Location preferences of rural settlements in the territory of Venusia: an inductive approach

Anita Casarotto

This paper aims to point out the location preferences underlying the pattern of rural settlements located in the hinterland of the ancient town of Venusia (Southern Italy). An inductive approach is used to systematically analyze differences and similarities in location preferences of different settlement distributions. Specifically, distribution graphs are constructed from and statistical tests are applied on the existing settlement dataset to identify significant correlations (and trends in these correlations) between the settlement positions and several environmental and cultural characteristics of the landscape. These correlations can provide valuable insights into favored or avoided land units for settlement in the Hellenistic and Roman periods (particularly in the 4th – 1st century BC) in the territory of Venusia.

1 Introduction

This analysis explores and describes the location preferences exhibited by distributions of ancient rural settlements. Certain cultural and physical characteristics of the landscape could have influenced the pattern underpinning the empirical settlement evidence recorded by means of field surveys (first-order effects, Orton 2004; Palmisano 2013, 349; see discussion in Stone 1996, 6-27). This paper addresses whether this may indeed be the case for the pattern of ancient settlements in the Hellenistic and Roman colonial landscape of Venusia (Southern Italy). Through an inductive analysis, significant correlations and statistically meaningful trends in patterns are formally pointed out.

It is important to state, however, that the settlement rationale behind the detected location preferences will be investigated thoroughly in another paper (Casarotto *et al.* forthcoming). As a matter of fact, in the above mentioned forthcoming paper the trends in pattern that are identified in the inductive analysis presented here are going to be confronted also with those identified in a previous analysis (Casarotto *et al.* 2016) in which, instead, a deductive approach had been used. This comparison between the results from inductive and deductive analyses will enable us to eventually move from observations of patterns (some of which are described below and some others are reported in Casarotto *et al.* 2016; forthcoming) to interpretations of these patterns. The current paper, however, focuses on a quantitative and systematic description of the data available, and some of their correlations with the landscape.

The relationship between landscape variability and changes in the properties of settlement distributions is the main object of study of locational analysis (Haggett *et al.* 1977; cf. the critical discussion in Barnes 2003). The inductive approach to locational analysis falls under the umbrella of the ecological tradition of studies in human geography. It investigates how people adapt to the environmental conditions of the geographical setting where they live (above all to physical conditions) and if their settlements are located in some predictable way with respect to this environment (see Haggett *et al.* 1977, 1-6 for a description of the two, economic- or ecological-locational traditions of studies in human geography).

This ecological approach has been particularly influential in archaeological predictive modeling (Judge and Sebastian 1988; Kvamme 1990a; van Leusen and Kamermans 2005; Verhagen 2007; De Guio 2015; see criticism in Wheatley 2004). Regional inductive modeling (Kamermans and Wansleeben 1999), also known as data-driven predictive modeling (Wheatley and Gillings 2002, 166), aims to predict the position of archaeological sites in regions were systematic investigations were not conducted. It does this by projecting onto the *terra incognita* the correlations between settlement and environment that were previously detected by means of observations and/or statistical tests in known samples and regions (see the discussion in Kvamme 2006, 2011; for an example see Carrer 2013).

The focus of this paper lies on identifying these correlations for research purposes (Casarotto 2015, 35-38), rather than on predicting new sites in unexplored regions. The area under consideration here was systematically surveyed between 1989 and 2000 (Marchi and Sabbatini 1996; Sabbatini 2001; Marchi 2010; see also Stek 2012). Complete survey coverage of all accessible fields has been carried out and a representative sample of the (visible) surface evidence can be expected to have been successfully recorded. In this paper an explorative, bottom-up analysis is implemented on the available settlement record to point out the ecological zones and the land types within the surveyed sample area that, on the basis of attractive or repulsive properties, may have prompted the already-known settlements to favor or avoid certain locations. Eventually, this inductive location preference analysis will offer the opportunity to gain further understanding of ancient settlement strategies in this surveyed region of Southern Italy (Casarotto *et al.* forthcoming).

2 Data

The hinterland of the ancient town of Venusia was systematically surveyed by an Italian team led by M. L. Marchi and G. Sabbatini, who published in three books precise data about the position, the size and the chronological range of occupation for each site recorded (Marchi and Sabbatini 1996; Sabbatini 2001; Marchi 2010). On the basis of this information sites are organized per size and per period (see table 1 and fig. 1). For the purpose of this paper, the position of these attested archaeological sites was digitalized in GIS using the site distribution maps attached to these books (IGM maps, 1 : 25,000) as a georeferenced base. Only the location of the settlement sites was considered in the presented analysis.

It is important to bear in mind that the size of those settlement sites with multiple phases of occupation (*i.e.* "inherited settlements" in table 1) may have been different in the different phases (*e.g.* for multi-period large sites)[1]. It is difficult to trace, in the field, the chronological development in size of a site simply through the visual inspection of the artifact scatter configuration. For the majority of these inherited sites, surveyors could record only their largest extent.

An inductive analysis was implemented on the settlement samples listed in table 1, which are organized per period and per size. While it must be acknowledged that unpredictable or irretrievable cultural and environmental factors may have

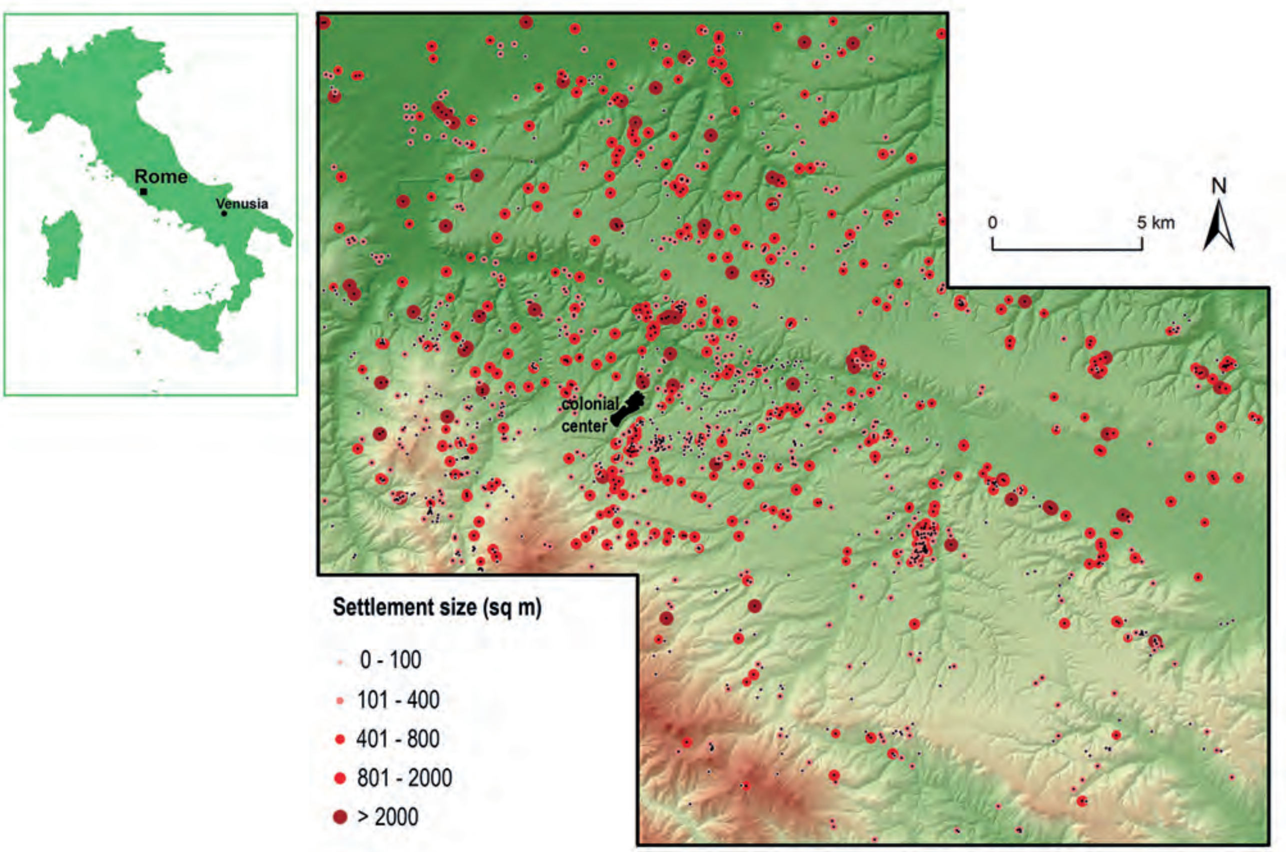


Figure 1 Settlement distribution (pre-Roman to Imperial period settlements). The position of the settlements is indicated by black dots. The extension of the red circles circumscribing these black dots does not match with the scale of the map; they are used here, and in the following figures, only as symbols for the size of these settlements (see legend). The raster base map for this and all subsequent figures is the shaded relief calculated from the 10 m-resolution DEM named TINITALY/01 (Tarquini *et al.* 2007, 2012; Tarquini and Nannipieri 2017) and is combined with an elevation colour palette

influenced (and possibly caused) past location decisions and resulting settlement patterns, only those factors which were retrievable and which could possibly have been influential for settlement purposes in this type of landscape can be analyzed (see below). The aim was to note macro-spatial tendencies in location preferences and to evaluate whether these regional tendencies changed through time.

Particular attention was paid to whether location preferences significantly changed from the pre-colonial to the early Roman colonial period (*i.e.* from the 5th – 4th to the 3rd century BC), the moment when Rome conquered this territory and supposedly revolutionized its rural organization (see discussion in Salmon 1969; Brown 1980; Rathbone 1981, 2008; Celuzza and Regoli 1982; Settis 1984). In order to assess this alleged drastic change in settlement organization, 3rd century BC settlement sites were selected and their location preferences compared with those of previous (and later) phases. In the graphs displayed in figures 3, 5, 7, 9, 11, 13, 15 and 17 the trends in distribution of both the totality of 3rd century BC sites (*i.e.* those sites that continue to exist plus those newly founded in this period) and the newly founded early colonial period sites are reported because, as previously underlined, the aim was to highlight the settlement developments occurred in this phase of occupation.

3 Method

As a first step, the environmental and cultural factors to be analyzed in the inductive analysis were calculated or imported in GIS (mostly using Idrisi GIS, Selva Edition – Eastman 2012, see below). These factors are altitude, slope, aspect, soil, location of dominant positions in the landscape (*i.e.* ridges and peaks), distance from a water source, distance from the city of Venusia, and distance from a road. Secondly, the settlement positions were confronted with these variables to calculate settlement counts that were subsequently converted into settlement percentages for each variable category. From this calculation, settlement distribution graphs were produced. These graphs were used as the main tool to observe and highlight possible trends and changes in the arrangement of settlement samples (figures 3, 5, 7, 9, 11, 13, 15, 17). Finally, statistical tests were applied[2]

Settlement size (sq m)

	0-100	101-400	401-800	801-2000	> 2000	Tot.
Pre-Roman settlements (5th-4th century BC)	100	88	34	45	22	**289**
Early colonial period settlements (3rd century BC)	18	34	9	18	10	**89**
Inherited settlements	7	13	6	6	7	39
New Early colonial period settlements	11	21	3	12	3	50
Republican settlements (3rd - 1st century BC)	168	218	74	109	37	**606**
Inherited settlements	20	21	12	13	10	76
New Republican settlements	148	197	62	96	27	530
Late-Republican - Triumviral settlements (1st century BC - 33 AD)	78	138	64	93	37	**410**
Inherited settlements	22	62	25	51	27	187
New Late Republican-Triumviral settlements	56	76	39	42	10	223
Imperial settlements (1st - 4th/5th century AD)	144	194	78	125	53	**594**
Inherited settlements (see note)	9	8	5	13	4	39
Inherited settlements	34	78	32	72	36	252
New Imperial settlements	101	108	41	40	13	303
Uncertain Pre-Roman-Imperial settlements	19	12	4	7	6	**48**

Table 1 Legacy survey data organized per period and per size. Archaeological sites were identified by teams of three to five surveyors spaced at five to ten m intervals, on a territory of ca. 700 sq km, using a minimum threshold of 5 sherds per sq m (see Marchi and Sabbatini 1996; Sabbatini 2001; Marchi 2010).
Note: These sites are not occupied in the Late Republican-Triumviral period but have a Republican phase of occupation

to further explore these trends and identify possible significant correlations between site distributions and these variables (Hodder and Orton 1976; Shennan 1988; Drennan 2009; Field 2009).

Statistical tests help discriminate between significant and non-significant correlations. It is possible for sites to occur with remarkable frequency in a certain land unit not necessarily because there was an intention in ancient human behavior to preferentially place dwellings there, but simply because this land unit covers a large extent of the territory. Chances to find sites in large regions are expected to be higher than in small regions, and thus the recorded number of sites may actually be statistically not-significant in this case. This is an important observation to bear in mind while analyzing the graphs in figures 3, 5, 7, 9, 11, 13, 15 and 17: peaks in settlement distribution, which indicate high percentages of sites in certain land units, may sometimes be explained by the large area covered by those land units rather than by real location preferences. For this reason, in order to single out location preferences that are more likely to be the result of intentional settlement choices (in other words, significant location preferences), both parametric and nonparametric statistical tests were used[3] (a significance level α of at least 0.05 was selected).

In the presented analysis, the former type of test assesses whether a significant difference may exist between the distribution of various settlement samples, whereas the latter type assesses where this difference emerged more prominently in the landscape. Specifically, parametric tests were used to evaluate whether, for each variable, the mean values of the distributions of periodic-size-site samples significantly differ from one another. For these tests, only continuous variables (*i.e.* variables that are measured along a continuum of numerical values) shall be considered (*e.g.* altitude).

On the other hand, nonparametric tests were performed on categorical variables, which are discrete variables composed of either ranked classes (*i.e.* ordinal variables, *e.g.* distance from the town of Venusia categorized in subsequent distance bands) or qualitative classes (*i.e.* nominal variables, *e.g.* soil categorized in soil units). Nonparametric tests are better suited for behavioral sciences, on account of several advantages: for instance, they are easier to use, they have less conditions (or, in other words, assumptions) to be met (or assumed to hold) in order to be appropriate, they can handle relatively small samples, and allow researchers to make inferences on the strength and, sometimes, also on the direction of the correlation (in other words, they can discriminate between favored and avoided classes/bands/units). They eventually indicate whether a correlation exists and where (in which class/band/unit) this correlation manifests itself. For the reasons specified above, in this paper greater significance is appointed to the results from the nonparametric tests (see also the discussion in Siegel 1956, 18 – 34).

