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A METHOD FOR MODELING DISPERSED SETTLEMENTS: VISUALIZING AN EARLY ROMAN COLONIAL LANDSCAPE AS EXPECTED BY CONVENTIONAL THEORY

1. Introduction

In the debate on the ancient settlement organization of Roman colonies, an important role is played by the extent to which rural colonial settlements have been detected by modern archaeologists in the field. A loss in recovery of sites as a result of the limitations of field survey methodology (i.e. visibility biasing factors) is generally known, but seldom its precise scale is clearly connected to historical interpretation. Indeed, 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 expected on 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.

Over the last few decades many extensive field survey projects have been carried out in the Mediterranean, and especially in Italy (Barker, Lloyd 1991; Cambi, Terrenato 1994, 21-30; Barker, Mattingly 1999; Alcock, Cherry 2004; Stek *et al.* 2015). As a result, concentrations of archaeological material ploughed-out at the surface (in other words, sites), were mapped over large regions (see the discussion in Witcher 2008). The enthusiasm for the envisaged potentiality that these datasets could have for historical reconstructions of rural landscapes was great. However, archaeologists quickly started to wonder about the actual representativeness and completeness of their datasets. The methodological difficulties inherent in the practice of field survey became soon apparent (e.g. De Guio 1985, 1995; Bintliff, Sbonias 1999; Francovich, Patterson, Barker 1999; Banning 2002, 39-74; Terrenato 2004), and this awareness has triggered the continual search for formal methods with which to "correct" the legacy survey data for the effect of biasing factors.

As regards intensive, parcel-based off-site field survey, numerous studies have addressed the impact of factors that could distort object detection in the plough-soil (i.e. artifact taphonomy), while also proposing methods for the adjustment of artifact density (e.g. Haselgrove, Millett, Smith 1985; Shennan, Gardiner, Oake 1985; Allen 1991; Gaffney, Bintliff, Slapsak 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 search for methods to correct site recovery rates in regional field surveys, which take the site (rather than the artifact) as the main target of discovery, has not been as striking (discussion in Cambi 1999; Witcher 2006, 2011; Wilson 2008; Fentress 2009). As regards surveys in Italy, only few studies have proposed concrete methods for simulating the sites that may have not been detected due to the poor ground visibility conditions in which the extensive, 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). Such works are groundbreaking in acknowledging the need for dealing with the methodological issues related to survey visibility in regional investigations. 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), by way of experiment hypothetically "corrected" site recovery rates and "complete" regional patterns will be proposed for the Roman colonial landscape of the Latin colony of Venusia (founded in 291 B.C. in southern Italy). The field survey 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 (especially 3rd century B.C. farms) expected based on the demographic information recorded in ancient literary sources (see the discussion in Rathbone 1981, 2008; Pelgrom 2008, 2013). The most commonly 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, therefore, this obstacle for site discovery would explain why the expected densely populated and regularly settled colonial landscape is not visible through field survey data.

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 of early Roman colonial settlement organization was correct (for this model of dispersed settlements see e.g. Salmon 1969; Brown 1980; Rathbone 1981, 2008; Celuzza, Regoli 1982; Settis 1984; Bussi, Vandelli 1985; for a criticism of this model see Pelgrom 2008, 2013; Stek, Pelgrom 2013). This is achieved by means of computer-based simulations that uniformly allocate a large amount of hypothetical missing sites (in other words, sites which may not have been registered by previous field survey 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; an idea that, as previously mentioned, is widely accepted by the conventional theory on colonial settlement.

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

Recently, several scholars have started to question the conventional Roman colonial settlement theory which predicts a colonial countryside settled regularly and densely. By noting, instead, that irregular patterns underlie the settlement sites registered in surveys, the question has been raised as to whether these patterns reflect another, alternative settlement model (Pelgrom 2008) rather than being the result of visibility biasing factors (Rathbone 2008). This paper aims to contribute to this debate by offering a tool that enables a visual, direct assessment of the impressive spatial discrepancy that does exist 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. 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). 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 m^2 (see Pelgrom *et al*. 2014, 31-35; Marchi 2016a for more details on the survey method).

