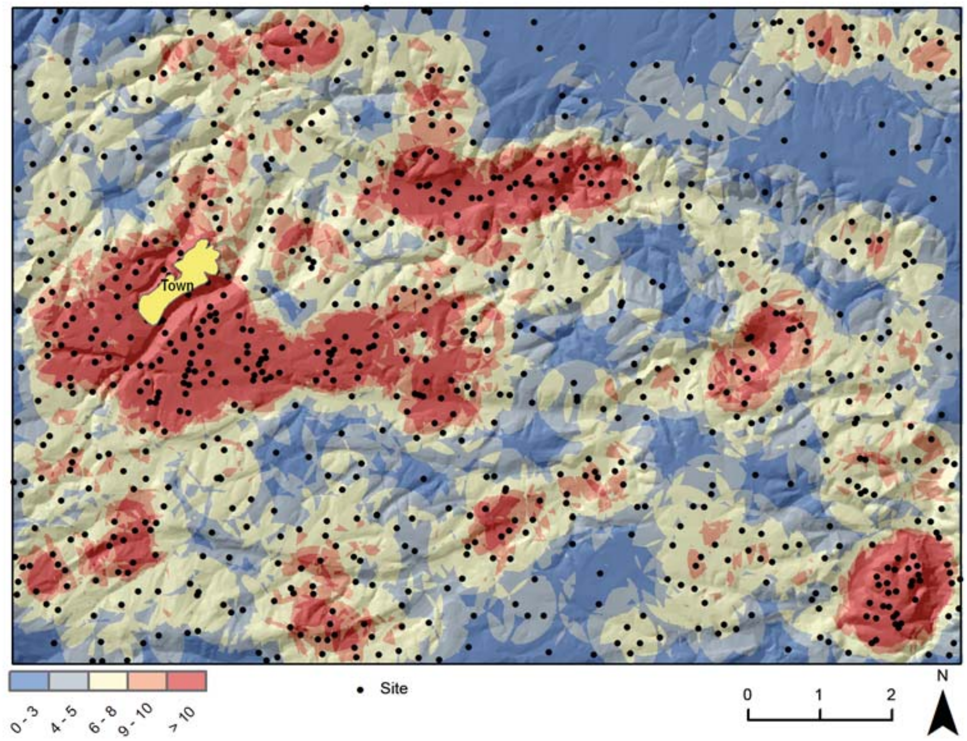


**Fig. 2.5** Point-density analysis of the "complete" early colonial distribution (262 recorded sites plus 600 missing sites, therefore 862 sites in total). The legend indicates the number of sites located in a circle of one square km from each location (cell resolution 10 x 10 m). The raster base map is the shaded relief calculated from the 10 m-resolution DEM named TINITALY/01 (Tarquini *et al*. 2007; 2012; Tarquini & Nannipieri 2017).

to be allocated over the trend surface and added to the 262 recorded settlements (Fig. 2.4). From this new hypothetical "complete" distribution (in total 862 sites), the nearest neighbor ratio tallies to 1.037621, the z-score is 2.113060, and the p-value is 0.034596.

This simulated dispersed settlement distribution has an average density of 6.8 sites per sq km (Fig. 2.5). What is interesting to note is that this figure aligns very well with the demographic information cited in the literary sources, from which a number of 7-8 colonists' farms per sq km has been calculated by previous studies (Pelgrom 2008; 2012; 2013). Moreover, this amount of missing colonial sites is consistent with the 20-33% recovery rate that has been estimated for a regional site-based survey carried out in another Roman colonial context in Italy (*i.e.* the Albegna valley in Tuscany for the Latin colony of Cosa, Cambi 1999; for other calculations see Rathbone 1981; Wilson 2008; Witcher 2011). Indeed, for this simulated early colonial distribution (Fig. 2.4), the number of hypothetical unrecorded missing sites amounts to 69.6% of the total. Therefore, the number of recorded sites corresponds to 30.4% of the total. Interestingly, the GIS method described in this paper proposes thresholds for both the expected and the missing colonial sites that comply with the thresholds calculated by other scholars who used a completely different method (*i.e.* text-based demographic method, cf. *supra*).

It is important to stress, however, that the scale of the source visibility map played a key role in the simulation. If finer, more-detailed base maps on which to perform the allocation of missing sites were available, a different hypothetical distribution of early colonial settlements would probably have been obtained, and thus different percentages for recorded and missing sites.

## 2.4 DISCUSSION AND FURTHER DIRECTIONS

It is generally understood by archaeologists that biasing factors such as ground visibility conditions can strongly affect the detection of sites. These potential biases are usually seen as the explanation for the missing colonial farm sites in most field survey projects in central-southern Italy (*e.g.* Rathbone 2008). The legacy site distribution maps compiled during these projects do not show, as a rule, the expected evenly dotted colonial landscape.

In this paper, a theoretical exercise to spatially visualize the conventionally expected site configuration was offered. If we accept such an understanding of colonial settlement organization, as well as the existence of a strong relationship between site density and survey visibility, the computer-based simulation proposed here clearly shows the high number of sites that need to be simulated in order to create a dispersed distribution.

However, this conclusion of very high missing site percentages fully depends on the validity of the conventional and historically informed theories about colonial population density and settlement configuration. As this understanding of colonial rural landscapes has recently been undermined by a series of revisionist studies, the question arises whether the idea of biasing factors heavily hampering the detection of this alleged dispersed landscape is actually correct (see Chapters 4 and 5). Therefore, as a subsequent research step, the validity of the conventional model needs to be tested using descriptive methods and computer-based statistical tools, as well as in the field with new surveys.

As a matter of fact, the new colonial settlement models that have been proposed recently not only question the conventional theories on Roman territorial strategies in recently conquered areas, but also have a significant impact on broader discussions about missing sites and field survey biases (Pelgrom 2008; Stek & Pelgrom 2013; Stek *et al.* 2015; Casarotto *et al.* 2016; Casarotto *et al.* 2018; for a discussion of the scholarly debate related to these settlement models see *e.g.* Bispham 2006; Bradley 2006; Terrenato 2007; Van Dommelen & Terrenato 2007; Stek & Pelgrom 2014). The focus now shifts from showing how sites could have appeared on a map to understanding whether ancient settlements should even be expected in the first place, and most importantly, which site patterns are the result of biasing factors, and which, instead, are the result of genuine settlement preferences.

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