First, a preliminary, explorative analysis was carried out to get a general impression of possible differences in distribution between site samples. The ANOVA and the parametric t-test were used to compare site samples of different periods and sizes[4] (Siegel 1956, 18-20; Drennan 2009, 147-163, Field 2009, 316-394). The one-way ANOVA (*i.e.* analysis of variance with one factor) was applied to assess whether the distribution mean of a group composed by site samples of subsequent periods, with the same size, was similar or not. When a divergence was detected, the t-test was applied to evaluate which pairs of samples may have had a significant difference in distribution mean (example in appendix I).

In order to detect possible differences in frequency distribution, the nonparametric Kolmogorov-Smirnov two-sample test (Siegel 1956, 127 – 136; Shennan 1988, 54 – 61) and the Chi-squared two-sample test (Siegel 1956, 104-116) were also used. They permitted to compare site proportions (of two independent site samples) attested in the variable categories[5].The former test was applied for ordinal variables, the latter for nominal variables.

Confronting the results from these tests with the distribution graphs (figures 3, 5, 7, 9, 11, 13, 15, 17), helped identify those site samples that seemed different from one another in their distribution[6].

Once the presence of possible distribution differences between site samples was assessed, the next question was where, most likely, these differences in distribution manifested themselves in the landscape. As a second step, the nonparametric one-sample Chi-squared (Siegel 1956, 42 – 47; Shennan 1988, 65 – 70), Kolmogorov-Smirnov (Siegel 1956, 47 – 52; Wheatley and Gillings 2002, 136 - 142) and Attwell-Fletcher tests (Attwell and Fletcher 1985; 1987) were used on relative frequencies of sites occurring in discrete variable categories (*i.e.* land types: classes, bands or units) to test for significant location preferences. These tests, especially the former two, are used widely in regional archaeological analysis to assess the degree of preference in site location (for other tests see *e.g.* Shennan 1988, 61 – 64, 114 - 189; Kvamme 1990b; Whatley and Gillings 2002, 136 - 142; Verhagen 2007, 48 - 50). In order to apply them to the data, the variables needed to be first classified into categories, after which the frequency of settlements occurring in each category could be controlled to assess the presence of a preference (or a disfavor) for the land type under study[7]. Subsequently, these preferences were compared to evaluate where precisely (*i.e.* in which land unit) sites of different period and/or size exhibited divergences in distribution (see results in appendix II). The distribution graphs helped locate possible differences in location preferences between samples in this case as well (figures 3, 5, 7, 9, 11, 13, 15, 17).

All these three tests are of the goodness-of-fit type. This means that they are tailored for detecting significant differences between an observed pattern of archaeological sites and an expected one (in other words, a theoretical, referent, random distribution of sites) with respect to certain environmental factors or cultural conditions of the landscape (Kvamme 1990b). The Chi-squared one-sample test (Siegel 1956, 42-47, best suited for nominal variables) only allows identification of whether a difference in frequency distribution exists between the observed and the expected sites but it cannot inform us about which significant correlations underpin the observed pattern (see also Shennan 1988, 74). It simply tells us if, for instance, settlements of a certain period or size are or are not equally located across all soil types (Shennan 1988, 69). The Kolmogorov-Smirnov one-sample test (for ordinal variables) can also pinpoint which land type has the greatest divergence between observed and expected cumulative frequency distributions of sites (Siegel 1956, 47-52). The Attwell-Fletcher test (1985, 1987) provides a very useful indication about the strength and the direction of a relationship in each land type (*i.e.* we can pose questions to our data like "are there significantly more or fewer sites than expected in a certain environmental category (*e.g.* altitude band 301 to 400 m a.s.l.)?"), and allows making statements like "the altitude band from 301 to 400 m a.s.l. is likely to have been significantly favored by small Republican settlements" (examples in appendix I)[8].

The procedure for calculating each variable is illustrated below, along with the significant correlations detected by means of distribution graphs and statistical tests (Results sections).

4 Altitude, Slope and Aspect

The basic topographic characteristics of a landscape can be described in terms of altitude, slope, and aspect conditions. These variables can be easily extracted from a digital elevation model (DEM). In this case, the 10-m resolution DEM named TINITALY/01 was used for such a calculation (Tarquini *et al*. 2007, 2012; Tarquini and Nannipieri 2017)[9]. As a second step altitude, slope, and aspect variables were classified into bands or classes (figs 2, 3, 4, 5, 6 and 7).

Altitude, slope, and aspect conditions may have an impact on both settlement and agriculture: for instance, south-facing slopes receive a good level of sunlight and are less exposed to winds, which could ease cultivation. On the contrary, more extreme elevation and slope conditions were likely avoided for settlement and cultivation purposes in the past due to the difficulty in living in and farming on these locations (see also Goodchild 2007, 123 – 140).

4.1 Results

Site samples generally have a quite similar distribution with respect to slope and aspect variables and do not exhibit significant correlations with them (figures 5 and 7). On the contrary, clear significant correlations in distribution could be pointed out for the altitude variable (fig. 3). Both pre-Roman and early colonial period settlements exhibit a positive correlation (more sites than expected) with the 4th altitude band (401 – 500 m a.s.l) and a negative correlation (fewer sites than expected) with the 1st band (138.6 – 200 m a.s.l) (see results in appendix II). The Republican and Late Republican (LR) - Triumviral settlements tend, instead, to be preferentially located in the 3rd altitude band (301-400 m a.s.l).

As regards size site samples, the highest variability in location preferences is exhibited by the smallest site categories (0-100 and 101-400 sq m settlements), that have the most typical and diverging distribution in the different periods with respect to altitude and slope values. This is evident if we look at the various graphs of the periodic-size-site samples (figures 3 and 5). Interestingly, for elevation and slope factors also the t-test and the Kolmogorov-Smirnov two-sample test pointed out significant differences in distribution between small pre-Roman settlements and small Republican settlements, and between small Republican settlements and small Imperial settlements (see results in appendix II).

According to the Attwell-Fletcher test results (see appendix II), indeed, the small pre-Roman settlements display a significant preference for the 4th and 5th altitude band and a refusal for the 1st band, small Republican settlements have a preference for the 3rd altitude band, and small Imperial settlements have a preference for the 5th band and a refusal for the 1st band. Similarities, instead, were exhibited by small pre-Roman settlements and small early colonial period settlements, small early colonial period settlements and Republican settlements, small Republican settlements and small LR-Triumviral settlements, and small LR-Triumviral settlements and small Imperial settlements. As regards medium and large sites, there are similarities between pre-Roman, early colonial period, and Republican settlements, and also between Republican and LR-Triumviral settlements. The one-sample tests detected only one clear correlation, namely with the large Imperial settlements (and probably also with the large LR-Triumviral settlements) that exhibited a preference for the 1st altitude band (138.6 - 200 m a.s.l).

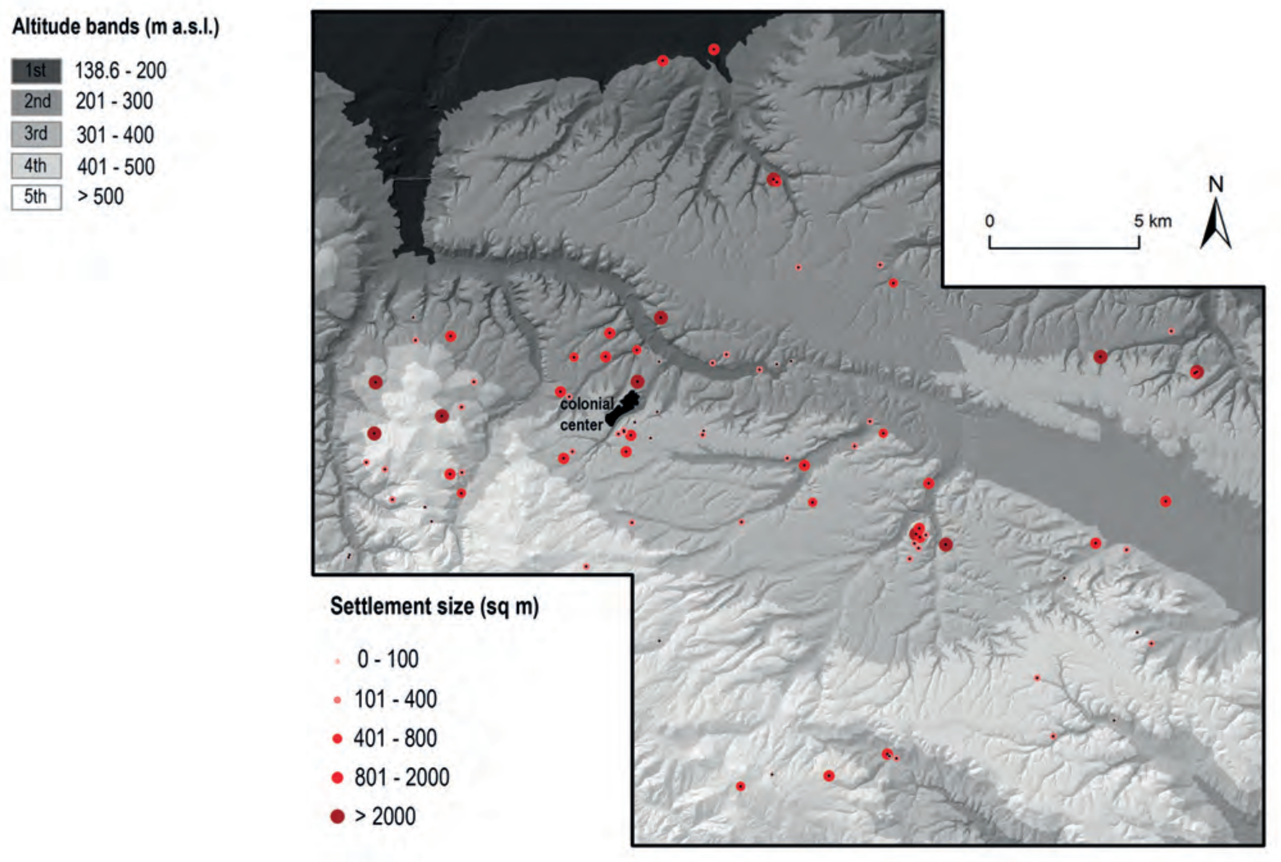
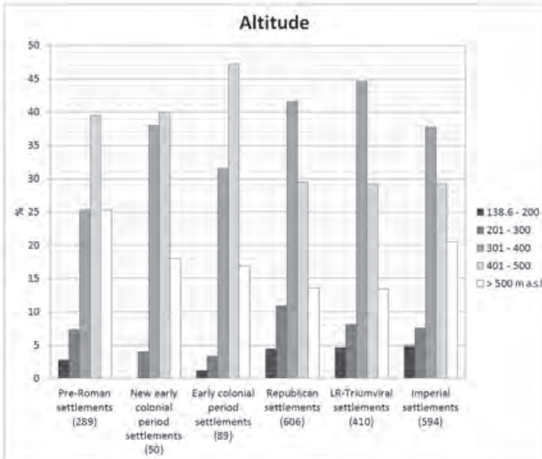


Figure 2 Altitude variable (based on the 10 m-resolution DEM named TINITALY/01, Tarquini *et al.* 2007, 2012; Tarquini and Nannipieri 2017) categorized in elevation bands and distribution of the early colonial period settlements



Altitude band		Area (sq m)	%
1st	138.6 - 200	42809500	6.2
2nd	201 - 300	78911100	11.3
3rd	301 - 400	236098000	34.0
4th	401 - 500	179970600	25.9
5th	> 500 m a.s.l.	157493000	22.7
	Tot.	695282200	100

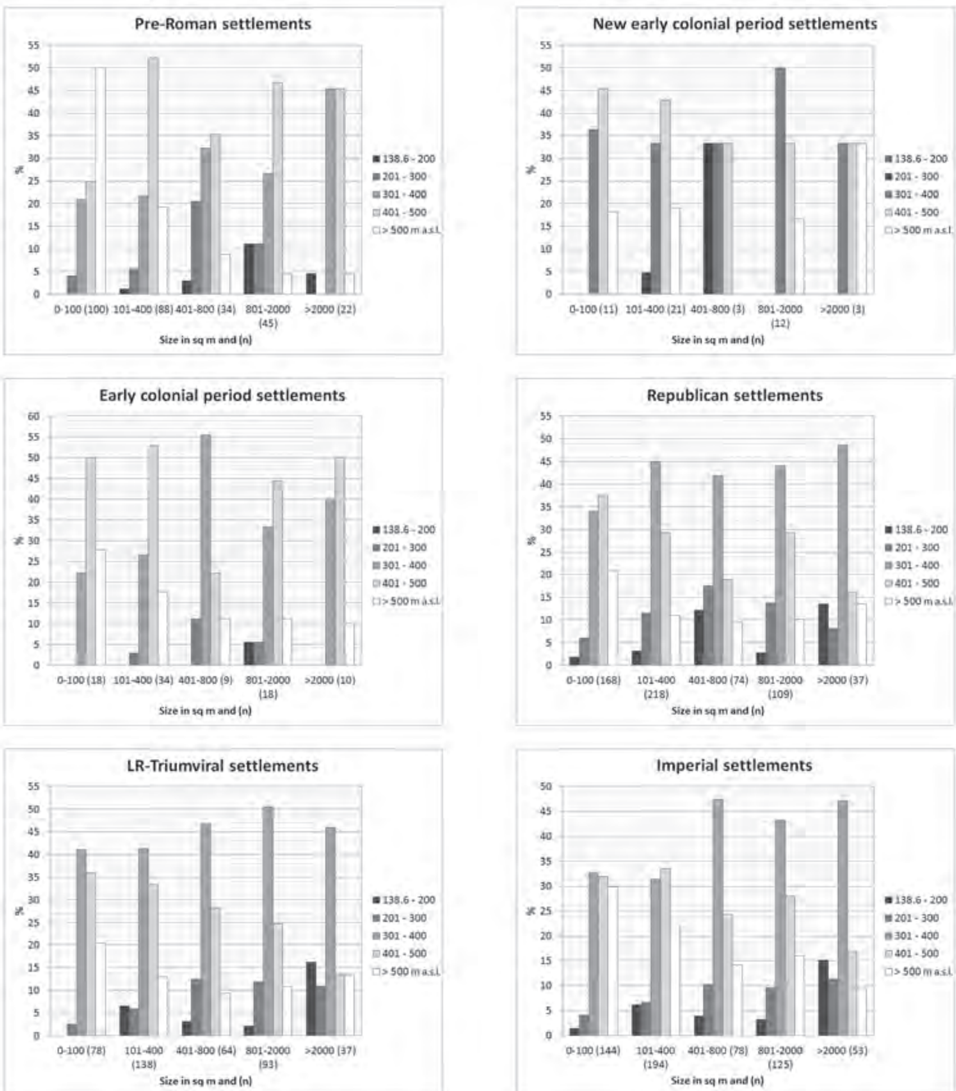


Figure 3 Settlement percentages with respect to altitude bands. In brackets, total number of settlements per sample (n)