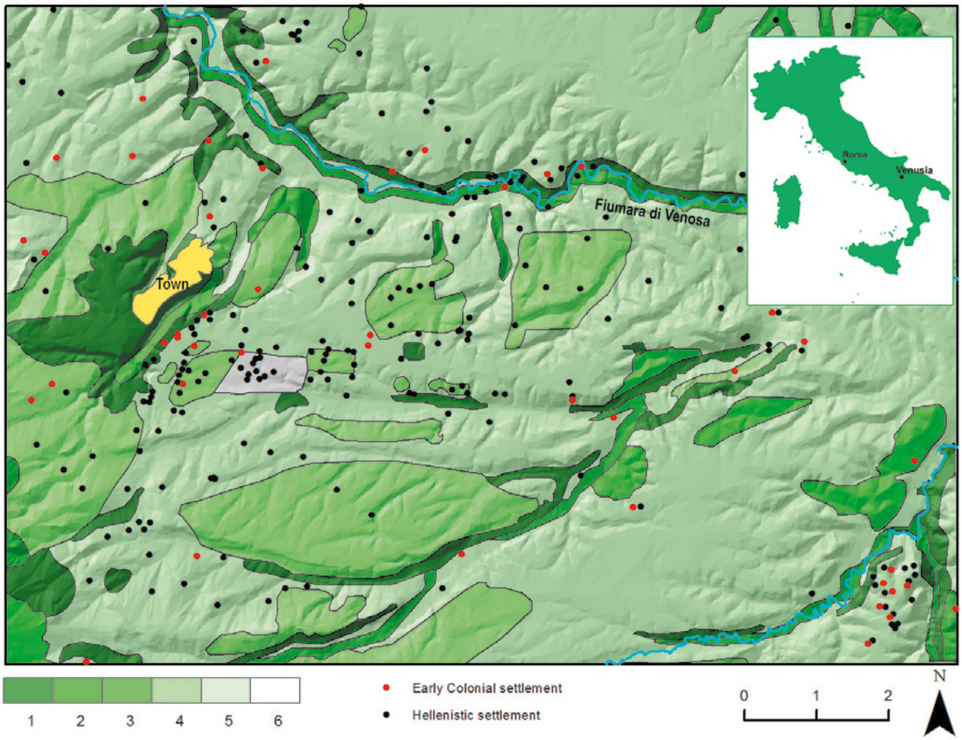

Fig. 1 – Hellenistic settlement distribution and visibility map (based on Marchi, Sabbatini 1996, 107; graphic elaboration by the author). The raster base map is the shaded relief calculated from the 10 m-resolution DEM named TINITALY/01 (Tarquini *et al.* 2007, 2012; Tarquini, Nannipieri 2017). Figure by the author.

IGM (Istituto Geografico Militare) maps (1:25,000) were used as a support to register the position and the extension of sites, as well as CTRs maps (Carta Tecnica Regionale 1:5,000; 1:10,000) and GPS technologies (Azzena, Tascio 1996). The first data published were collected in the area around the ancient urban center of the Latin colony of Venusia, which covers the IGM 187 I NE map and, partly, the IGM 187 I NO map for an area of ca. 120 km² (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 surely-dated to the early colonial period, given that 3rd century black gloss pottery is attested at these sites (Fig. 1).

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. For the reasons specified above, all settlement sites are treated in our simulation as simple and homogeneous dots.

In this paper, all Hellenistic 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 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 the reasons of this choice see also Casarotto, Pelgrom, Stek 2016, 569-571).

Attention was paid by the survey team to the relationship between ground visibility and site discovery. After noting that different land uses and the plough status of the fields offered suitable visibility for surveying 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 the author) is offered in Fig. 1.

Such a map integrates the land use information 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, Tascio 1996, 292-296, especially footnote 18). The main reason behind the construction of such a visibility map was two-fold: surveyors wanted to test if there was a link between the dearth of archaeological sites recorded in wide portions of the landscape and surface visibility. The second research aim was to investigate whether the heterogeneous pattern exhibited by the recorded site distributions could be misleading. The peculiar configuration of the dots representing sites in the initial distribution maps was immediately noticed by archaeologists working in the territory, who pinpointed very densely populated zones that constantly alternate 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 may have been the result of visibility biasing factors or, rather, the result of precise ancient settlement rationales.

3. Visualizing the conventionally expected early colonial landscape

In this section, it is proposed a quantitative method to correct possible visibility distortions in site density and distribution. The association between local variations in ground visibility and site discovery is extremely complex; the variable effect of visibility on site recovery rates must be taken into account when constructing a simulation of missing sites in a landscape. As a matter of fact, hypothetical missing sites should be allocated in a way that has to be calibrated in accordance with the contextual relationship between visibility and the recorded site density and pattern. The simulation of a dense and dispersed early colonial landscape presented below is founded on the assumption of uniformity in the original settlement pattern. 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.

In order to simulate hypothetical sites and eventually examine their spatial effect and the resulting pattern, we need to first construct a probability surface. This surface must indicate the likelihood that a missing site might have existed in each location of the landscape but was not recorded by surveyors. This probability therefore depends on both the ground visibility conditions experienced during the survey and the attested site density at each location of the landscape. This is done in ArcGIS 10.2.2 in three steps:

a) A kernel density estimation on the location of the Hellenistic sites is carried out (Fig. 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 the point and diminishes gradually with increasing distance from the point (Esri 2014a). The site probabilities are calculated in a circle of one km^2 from each recorded dot, and then are summed up in each cell (cell size sets at 10 m by 10 m). The resulting density surface displays the probable intensity for a particular distributional phenomenon in each cell and over a surface, and is based on the density of the observed sample of Hellenistic points.

b) Afterwards, the fuzzy tool of ArcGIS is used to linearly and inversely transform the density estimate into a probability surface for missing sites, with values that range from 0 to 1 (Esri 2014b). Following the traditional model for the organization of the colonial countryside that expects high and homogeneous site densities, cells with a low recorded site density will receive a high probability value for missing sites; conversely, cells with a high recorded site density will receive a low probability value for missing sites. This means that, for instance, the maximum density value will have the lowest probability (i.e. zero) and the minimum density value will have the highest probability (i.e. one) for the allocation of missing sites. The same operation is performed on the ground

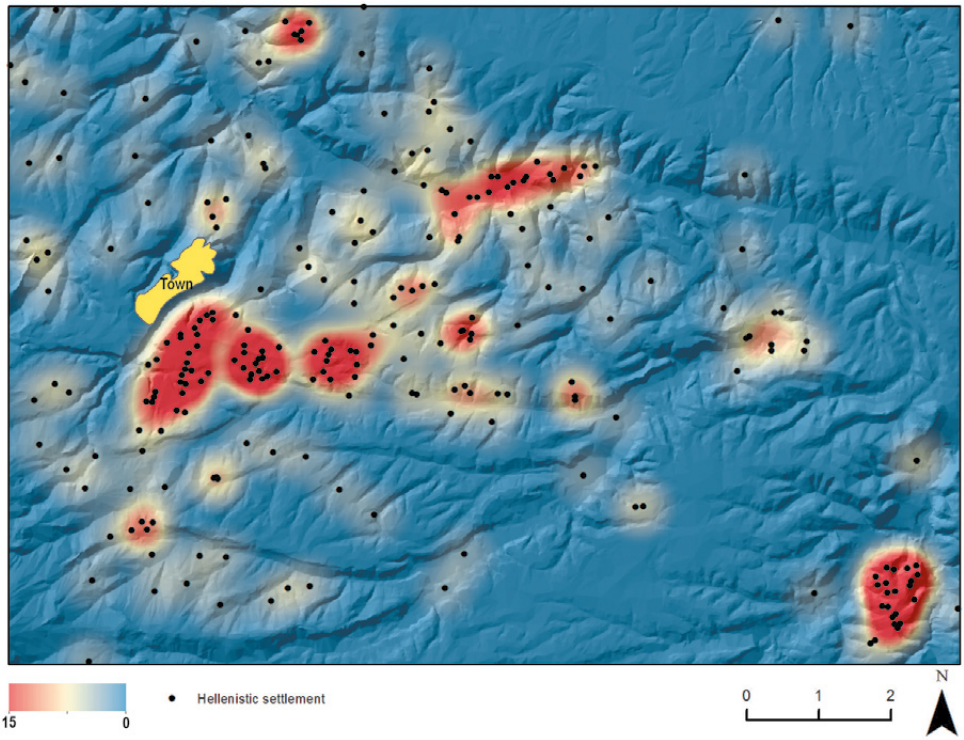

Fig. 2 – Kernel density surface calculated for the Hellenistic settlements. The legend indicates the number of estimated sites in a circle of one square km from each cell (resolution 10×10 m). The raster base map is the shaded relief calculated from the 10 m-resolution DEM named TINITALY/01 (Tarquini *et al.* 2007, 2012; Tarquini, Nannipieri 2017). Figure by the author.