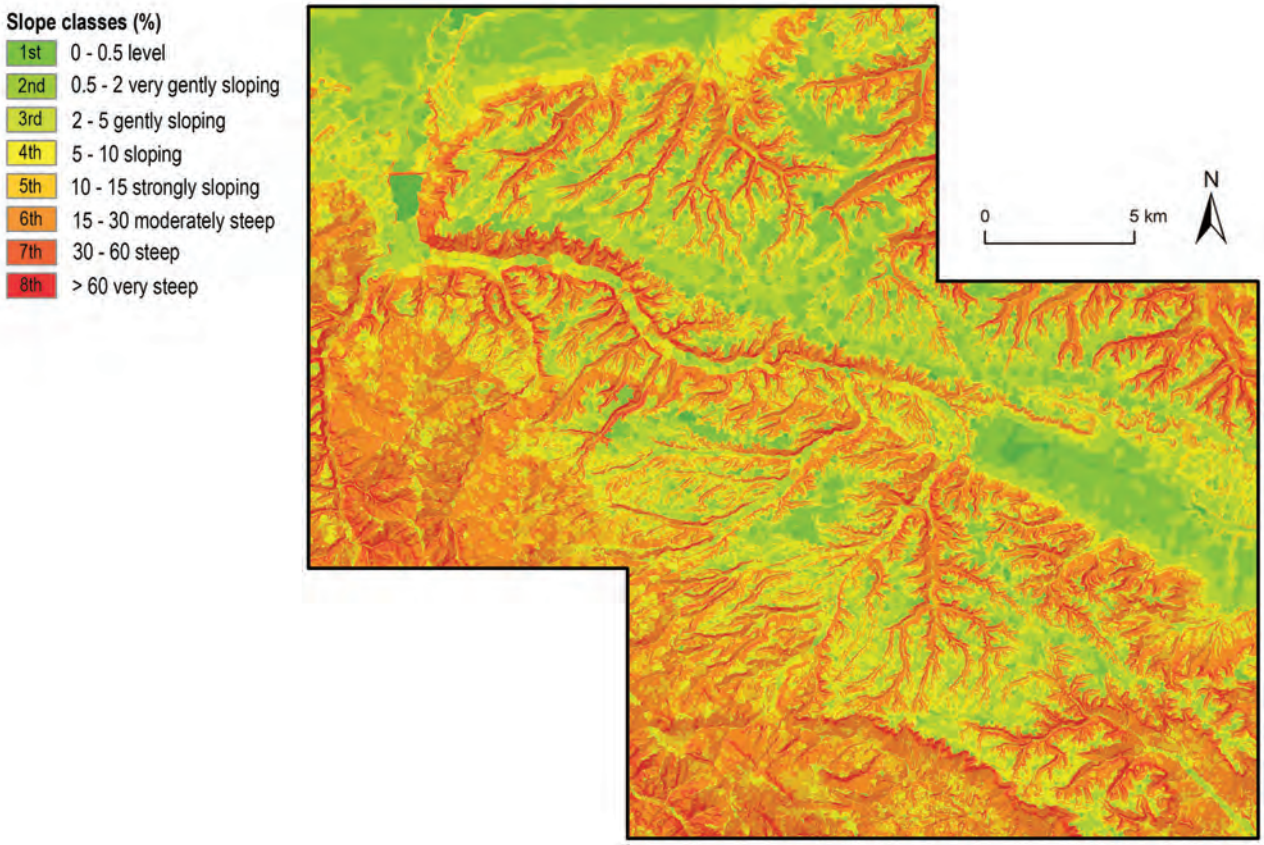
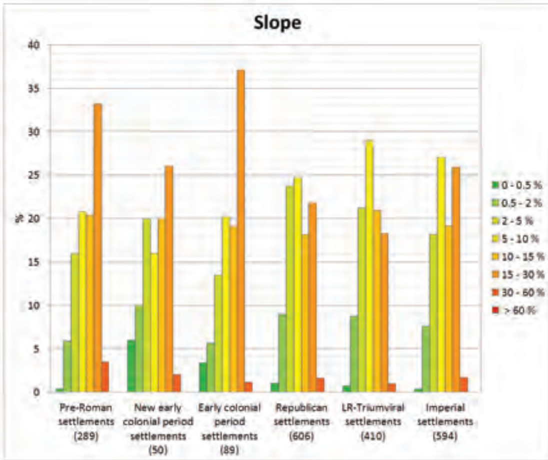


Figure 4 Slope variable (calculated from the 10 m-resolution DEM named TINITALY/01, Tarquini *et al.* 2007, 2012; Tarquini and Nannipieri 2017) categorized in classes. The categorization in slope classes is based on FAO 2006 (p. 12)



Slope class		Area (sq m)	%
1st	0 - 0.5 %	3679400	0.53
2nd	0.5 - 2 %	79234200	11.40
3rd	2 - 5 %	130012400	18.70
4th	5 - 10 %	121022700	17.41
5th	10 - 15 %	107931100	15.52
6th	15 - 30 %	201213300	28.94
7th	30 - 60 %	49488800	7.12
8th	> 60 %	2700300	0.39
Tot.		695282200	100

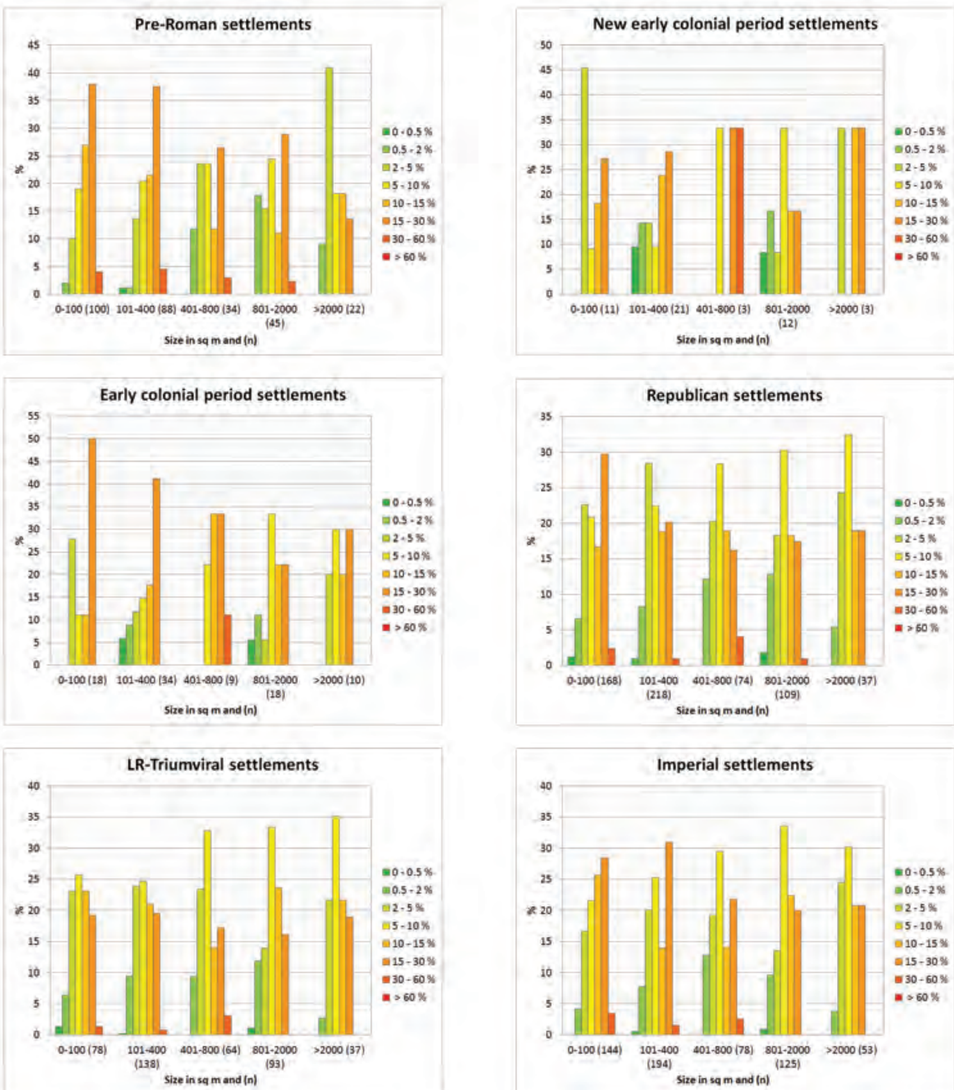


Figure 5 Settlement percentages with respect to slope classes. In brackets, total number of settlements per sample (n)

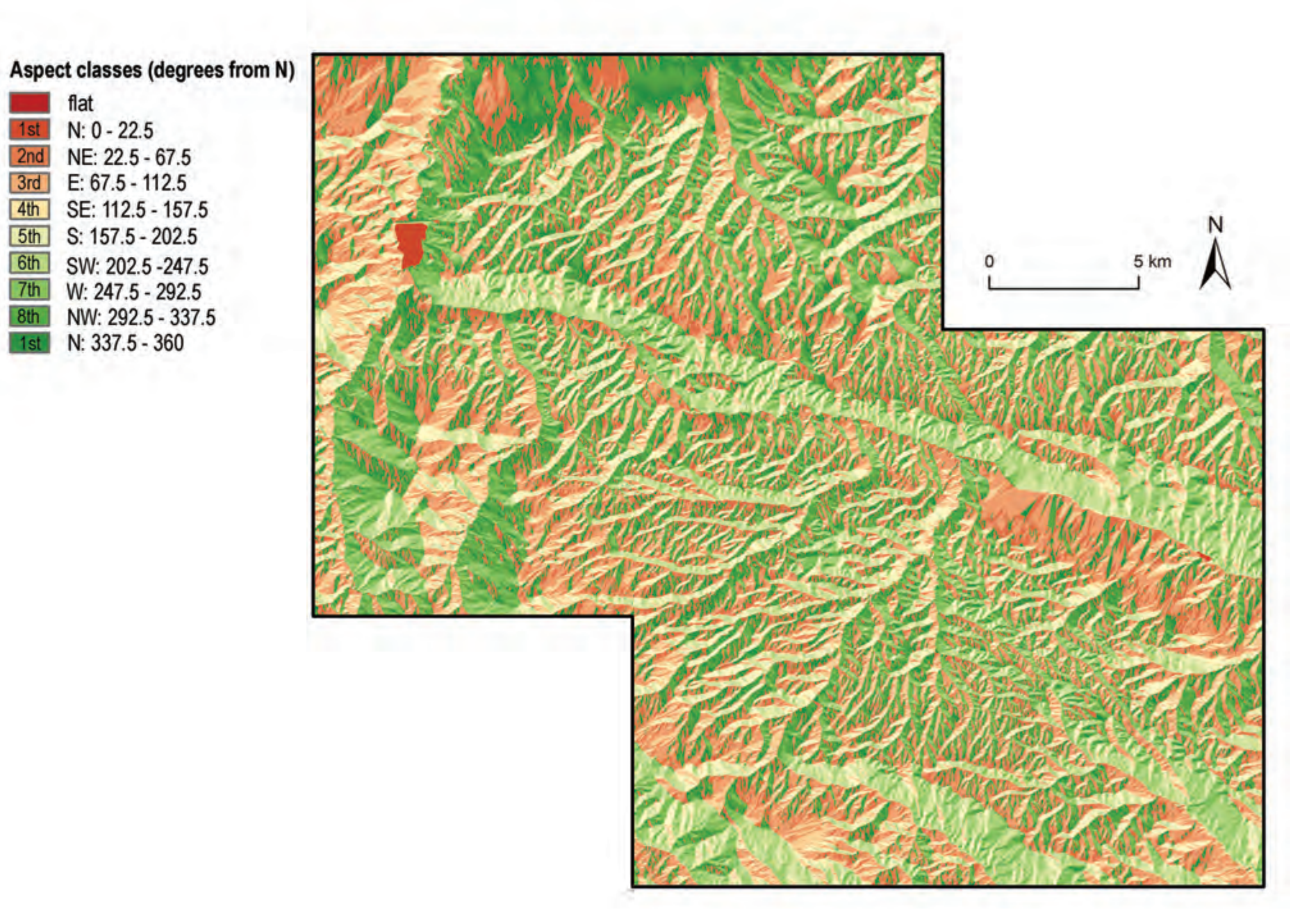
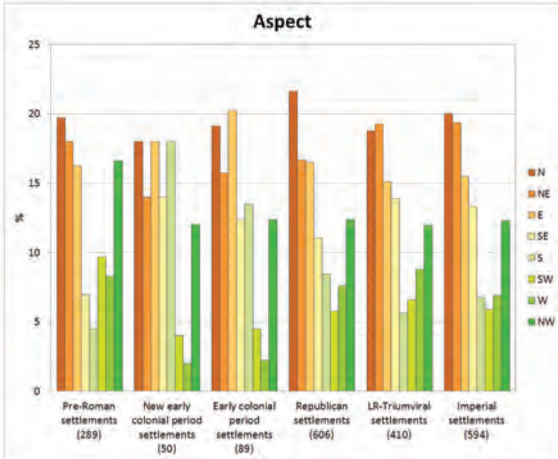


Figure 6 Aspect variable (calculated from the 10 m-resolution DEM named TINITALY/01, Tarquini *et al.* 2007, 2012; Tarquini and Nannipieri 2017) categorized in classes. The categorization in aspect classes is based on ESRI 2014



	Aspect class	Area (sq m)	%
	Flat	63400	0.01
1st	N	143747900	20.67
2nd	NE	112804900	16.22
3rd	E	84013500	12.08
4th	SE	74520900	10.72
5th	S	60661100	8.72
6th	SW	55319500	7.96
7th	W	64981400	9.35
8th	NW	99169600	14.26
Tot.		695282200	100

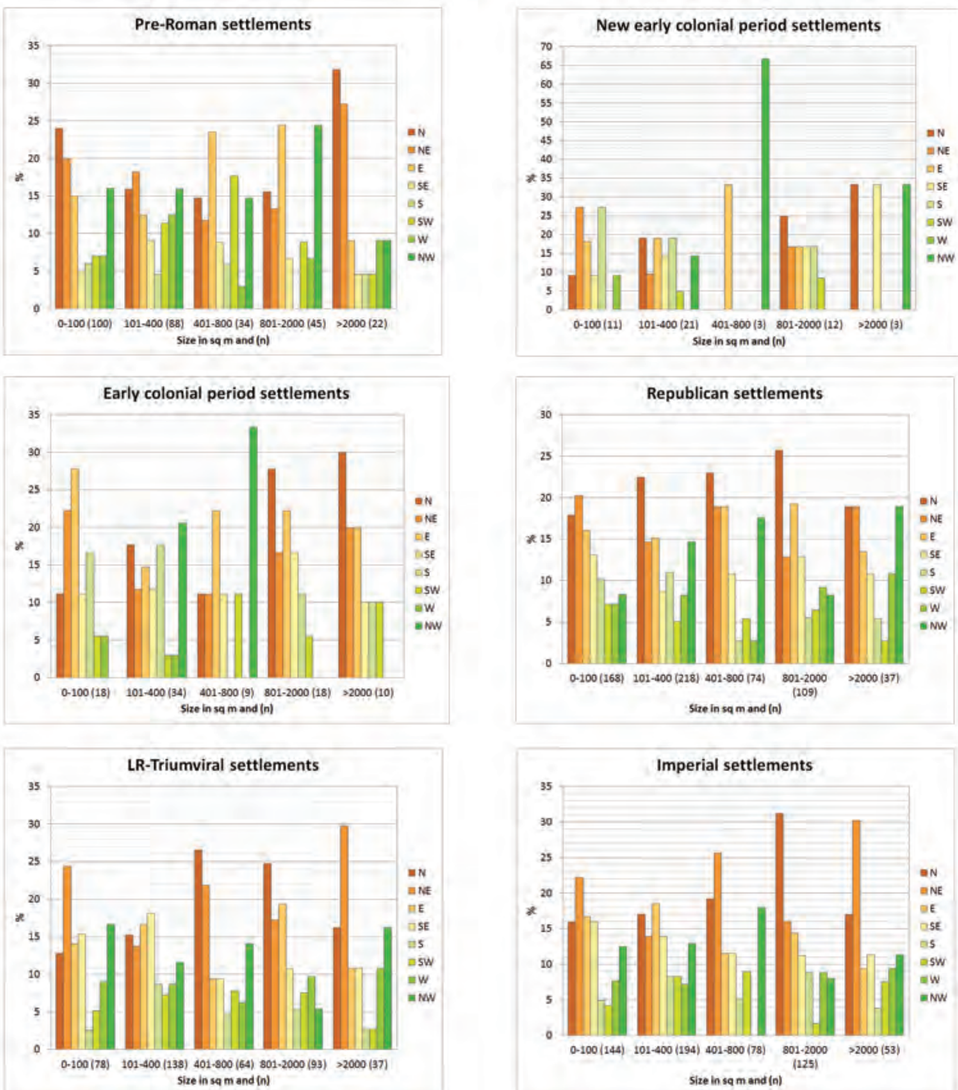


Figure 7 Settlement percentages with respect to aspect classes. In brackets, total number of settlements per sample (n)

5 Soil

Topographic, geological, and pedological information is extremely useful for distinguishing the types of land units characterizing a landscape. This information can be acquired from a soil map and its legend. The soil map of the Regione Basilicata (1 : 250,000)[10] was used for such a purpose (fig. 8)[11]. This soil map provides a very good description of the macro-regional geomorphological units characterizing this landscape. The land units outlined in table 2 were controlled to see whether correlations between settlement distributions and soil/geomorphological conditions may have existed, and if these correlations changed over time (fig. 9). It is important to underline, however, that the present natural conditions and the present distribution (and qualities) of soil types may, of course, be different to those which existed in the past. As a matter of fact, erosion and deposition processes that occurred after the abandonment of settlements, along with modern anthropic transformations, may have altered the appearance and the properties of the Hellenistic and Roman landscape (Judson 1963; Vita-Finzi 1969; Potter 1976; Sevink 1985; Bintliff 1992; Allen *et al.* 2002; Lefèvre *et al.* 2010; Casarotto *et al.* 2017).

According to conventional views on Roman settlement and economy, fertile and easily workable soils were particularly attractive for settlement and related agricultural activities in Roman times (see the discussion in White 1970; Dyson 1978; Celuzza and Regoli 1982; Settis 1984; Garnsey 1988, 49; Rathbone 1981, 2008; Goodchild and Witcher 2010; Witcher 2016; but see also the discussion in Boserup 1981, 63 – 80). Favorable soils may have been those rich in volcanic minerals and nutrients developing in alluvial plains, in gentle and wide middle-height plateaus, or in low, gently sloping hills. The former situation is represented, for instance, by land unit 14.1; the second condition is represented by unit 14.2 and the latter situation by unit 9.2 (see table 2 and fig. 8).

5.1 Results

A significant correlation with the most fertile soils of this landscape is exhibited by the LR-Triumviral and Imperial settlements (respectively with unit 14.2 and 9.2). This does not seem to be the case for the early colonial and Republican settlements that, instead, concentrate on less-conducive sandy conglomeratic soils (unit 11.1). It is also interesting to note that the totality of pre-Roman settlements exhibits a preference for unit 6.3 and 6.4 corresponding to the mountainous and hilly areas of the landscape.

As underlined for altitude, slope and aspect, for the soil variable the smallest site samples (0-100 and 101-400 sq m settlements) are also characterized by the highest number of significant differences between periods. Interestingly, small Imperial settlements have a significant preference for unit 9.2 whereas small pre-Roman settlements have a preference for unit 6.3. On the other hand, small Republican settlements have a pattern which seems very similar to the LR-Triumviral one (fig. 9). In addition to that, the Attwell-Fletcher test indicates a correlation for the large pre-Roman settlements that have a preference for unit 14.3.

6 Location of dominant positions in the landscape

Beside landscape exploitation, the visual control over the surrounding territory, or over other settlements, could also have been a strategic factor for the survival and success of a settlement system. Dominant positions in the landscape may thus have been appealing points for certain types of settlement sites. Ridges and peaks, therefore, can be expected to have attracted settlement interests at certain historical periods (figs 10 and 11). The ridge and peak environmental condition was calculated from the TINITALY/01 DEM (Tarquini *et al.* 2007, 2012; Tarquini and Nannipieri 2017) in LandSerf GIS (Wood 2009) through a geomorphological modeling of the relief ('feature extraction' tool)[12]. Only those

Table 2 Soil units. This is a basic classification based on the information provided by the legend of the soil map of Regione Basilicata. For more detailed descriptions of soils and soil properties see http://www.basilicatanet.it/suoli/carta2.htm ; http://www.basilicatanet.it/suoli/province.htm. For these land units a qualitative evaluation of the suitability for general agricultural purposes (*i.e.* plant growth) is proposed (see last column). The productive potential (*e.g.* low, medium, high) of each land unit is established on the basis of two important qualities of the soil (see also Vink 1975, 196 – 208), namely fertility (here depending on the availability of nutrients and minerals, and the drainage status of the soil) and workability (here depending on slope and stoniness qualities, White 1970; Frayn 1979; Spurr 1986). In principle, abundance of plant nutrients and minerals along with a good drainage are typical of fertile soils; flat to gently sloping surfaces with scarce presence of stones are typical of easily workable soils. The land qualities from which fertility and workability are inferred (cf. supra) have been estimated on the basis of the information provided in Vink 1975, Kamermans 2000, FAO 2014, and in the legend of the soil map. In addition to that, for several of these units the land qualities related to workability could also be assessed directly, in the field, during recent archaeological field surveys, in which surveyors recorded systematically both slope and stoniness conditions of the fields (LERC survey campaigns 2013 – 2016, see Pelgrom *et al.* 2014, Pelgrom and Tetteroo 2015; https://landscapesofearlyromancolonization.com/)

Soil unit	Area (sq km)	%	Landscape type	Topography	Geology	Soil type WRB 98	Modern land use	Fertility	Workability with basic tools	Suitability for agriculture
6.3	13.2	1.9	Mountains	Moderately steep to very steep	Quartz sandstones with thin layers of clay rocks	Eutric Cambisols / Endogleyi-Luvic Phaeozems	Mainly forest	Medium/ Low	Low	Low
6.4	6.7	1	Mountains	Gently sloping to steep	Sandstones and marls	Eutric Cambisols	Forest and pasture	Medium	Medium	Medium
7.3	67.3	9.7	Hills	Undulating	Clayey slate rocks and marls	Luvi-Vertic Phaeozems / Calcaric Regosols	Arable	Medium/ Low	Medium	Medium/Low
7.5	7.4	1.1	Surfaces connected the hills with the alluvial landscape	Flat to gently sloping	Clayey marls	Luvi-Calcic Kastanozems	Arable	Medium	Medium	Medium
9.2	15.8	2.3	Hills	Gently sloping to moderately steep	Pyroclastic colluvial deposits	Luvic Phaeozems / Eutric Cambisols / Dystri-Andic Cambisols	Mainly viticulture and olive orchards alternate to forest and pasture	High	Medium	Medium/High
11.1	280.0	40.2	High plateaus (ancient Pleistocene surfaces)	Flat to gently sloping	Sands and Pleistocene conglomeratic deposits	Luvi-Vertic Kastanozems / Luvic Kastanozems/ Calcic Vertisols	Arable	Medium	Medium/Low	Medium/Low
11.2	136.0	19.5	Slopes of the higher plateaus	Gently sloping to steep	Sands and Pleistocene conglomeratic deposits	Luvic Kastanozems / Eutric Cambisols / Calcari-Arenic Regosols	Arable	Medium/ Low	Low	Low
12.1	23.3	3.4	Hills	Undulating	Clayey and silty marine deposits, mainly marls	Hyposodic Vertisols / Luvi-Vertic Kastanozems	Arable	Medium	Medium	Medium
14.1	29.0	4.2	Alluvial plain	Flat	Fluvio-lacustrine deposits (with pyroclastic material)	Pelli-Calcic Vertisols	Arable	High	High	High
14.2	61.5	8.8	Low plateaus (fluvio-lacustrine terrace)	Flat	Fluvio-lacustrine deposits (with pyroclastic material)	Luvi-Vertic Phaeozems / Calcic Vertisols	Arable and pasture	High	High	High
14.3	8.9	1.3	Surfaces connected the plateaus with the alluvial landscape	Flat to gently sloping	Alluvial deposits and colluvial deposits with clayey and sandy granulometry	Eutri-Vertic Cambisols	Arable	Medium	High	Medium/High
14.4	2.5	0.4	Alluvial terraced conoids	Flat to gently sloping	Sandy and clayey deposits	Calcic Luvisols	Arable	High	High	High
14.5	9.7	1.4	Alluvial terraces	Flat to gently sloping	Sandy, clayey and silty deposits	Petric Calcisols / Eutri-Fluvic Cambisols	Arable	Medium	Medium	Medium
14.6	15.4	2.2	Alluvial terraces	Flat to gently sloping	Higher clayey and silty deposits, lower sandy and gravelly deposits	Luvic Phaeozems / Haplic Calcisols / Eutric Vertisols	Arable	Medium	High	Medium/High
14.7	19.1	2.7	Valley floors	Flat	Sandy and stony deposits	Eutri-Fluvic Cambisols / Calcaric Phaeozems / Calcari-Arenic Regosols	Arable	Medium/ Low	Medium	Medium

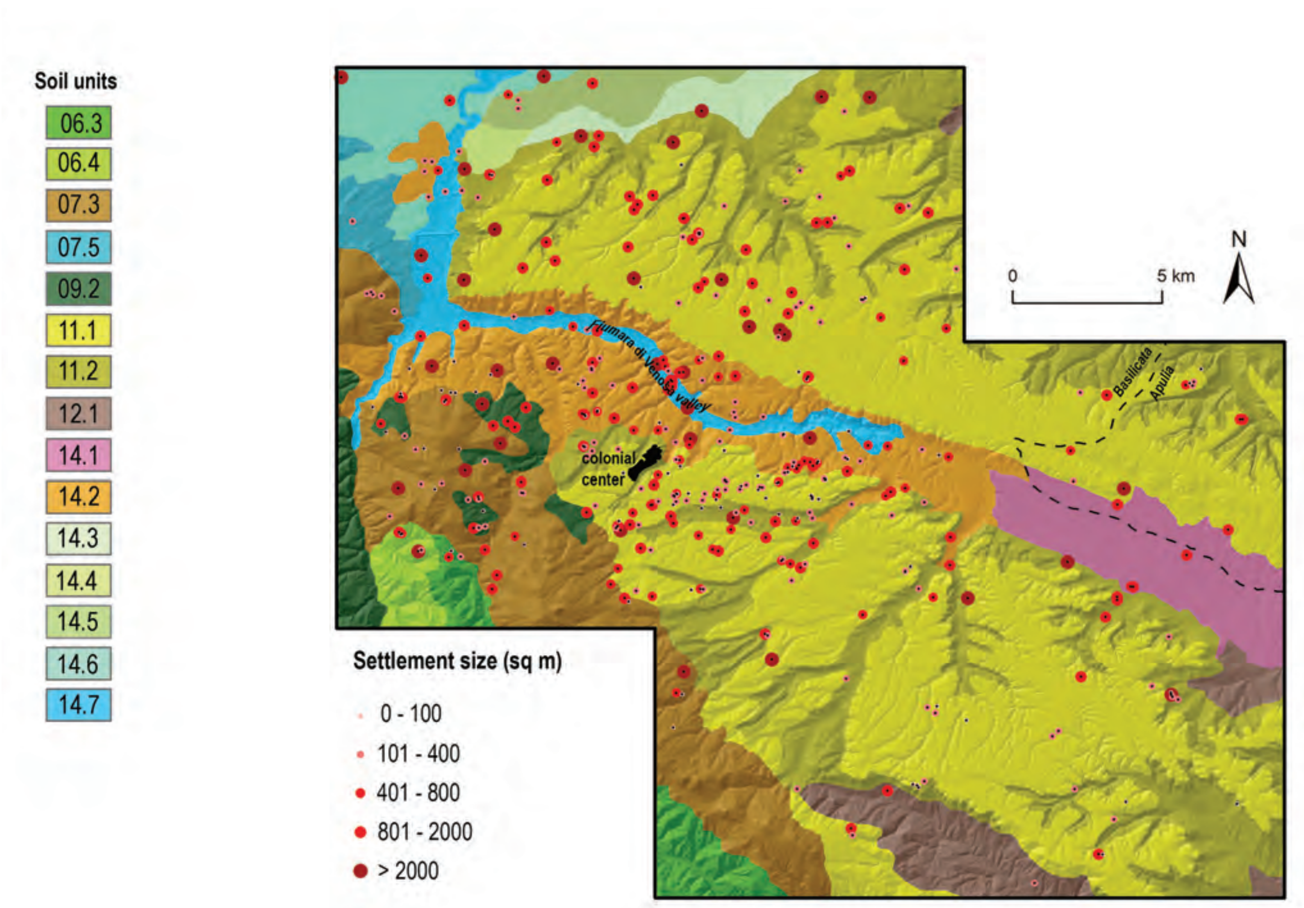
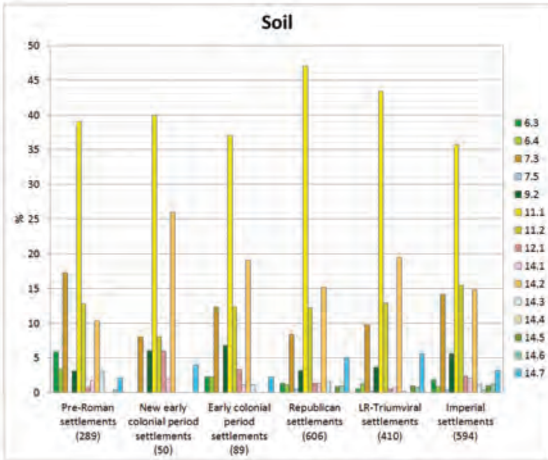