visibility map: high probability values for missing sites are appointed to low values of visibility and low probability values for missing sites are assigned to high values of visibility. Again, this means that the maximum and the minimum visibility values (i.e. 6 and 1, see Fig. 1) will receive respectively the lowest and the highest probability for missing sites (i.e. 0 and 1). The reclassification of these two variables (i.e. site density and ground visibility) on the same probability scale (from 0 to 1) makes them unitless, and allows for direct comparison and integration. Fig. 3 shows the result of the integration of these two variables: in order to correct the estimated site density probability for possible visibility biases, the reclassified density map is multiplied by the reclassified visibility map by means of a raster overlay operation. In this way, a trend surface for the allocation of missing sites can be 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.

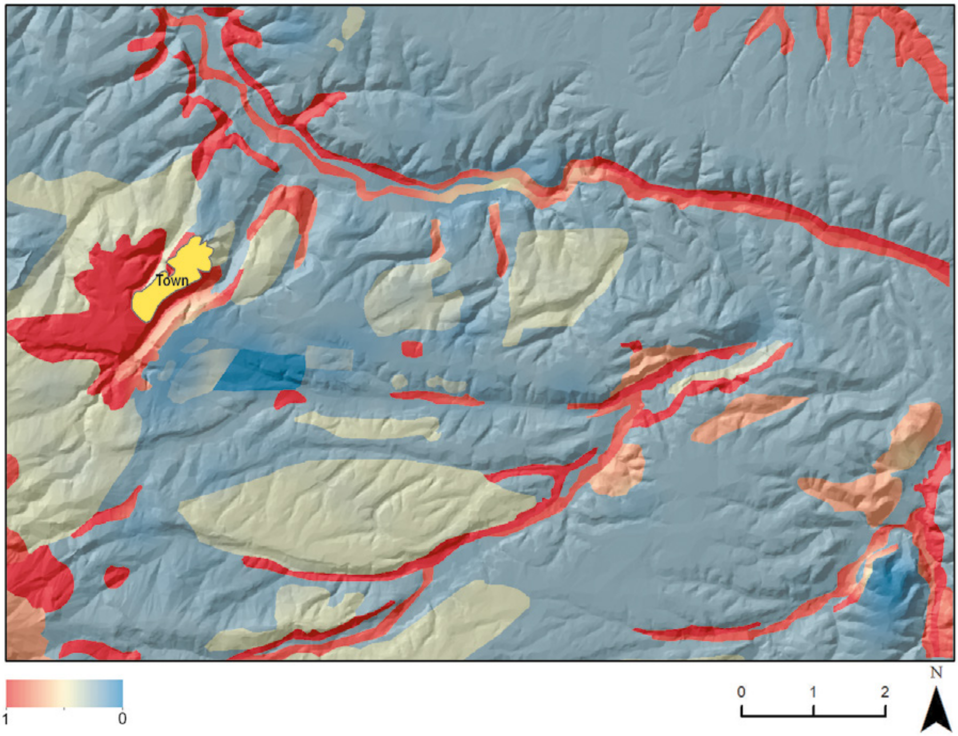

Fig. 3 – Trend surface created for missing site allocation. The legend indicates the probability for the allocation of missing sites and ranges from a minimum of 0 to a maximum of 1. The raster base map is the shaded relief calculated from the 10 m-resolution DEM named TINITALY/01 (Tarquini *et al.* 2007, 2012; Tarquini, Nannipieri 2017). Figure by the author.

c) The allocation of missing sites is implemented. The spatial principle underpinning the allocation of missing sites on the previously obtained trend map is very simple and in line with the conventional assumption of homogeneity in site density and pattern for the colonial countryside. Only few sporadic missing sites (or none at all) will be allocated in those cells where the recorded site density is high and the ground visibility is good since the probability for missing sites there is low. As the density and visibility decrease more sites will be allocated because of an inverse proportional relationship; in the zones where both the recorded site density and visibility are low, many sites will be spread out, because of the high probability for missing sites in these locations. Basically, this means that those cells characterized by both very low or low visibility and low recorded site density are more likely to receive a missing site than those cells with a high recorded site density in discrete or good visibility conditions. In ArcGIS there is a tool precisely suited for this type of operation: in order to create a uniformly dotted landscape, points representing missing sites can be scattered across the study area in a balanced way, in other words, in proportional accordance with the trend surface probability values (i.e. 'create spatially balanced points' tool in ArcGIS 10.2.2). As a future step to improve this simulation, it will be interesting to consider also other constraints for the allocation of sites (e.g. the relief), and note to what extent the exclusion of, for instance, steep slopes will change the simulated site configuration.