Figure 8 Soil variable classified in units and distribution of the LR-Triumviral settlements. The base map for the territory within the administrative borders of the Basilicata region is the soil map of the Regione Basilicata (1: 250, 000) (Ufficio Produzioni Vegetali e Silvicoltura Produttiva - Dipartimento Agricoltura, Sviluppo Rurale, Economia Montana - Regione Basilicata). Outside this territory soil properties were reconstructed; for further information see notes 10 and 11 of this paper



Soil unit	Area (sq m)	%
6.3	13156400	1.89
6.4	6690000	0.96
7.3	67255200	9.67
7.5	7361700	1.06
9.2	15808800	2.27
11.1	279720100	40.23
11.2	135817200	19.53
12.1	23297100	3.35
14.1	28993500	4.17
14.2	61494600	8.84
14.3	8919300	1.28
14.4	2542200	0.37
14.5	9745700	1.40
14.6	15408200	2.22
14.7	19072200	2.74
Tot.	695282200	100

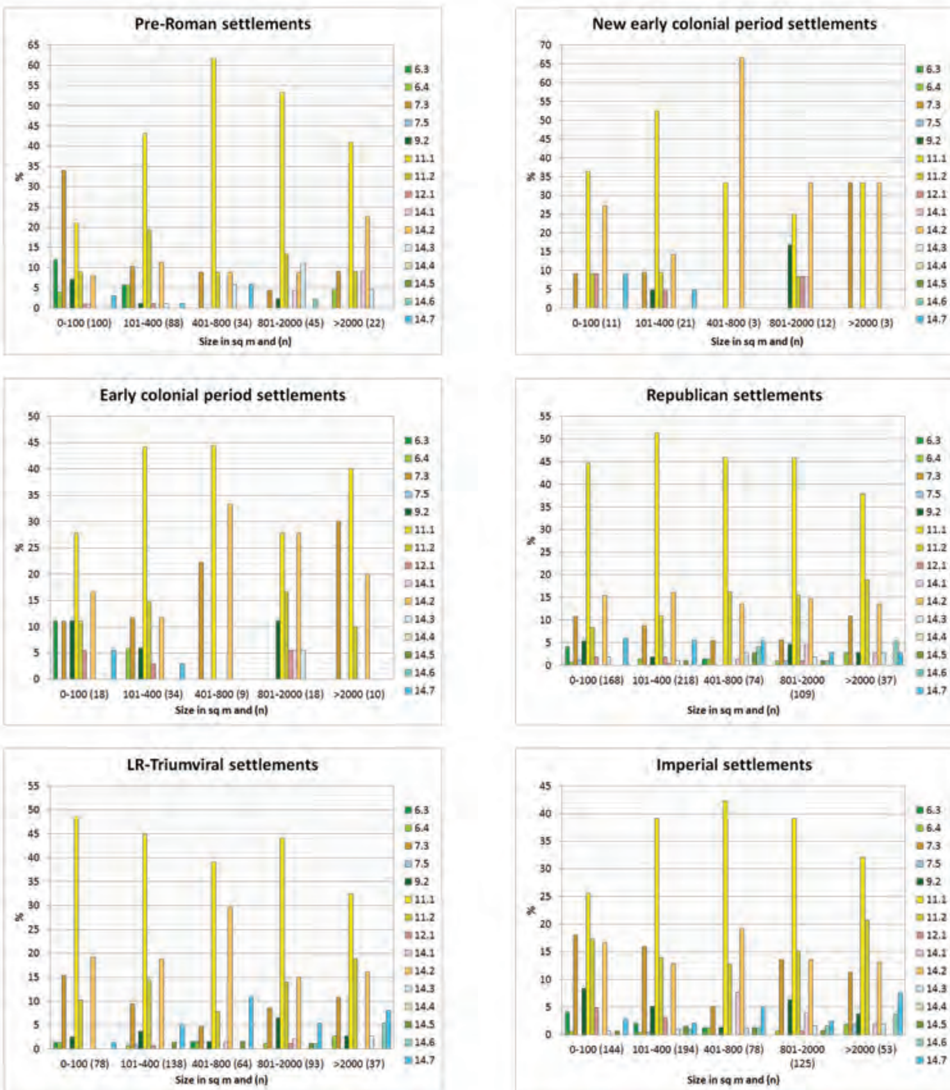


Figure 9 Settlement percentages with respect to soil units. In brackets, total number of settlements per sample (n)

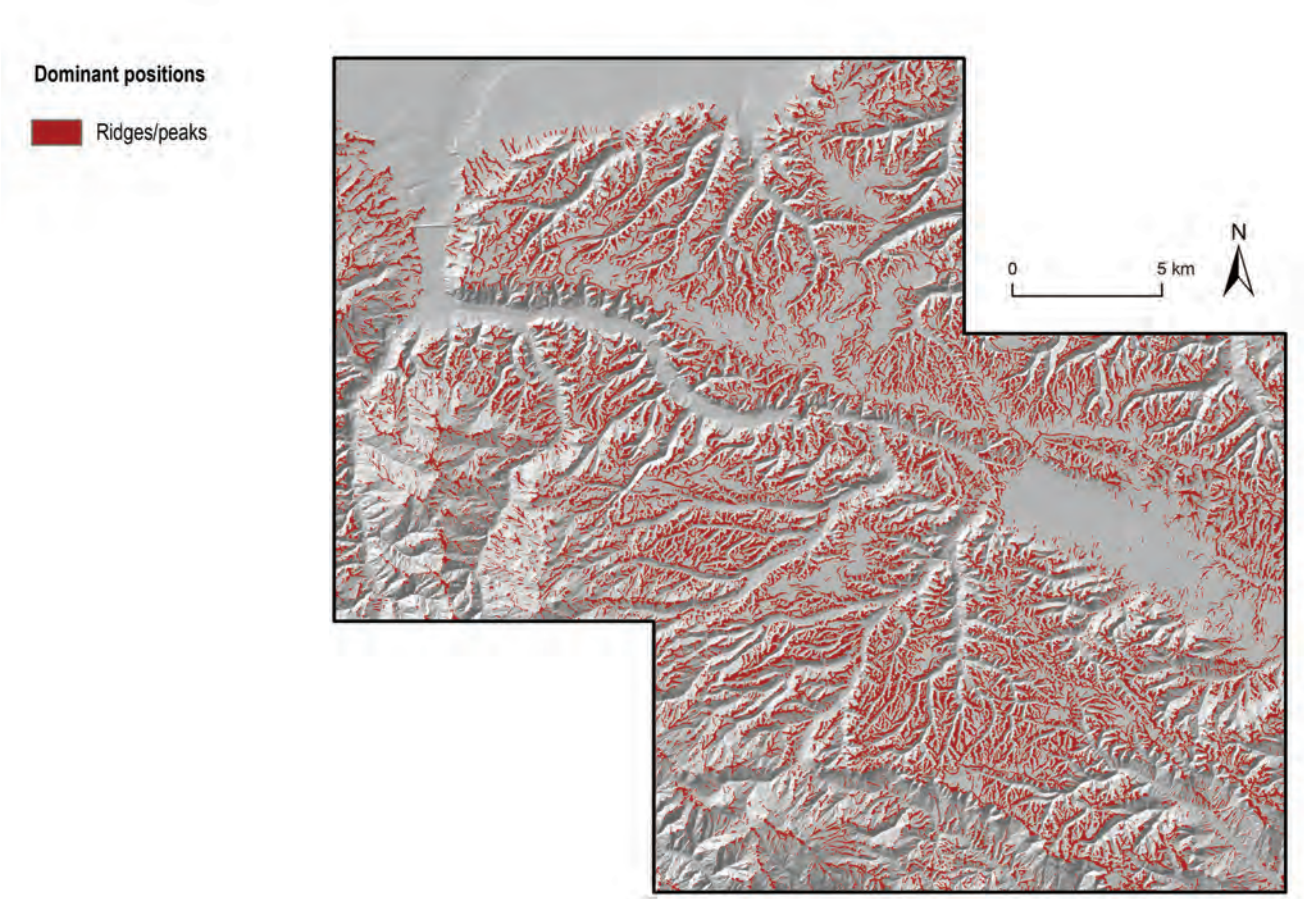
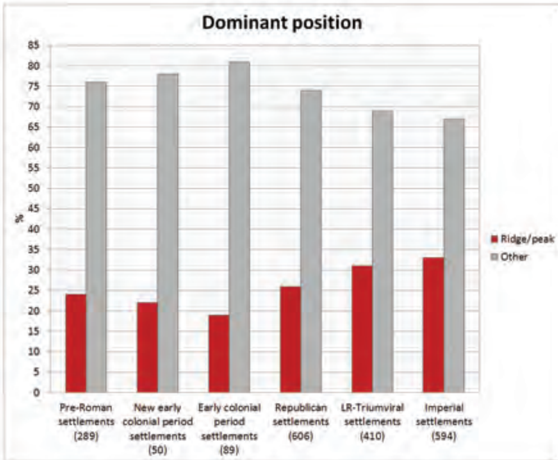


Figure 10 Location of dominant positions in the landscape (calculated from the 10 m-resolution DEM named TINITALY/01, Tarquini *et al.* 2007, 2012; Tarquini and Nannipieri 2017)



Dominant position	Area (sq m)	%
Ridge/Peak	129836500	18.67
Other	565445700	81.33
Tot.	695282200	100

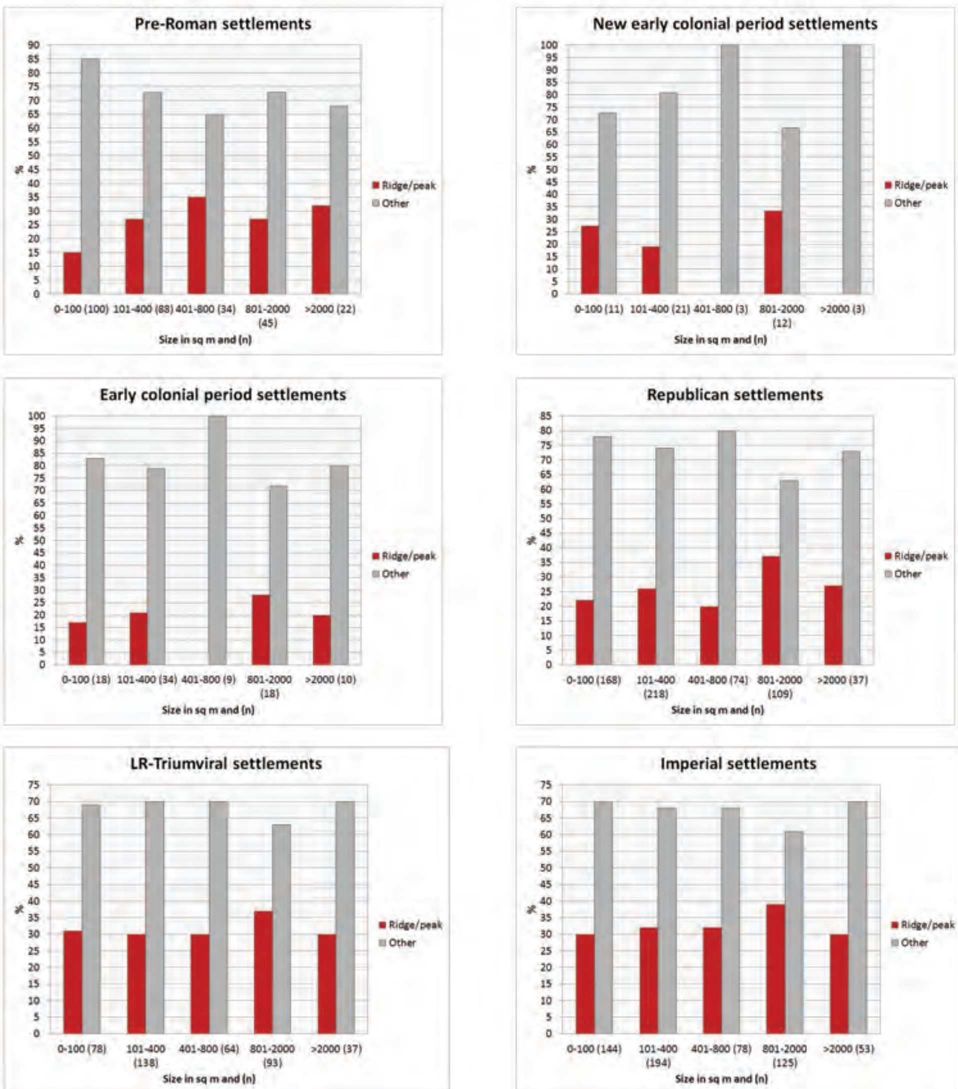


Figure 11 Settlement percentages with respect to dominant positions of the landscape. In brackets, total number of settlements per sample (n)

ridges and peaks located above the valley floors (higher positions) and in planar topographical locations were considered in the analysis. The aim was to assess whether there was a significant element of choice for dominant land marks in the location of settlements.