Once the trend surface has been obtained, it is necessary to calculate the hypothetical number of missing sites. 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, we do not use these previously-proposed numbers but we calculate new thresholds for missing sites using, instead, a GIS-based spatial and statistical method. Namely, the number of missing sites to be allocated in the landscape is scrutinized through several simulations and statistical tests: increasingly large samples of missing sites are allocated until the point at which the simulated settlement distribution clearly starts to exhibit a statistically significant regular pattern.

The pattern of these simulated distributions is evaluated by means of the nearest neighbor tool of ArcGIS (for other methods see e.g. Orton 2004; Ducke 2015). This tool permits to categorize the dominant pattern displayed by the simulated dots allocated in this region (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).

By applying the nearest neighbor analysis, we can establish the number of missing sites required to create a dispersed early colonial settlement distribution. For our case-study, the initial 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

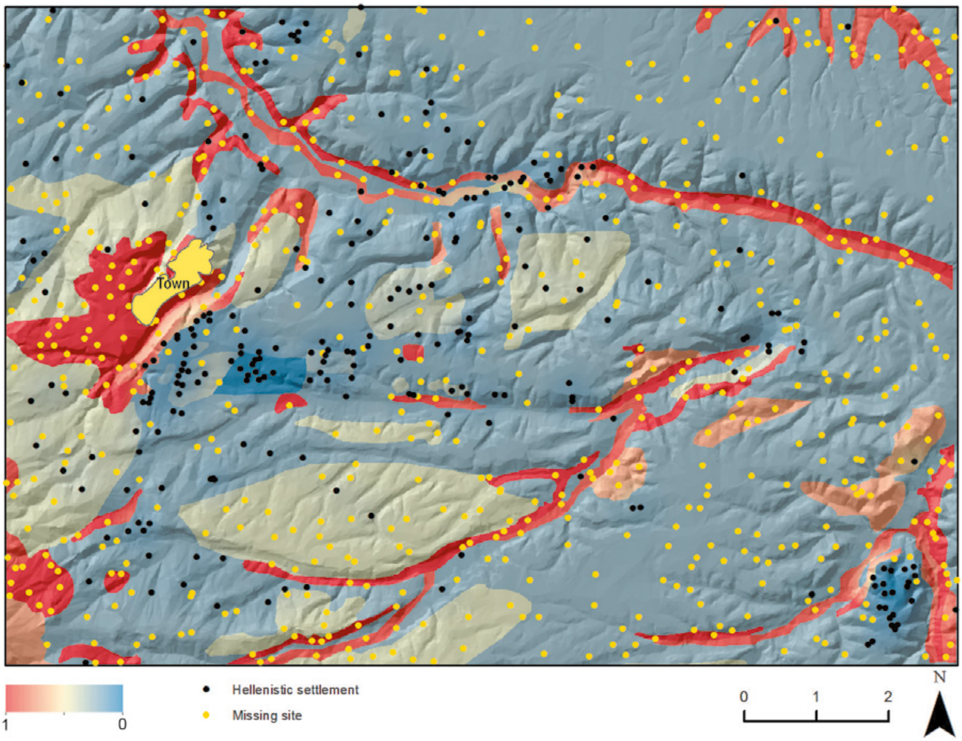

Fig. 4 – Trend surface created for the allocation of missing sites (probability from 0 to 1), and the simulated "complete" early colonial settlement distribution (262 recorded settlements plus 600 missing sites, therefore 862 sites in total). The raster base map is the shaded relief calculated from the 10 m-resolution DEM named TINITALY/01 (Tarquini *et al.* 2007, 2012; Tarquini, Nannipieri 2017). Figure by the author.