6.1 *Results*

There is a tendency for pre-Roman, Republican, LR-Triumviral, and Imperial settlements to be located on peaks or ridges. This preference is also exhibited by several size site samples and, interestingly, by all Imperial size site samples but the largest. The largest settlements (> 2000 sq. m) of all historical periods considered here do not seem to be attracted by such locations (for a possible explanation see Casarotto *et al.* forthcoming).

7 Distance from water

Access to water is probably the most important pragmatic need of humans, both for their own survival and for the carrying out of agricultural activities. A regular supply is required in any type of economy, but the extent of the demand can be different, and dependent on demographic and economic conditions. As a general rule, constant flow-rate rivers and perennial springs are expected to attract settlements.

The specific case of Venusia is quite exceptional with respect to water availability (Marchi and Sabbatini 1996, 115). The territory was well served, with *fiumare* (small rivers), streams, water springs, and starting from the Triumviral period, also with an aqueduct (Salvatore 1984, 38; Marchi and Sabbatini 1996, 47; Capano 1999). The main rivers and main streams were extracted from the shapefile of the hydrological system of Regione Basilicata[13]. The perennial springs were digitalized in ArcGIS 10.2.2 from the IGM maps (1:25,000)[14]. These two layers were then merged and the variable representing the Euclidean distance from water was carved up into bands of 200 m (figs 12 and 13). It is worth noting that the present-day river system was considered in this analysis: it is evident that this may differ from the past situation. However, the typical geomorphology of this landscape consisting of deep, incised valleys and interposing large plateaus would have probably allowed river migrations within these quite narrow valleys. In consequence, their current position was considered indicative for the periods under consideration.

The probable route of the aqueduct is reported in photos and in a map dating to 1883 (Venosa, Archivio Comunale) (see Salvatore 1984, 38; Rosa *et al.* 2016)[15]. This important element for water supply functioned both for diverting water to the city and possibly also to the surrounding fields for irrigation. Therefore, the position of the *castellum aquae*, where the water transported by the aqueduct was collected and then distributed, may have influenced the position of arable fields close to the city and the building structures related to them from the Augustan age onwards (Marchi and Salvatore 1997, 47 – 49). Therefore, its location was taken into account when the distribution of the LR-Triumviral and Imperial settlement samples was analyzed.

7.1 *Results*

There is high homogeneity in settlement distributions with respect to distance from water sources. As a general trend, sites tend to be located at a certain distance to rivers and streams (possibly due to the high risk of flooding at the nearby locations) but close enough to reach them easily. Settlements seem to avoid the farthest distance bands and to favor, instead, the second distance band (201 to 400 m from a water source). If we look at the size site samples per period (see results tables in appendix II), a significant association with water is displayed by the smallest Republican settlements (0-100 sq m) and by the small pre-Roman settlements (101-400 sq m) that significantly favor the 2nd distance band and avoid the more distant ones.

8 Distance from the town and from major roads

The town of Venusia may have functioned as an important market place for local and regional exchange of products yielded by the surrounding rural territory. In addition to that, the colonial center provided the rural population with defensive, administrative, ritual, and political facilities. On the other hand, rural settlements played a crucial role for the survival of the city itself since they supplied it with food, bulk products and basic materials (see discussion in Vogel *et al.* 2016). The consumption center, thus, may have been an important attractor for productive location and settlement in Roman times. Connecting routes are another important cultural attractor for settlements (see for instance De Neeve 1984, 25), both for human movement and for the transport of goods from the countryside to the markets and the other way around. However, differently from the position of the colonial central place (*i.e.* town) which is known, road route reconstructions are problematic, as is the issue of dating and reuse of roads over different periods.

In this analysis all major roads arguably in use during the Roman period are considered, connecting the countryside to the town of Venusia (reconstructions are provided in Buck 1971; 1981; Vinson 1972; 1979; Salvatore 1984, 17 - 21; Marchi and Sabbatini 1996, 123 - 127; Sabbatini 2001, 78 - 80; Marchi 2010, 281 – 285 with further references), and whether they influenced the position of settlements in this period was analyzed. The variable representing the Euclidean distance from the town was carved up into bands of 2 km, whereas the distance from major roads was divided up into Euclidean bands of 200 m (figs 14, 15, 16 and 17).

8.1 Results

These two cultural variables have the highest number of significant correlations with settlement distributions and thus seem to be the most influential in settlement location preferences in Roman times. This is especially true for the distance from the colonial center. As a rule, all sites from the early colonial to the Imperial period have a preference for the closest distance bands from the town, and significantly fewer sites are located far from it (see also Marchi and Sabbatini 1996, 112 – 114; Casarotto *et al.* 2016). The opposite is true for the pre-Roman period settlements, which are located quite distant from the town and do not favor the territory close to it.

It is important to note that the Imperial settlements are more homogeneously distributed across the survey sample area than the other previous Roman period settlements (see also Marchi and Sabbatini 1996, 117 – 123; Sabbatini 2001, 72 – 75; Marchi 2004, 139). In addition to that, other differences and similarities amongst Roman period sites with respect to the distance to the town and roads can be pointed out if we look at the various size site samples per period (figures 15 and 17).

For instance, as regards the distance to town, the small Imperial sites (0-100 and 101-400 sq m) differ in distribution from the small early colonial, Republican, and LR-Triumviral sites (which are, instead, more similarly distributed). The early colonial, Republican, and LR-Triumviral sites remarkably favor the 1st band from the town (0 to 2 km, already noted by Marchi and Sabbatini 1996, 112 - 113; Marchi 2004, 133). Significantly fewer small Republican sites are attested in the more distant bands, but this is not the case for small LR-Triumviral and Imperial sites. As regards the largest sites (> 800 sq m), the Republican and LR-Triumviral sites are similar in their distribution whereas the largest Imperial sites (> 800 sq m) seem more homogeneously distributed across the territory with a preference for the 3rd distance band (4 to 6 km, size category 801 – 2000 sq m).

With regard to the variable representing the Euclidean distance from a known (Roman) road, the Imperial sites seem to be the least interested in staying close to a road. They are, indeed, more homogeneously scattered than the Republican and LR-Triumviral sites with respect to the distance to roads. Significant differences in distribution also exist between size site samples, specifically between small Republican and small Imperial sites, and between small LR-Triumviral and small Imperial sites. As regards pre-Roman settlements, they seem to be less interested in staying close to these roads but a preference is attested for the 3rd distance band (401 – 600 m), especially for the size category 101 – 400 sq. m.

9 Summary of the results

This inductive location preference analysis offered the opportunity to systematically and formally assess patterns in location preferences of diachronic and hierarchical settlement distributions. It was noted that settlement distributions of different periods favor or avoid similar slope, aspect, and water distance conditions: the flat and gently sloping locations are not particularly favored (for a similar conclusion in another Roman landscape see also Goodchild 2007, 131) but at the steepest slopes low site density is always attested. There is no preferential orientation in settlement locations, neither per size nor per period. Moreover, as a general trend the totalities of sites per period avoid locations farther away from water sources and prefer, instead, the closest ones (in particular the 2nd distance band). Interestingly, this preference for the 2nd distance band (201- 400 m from a water source) is significantly displayed also by two size site samples: the smallest Republican settlements (0-100 sq m) and the small pre-Roman settlements (101-400 sq m). However, due to many similarities in distribution, it can be concluded that the slope, aspect, and water distance factors do not provide significant indication for drastic changes in settlement location preferences from the pre-Roman to the Imperial period.

A different situation is exhibited by the altitude and soil variables. Settlements of different periods cluster in different ecological parts of the landscape, which can be outlined on the basis of elevation, soil, and geomorphological conditions. Pre-Roman settlements favor the hills and mountain west of the town of Venusia (at quite high altitudes); early colonial period settlements prefer the hills west of the town as well, but also the conglomeratic plateaus in the central part of the survey sample area, especially those located in front of the urban center; Republican and LR-Triumviral settlements tend to concentrate on the conglomeratic plateaus surrounding the urban center as well, but also much farther, north / north-east of it on the conglomeratic plateaus located at the other side of the *Fiumara di Venosa* valley (corresponding to soil unit 11.1 and the 3rd altitude band). Differently from the Republican settlements, however, the LR-Triumviral sites also exhibit a preference for more productive types of soil. Lastly, Imperial settlements are clearly more widely and homogeneously distributed across the survey sample area than ever before, with a preference for the most fertile soils of this territory.

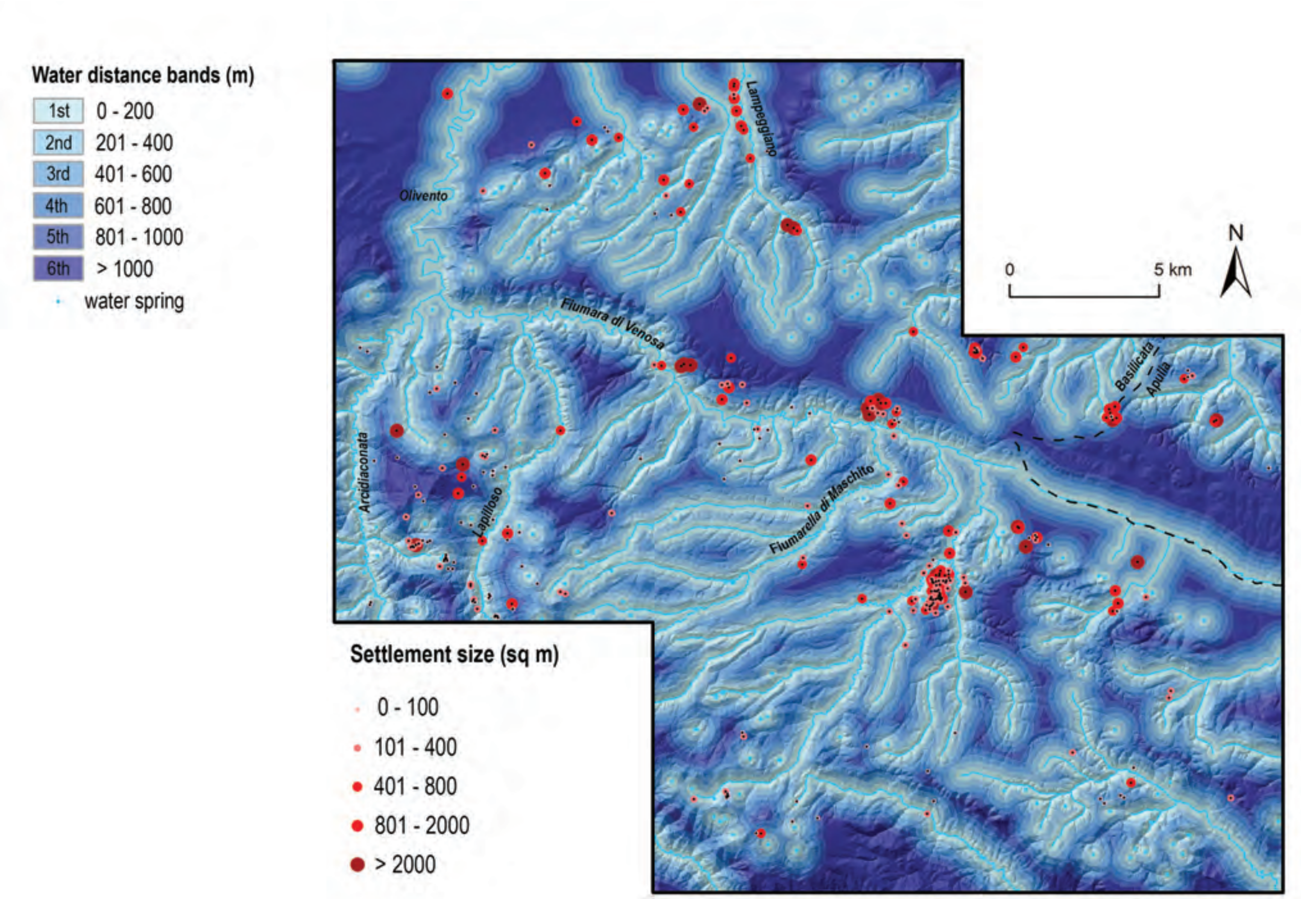
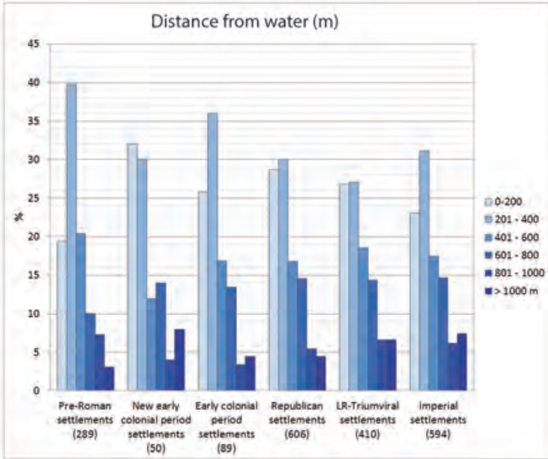


Figure 12 Distance from water sources classified in bands and distribution of pre-Roman settlements



Water band		Area (sq m)	%
1st	0-200 m	175648200	25.26
2nd	201 - 400 m	164570200	23.67
3rd	401 - 600 m	127113900	18.28
4th	601 - 800 m	89448700	12.87
5th	801 - 1000 m	56637100	8.15
6th	> 1000 m	81864100	11.77
	Tot.	695282200	100