(at least) 600 missing sites had to be allocated over the trend surface and added to the 262 recorded settlements (Fig. 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 new dispersed settlement distribution has an average density of 6.8 sites per km² (Fig. 5). What is interesting to note is that this figure aligns very well with the demographic information cited in literary sources, from which a number of 7-8 colonists' farms per km² has been calculated by previous studies (Pelgrom 2008, 2012, 2013). Moreover, such a figure for missing colonial sites also accords very well with the 20-33% recovery rate that has been estimated for a regional 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;

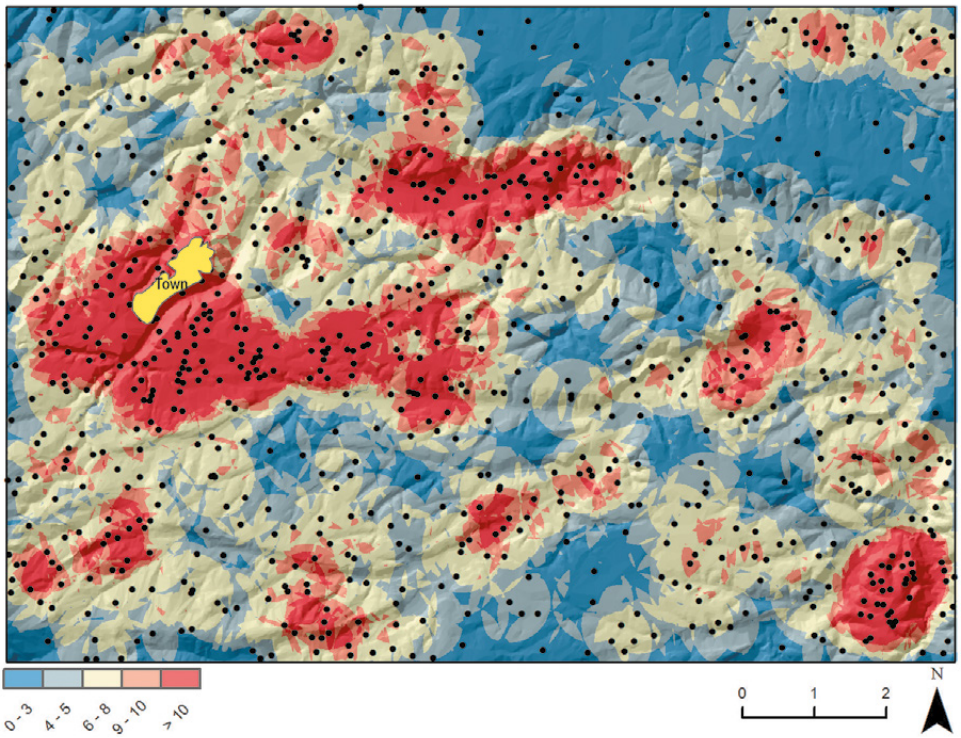

Fig. 5 – Point-density analysis of the "complete" early colonial distribution (262 recorded sites plus 600 missing sites, therefore 862 sites in total). The legend indicates the number of sites located in a circle of one square km from each cell (resolution 10×10 m). The raster base map is the shaded relief calculated from the 10 m-resolution DEM named TINITALY/01 (Tarquini *et al.* 2007, 2012; Tarquini, Nannipieri 2017). Figure by the author.

Witcher 2011). Indeed, for this simulated early colonial distribution (Fig. 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, cfr. *supra*).

It is important to stress, however, that the scale of the source visibility map plays a key-role in the simulation. As a matter of fact, if we had finer, more-detailed base maps on which to perform the allocation of missing sites, we would probably have obtained a different hypothetical distribution of early colonial settlements, and thus also different percentages for recorded and missing sites.

4. Discussion and further directions

As discussed above, 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 taken as the explanation for the missing colonial farm sites in most field survey projects (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 has been 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.

It must be kept in mind that 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 been recently 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 (e.g. Casarotto *et al.* forthcoming). 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 (Pelgrom 2008; Stek, Pelgrom 2013; Stek *et al.* 2015; Casarotto, Pelgrom, Stek 2016; 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), 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. The focus now shifts from showing how sites could have appeared on a map to understanding whether ancient settlements need to be even 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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Anita Casarotto
Faculty of Archaeology
Leiden University
a.casarotto@arch.leidenuniv.nl

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ABSTRACT

This paper proposes a GIS quantitative method for simulating dispersed distribution of sites in a landscape. A certain number of sites might have escaped archaeological detection due to the adverse surface visibility conditions experienced during field survey (the so-called missing sites). As regards early Roman colonial landscapes of central-southern Italy, these surface visibility factors were 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 a large amount of 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.