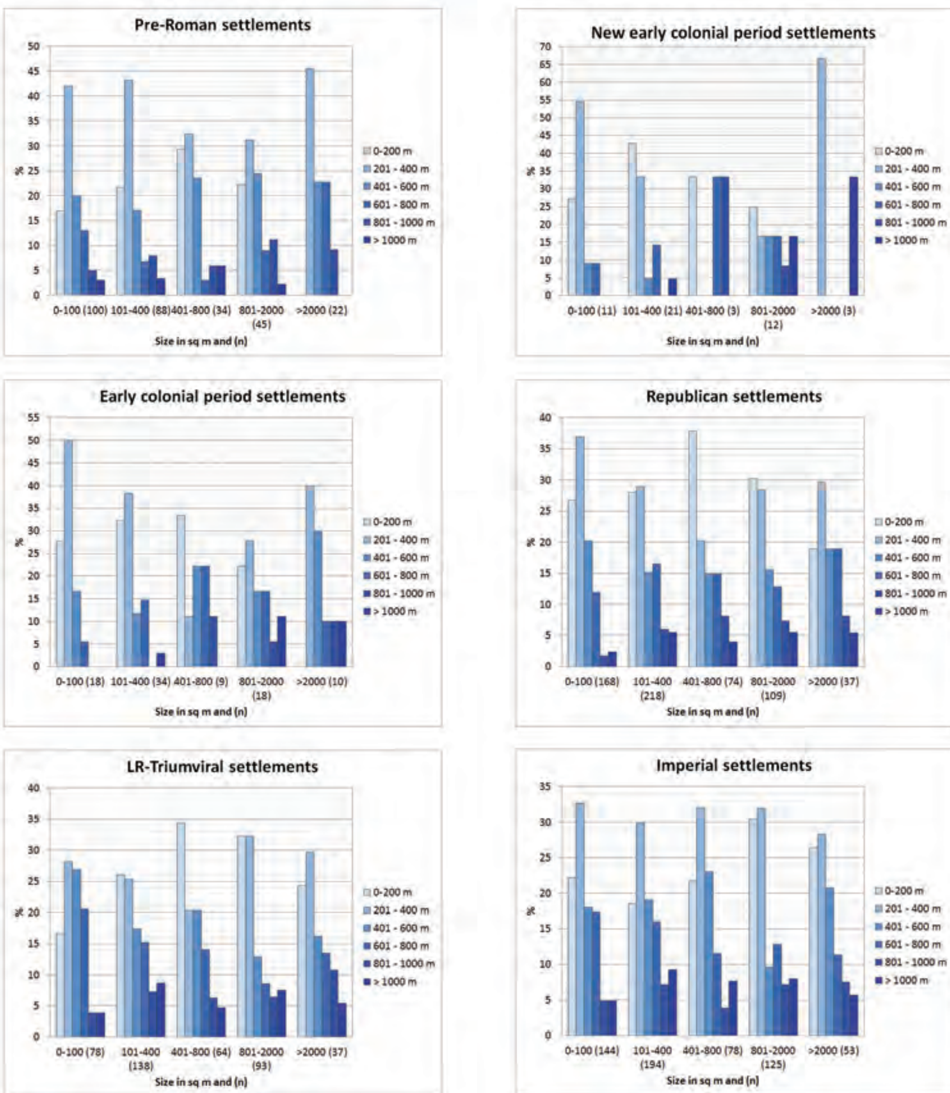


Figure 13 Settlement percentages in progressive distance bands from water sources. In brackets, total number of settlements per sample (n)

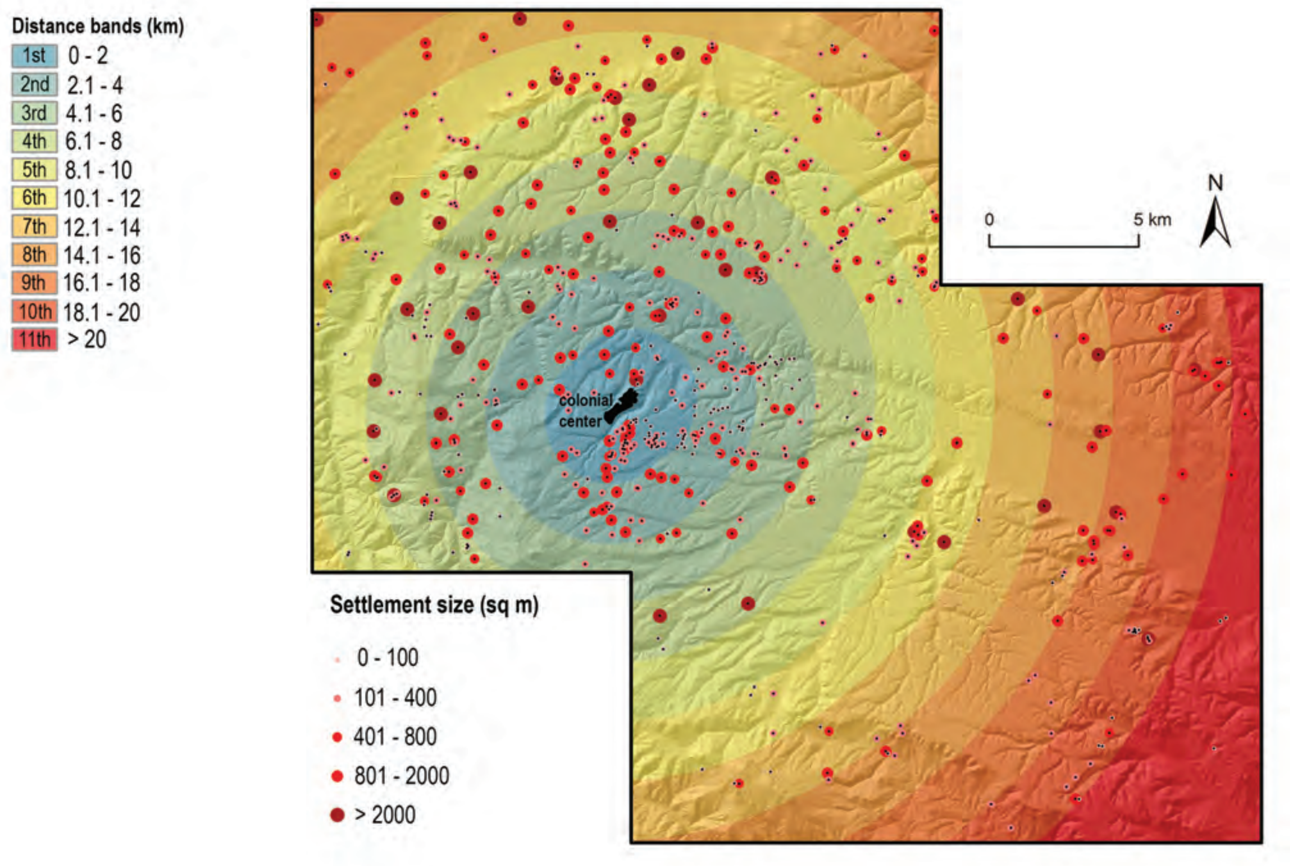
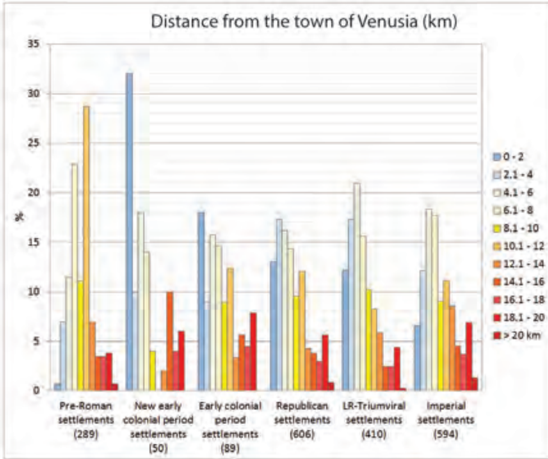


Figure 14 Distance from the town classified in bands and distribution of Republican settlements



Distance band		Area (sq m)	%
1st	0 - 2	20050700	2.88
2nd	2.1 - 4	44602500	6.42
3rd	4.1 - 6	66629100	9.58
4th	6.1 - 8	82483500	11.86
5th	8.1 - 10	99370200	14.29
6th	10.1 - 12	97895100	14.08
7th	12.1 - 14	88587200	12.74
8th	14.1 - 16	60777500	8.74
9th	16.1 - 18	43986300	6.33
10th	18.1 - 20	41855200	6.02
11th	> 20 km	49044900	7.05
Tot.		695282200	100

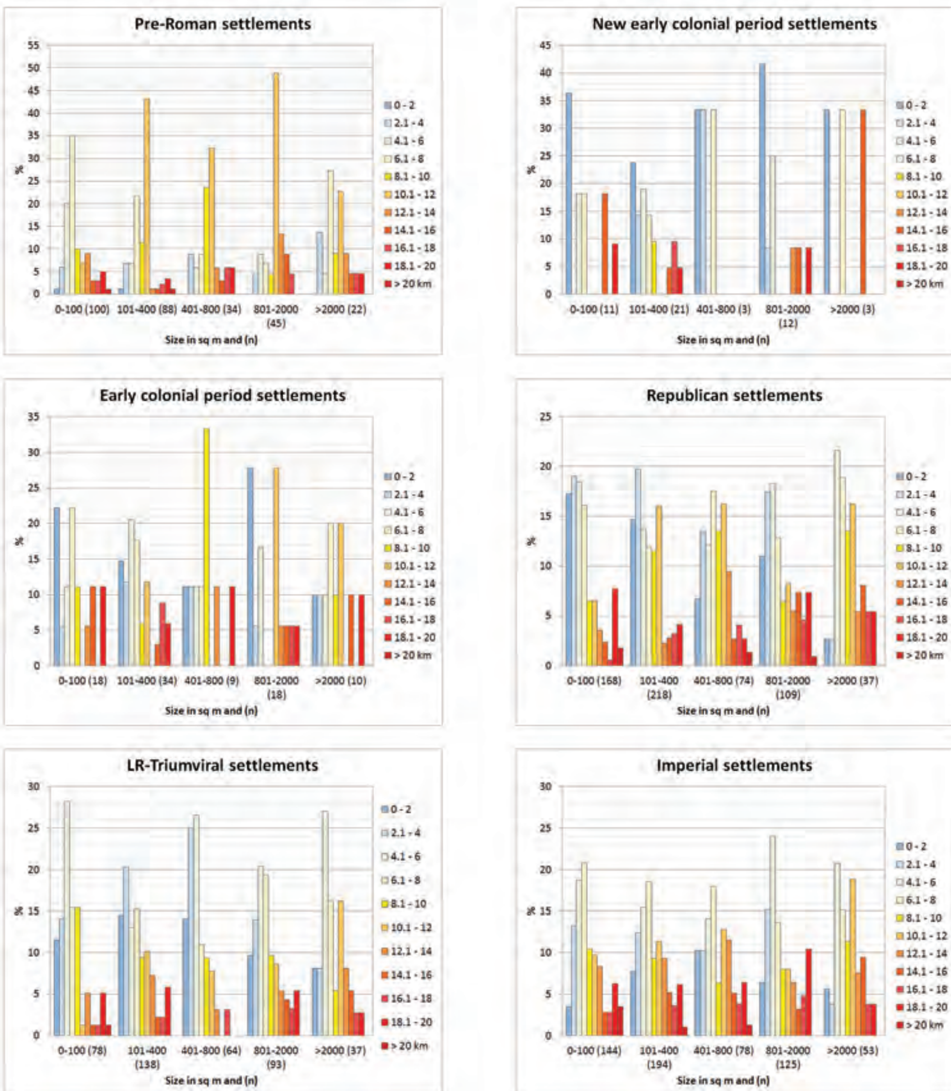


Figure 15 Settlement percentages in progressive distance bands from the town of Venusia. In brackets, total number of settlements per sample (n)

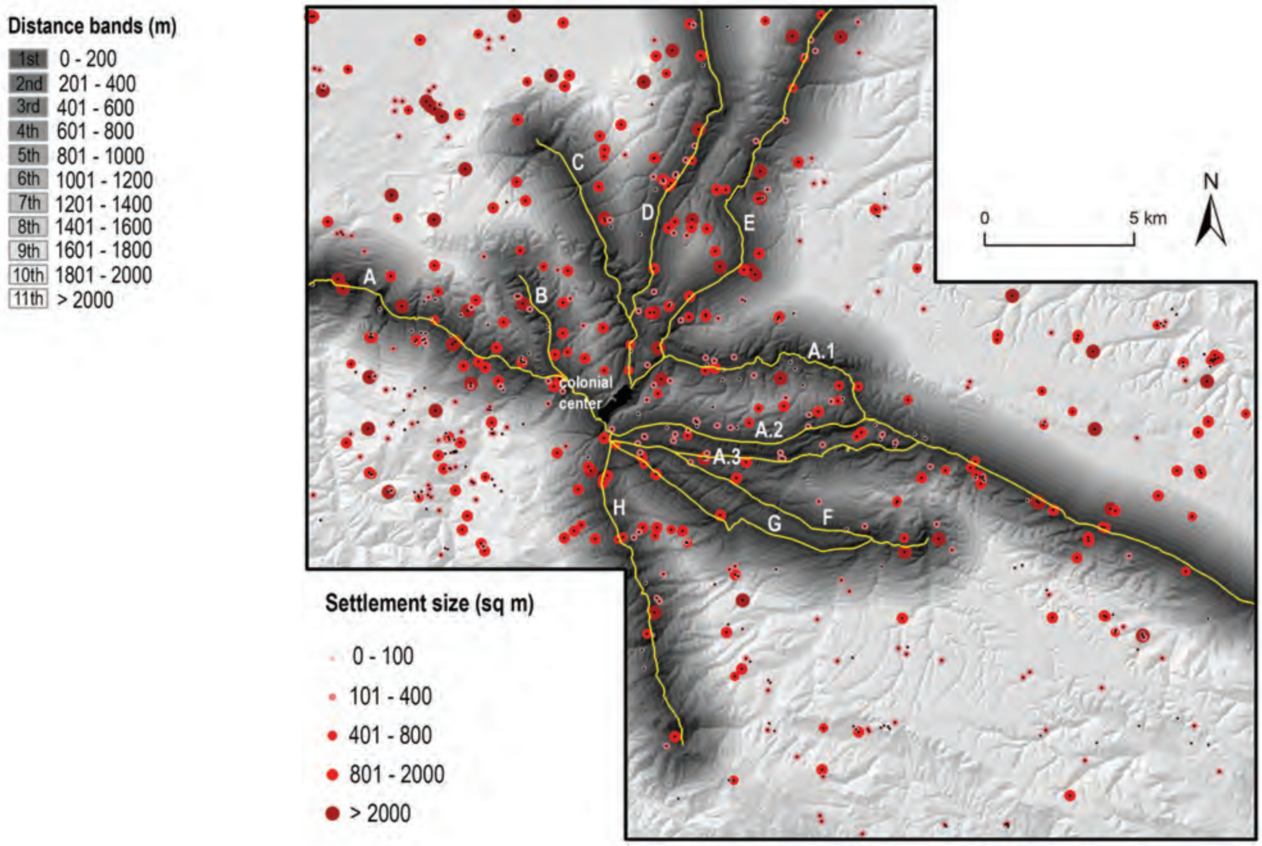
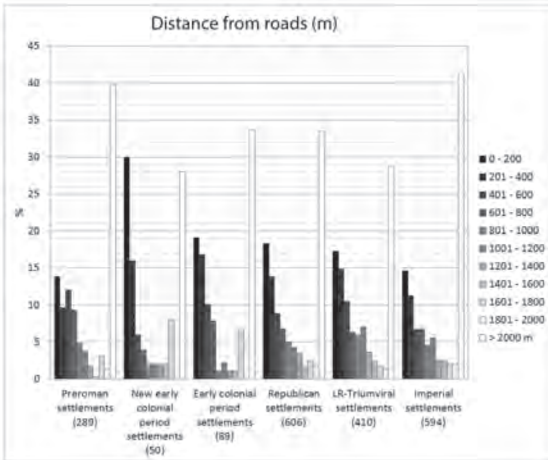


Figure 16 Distance from (Roman) roads classified in bands and distribution of Imperial settlements. The routes have been digitalized on the basis of the information and maps reported in Salvatore 1984 (pp. 17 – 21), Marchi and Sabbatini 1996 (pp. 125 – 127), Sabbatini 2001 (pp. 78 – 80) and Marchi 2010 (pp. 279 – 285). A: Via Appia; A.1: alternative route of the Via Appia (Marchi and Sabbatini 1996, 125); A.2: segment of the Via Appia (Marchi and Sabbatini 1996, 125 – 127, see also Marchi 2010, 279 – 285) ; A.3: segment of the Via Appia (Vinson 1979; Marchi, Sabbatini 1996, 125 – 127); B: Via Venusia – Herdonias (Salvatore 1984: 17 – 21; Marchi and Sabbatini 1996, 125 – 127); C: Via Venusia – Forentum (Marchi and Sabbatini 1996, 125 – 127); D: road parallel to the Lampeggiano river (Sabbatini 2001: 78 – 80); E: via Venusia – Canusium (Sabbatini 2001, 78 – 80). F and G: via Venusia – Bantia (Buck 1981; Marchi and Sabbatini 1996, 125 – 127); H: via Herculia (Buck 1971; Marchi and Sabbatini 1996, 125 – 127)



Distance band		Area (sq m)	%
1st	0 - 200	51136700	7.35
2nd	201 - 400	46892800	6.74
3rd	401 - 600	40638300	5.84
4th	601 - 800	37719400	5.43
5th	801 - 1000	34711500	4.99
6th	1001 - 1200	31034200	4.46
7th	1201 - 1400	27170200	3.91
8th	1401 - 1600	23640300	3.40
9th	1601 - 1800	21404100	3.08
10th	1801 - 2000	20094000	2.89
11th	> 2000 m	360840700	51.90
	Tot.	695282200	100

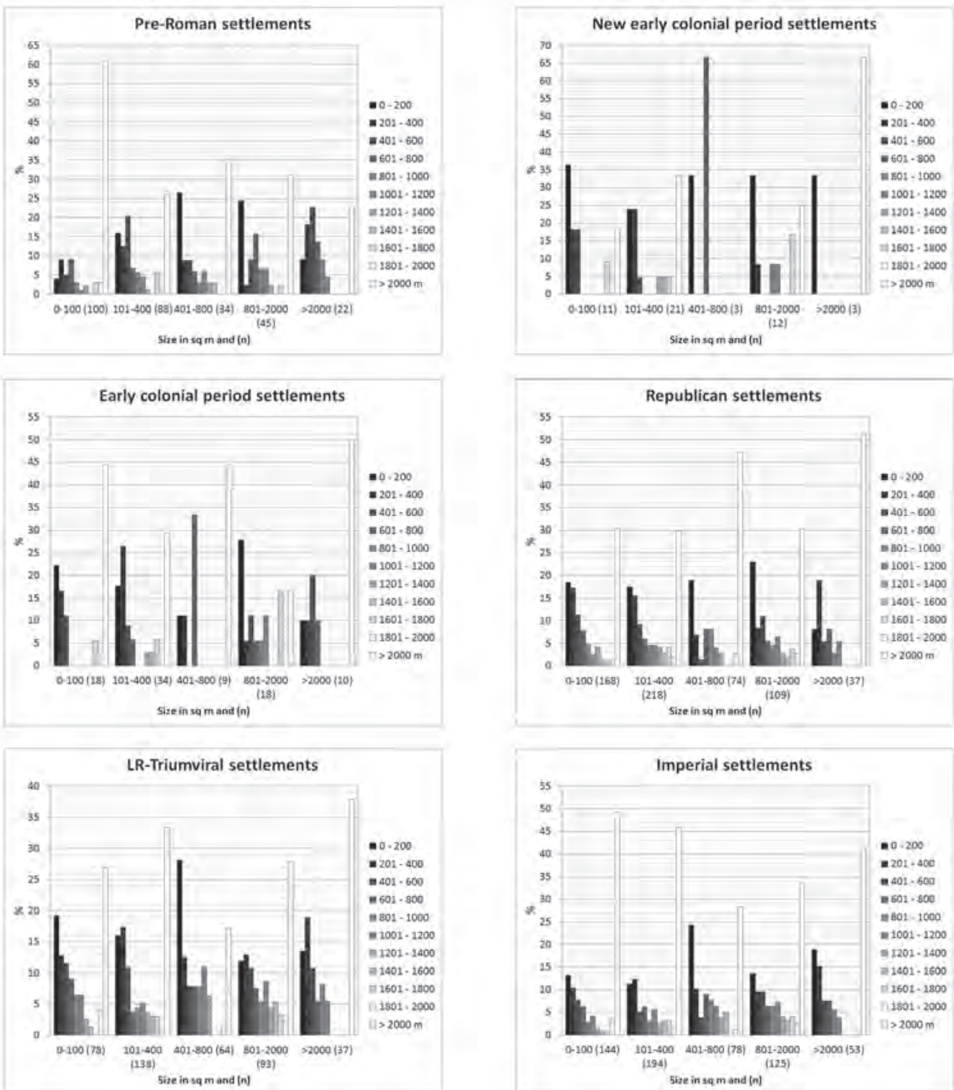


Figure 17 Settlement percentages in progressive distance bands from the (Roman) roads. In brackets, total number of settlements per sample (n)

We have seen that the pre-Roman and early colonial period settlement configurations often display similar location preferences and patterns with respect to the natural environment. The only clear difference in location preferences is cultural, and regards the way in which these settlements are located with respect to the town of Venusia (see Marchi 1991; Marchi and Sabbatini 1996, 47-48; Marchi 2000, 231; Marchi 2010, 249).

Early colonial period settlements also exhibit similarities with the larger sample of Republican settlements. This, of course, could depend on the fact that the early colonial settlement sample (3rd century BC) is not an independent sample but has been extracted from the Republican settlement sample (3rd – 1st century BC). It is likely that other early colonial period settlements are still incorporated in the Republican sample: as a matter of fact, those sites lacking diagnostic 3rd century BC archaeological material could be dated only to a broader chronological range (namely, the Republican period) (see also the discussion in Marchi and Sabbatini 1996, 111 footnote 129). Eventually, this may contribute in enhancing the similarity between surely-datable early colonial and generally-datable Republican settlements.

We also encountered similarities in location preferences between Republican and LR-Triumviral settlements and between LR-Triumviral and Imperial settlements. For instance, Republican and LR-Triumviral settlements are preferentially located in the 3rd altitude band and seem to preferentially gravitate towards the urban center or a road. However, differently from Republican settlements, the LR-Triumviral and Imperial settlements are both significantly attracted by fertile soils. The distance to town and roads is an important element in location choices in these periods too, but, especially for the Imperial period, clearly to a lesser extent than before.

Acknowledgments

This analysis is part of my Ph.D. research (supervised by Dr. Tesse D. Stek, Dr. Jeremia Pelgrom and Dr. Hans Kamermans), set within the overarching LERC project (Landscapes of Early Roman Colonization, led by Dr. Tesse D. Stek and Dr. Jeremia Pelgrom, https://www.universiteitleiden.nl/en/research/research-projects/archaeology/landscapes-of-early-roman-colonization ; https://landscapesofearlyromancolonization.com/). LERC is funded by the Netherlands Organization for Scientific Research (NWO, project number: 360-61-040) and is based at the Faculty of Archaeology of Leiden University in the Netherlands and at the Royal Netherlands Institute in Rome (KNIR). I wish to thank Dr. Hans Kamermans for his advice on the process of writing the early draft of this paper and for teaching me how to run and use the program for the Attwell-Fletcher test. He is also the person that encouraged me to explore the various uses and limits of predictive modeling in archaeology during my Ph.D. in Leiden. I am very grateful to Dr. Jeremia Pelgrom and Dr. Tesse D. Stek for the inspiration to implement this analysis, for the feedback they gave me while I was doing it and for the moral support that convinced me this was actually possible.

Notes

1 This may also be the case for those settlements founded in a certain period and attesting discontinuous occupation in later phases as well. Their recorded size may be indicative of these later phases rather than of the phase concerned. The role played by occupation phases prior to the pre-Roman period on size recording was not taken into account.

2 Performed in Excel 2010. The Attwell-Fletcher test was run in DOS.

3 In some cases the type of data used did not meet the conditions associated with the tests (*e.g.* the assumption of normality in the distribution of data considered in the ANOVA and t-test). These trends were subsequently compared with the distributions represented in the graphs to test whether similar trends were also displayed in these graphs. In a second step, during the interpretation of the results, untrustworthy trends and/or correlations will be discarded and the reliable ones will be pondered more thoroughly, taking into account possible limitations (Casarotto *et al.* forthcoming).

4 As for the impossibility to disentangle, for each phase, the actual extension of the inherited sites (see Data section of this paper), the statistical analysis was not performed on the inherited samples with large size categories (*i.e.* 401-800, 801-2000 and > 2000 sq m). Therefore, as regards the inherited sites, only the distribution of the smallest size categories (*i.e.* 0-100 and 101-400 sq m settlements) is analyzed with these tests. This is because, if we assume that the artifact scatter size provides reliable indication of the actual settlement size (see the discussion in *e.g.*, Dyson 1978; Potter 1979; Lloyd and Barker 1981; Fentress 2000; Given 2004), in these cases, the small size of such settlements should be expected not to have significantly changed from a period to the subsequent one.

5 Specifically, by means of these tests the frequency distribution of a periodic-size-site sample (*e.g.* pre-Roman 0-100 sq m settlements) and the frequency distribution of new settlements established in the subsequent phase and having the same size category (*e.g.* new Republican 0-100 sq m settlements) were analyzed.

6 However, these tests did not allow us to ascertain what precisely these differences or similarities are (for other limitations see also note 3 of this paper).

7 It is possible that the method chosen for the classification of the variables in categories does not correspond with the ancient perception of the landscape topography (Verhagen 2002, 202-203). The definition given here of what constituted, for instance, a gentle slope might not correspond with how people in the past perceived a slope to be gentle. Therefore, it cannot be totally excluded that significant preferences may have escaped detection because the reclassification method used in this analysis does not entirely accord with ancient judgments on the landscape suitability for settlement.

8 When conducting inference statistic, it is always advisable to use at least two different tests of significance. This was done also in this analysis. As previously stated, the Chi-squared test was implemented for the nominal variables, the Kolmogorov-Smirnov test for the ordinal variables, and the Attwell-Fletcher test for both types of variables. Only when the results from both tests concur on the presence or absence of a correlation can we be confident about the existence of a significant relationship (or absence of a relationship) between site distribution and the landscape variable under consideration. It is important to note, however, that the Chi-squared and the Kolmogorov-Smirnov tests have some limitations – which mainly depend on the size of the sample – and it is advisable not to apply them when required conditions are not met. As a matter of fact the Kolmogorov-Smirnov test should be used only with samples having more than 40 elements (Shennan 1988, 55; Wheatley and Gillings 2002, 140) and the Chi-squared test should not be used when more than 20% of the frequencies expected in each variable category are less than five sites or when at least one expected frequency is smaller than one (Siegel 1956, 46; see also Shennan 1988, 69). Moreover, in case of dichotomous variables (*e.g.* location of dominant positions) the Chi-squared test should be used only when the frequency of sites expected is higher than five in both dichotomous categories (*ibid.*).

9 Permission for download and use of this elevation dataset was released in May and June 2014, see http://tinitaly.pi.ingv.it/

10 Ufficio Produzioni Vegetali e Silvicoltura Produttiva – Dipartimento Agricoltura, Sviluppo Rurale, Economia Montana – Regione Basilicata. Data and legend can be found here: http://www.basilicatanet.it/suoli/index.htm (credits: http://www.basilicatanet.it/suoli/credits.htm) and in the catalogue of the Geoportale della Basilicata: http://rsdi.regione.basilicata.it/Catalogo/srv/ita/search?hl=ita. The shapefile of the soil map of Basilicata was kindly provided to the author by Regione Basilicata in May 2013.

11 The outmost west corner of the survey sample area belongs to the Apulia Region. The soil information for this small zone was inferred by the author on the basis of physiographic and geological conditions. The geological maps of this area (Carta Geologica d'Italia 1: 500,000 - Geoportale Nazionale - Ministero dell'Ambiente e della Tutela del Territorio e del Mare, and Carta Geologica d'Italia 1: 100,000 – Foglio 188, Servizio Geologico d'Italia) were controlled to map the soil units in this zone: since the geomorphological and geological characteristics of this area are the same of adjacent known soil units (*i.e.* 11.1, 11.2 and 14.1; see also Carta Geologica d'Italia 1: 100,000 – Foglio 175 and 187, Servizio Geologico d'Italia), this small portion of the survey area was classified accordingly, using these known soil units (see Figure 8).

12 The parameters applied for the reclassification of the landscape in geomorphological classes were: kernel window 9x9; distance decay 1; slope tolerance 7; curvature tolerance 0.1. See Wood (2009, 81 - 87) for more details on the procedure.

13 This data was kindly provided to the author by the Regione Basilicata in June 2013. Data concerning the hydrography can be found in the catalogue of the Geoportale della Basilicata: http://rsdi.regione.basilicata.it/Catalogo/srv/ita/search?hl=ita For the territory outside Basilicata, rivers and main streams were digitalized manually on the basis of topographic maps.

14 WMS server available through the Geoportale Nazionale: http://www.pcn.minambiente.it/

15 An exhibition on ancient water management systems was recently held at Venosa (Rosa *et al.* 2016).

References

Allen, J. R. M., W. A. Watts, E. McGee and B. Huntley 2002. Holocene environmental variability - the record from Lago Grande di Monticchio, Italy, *Quaternary International* 88 (1), 69 - 80. doi: 10.1016/S1040-6182(01)00074-X

Attwell, M. and M. Fletcher 1985. A New Technique for Investigating Spatial Relationships: Significance Testing. In: A. Voorrips and S. H. Loving (eds), *To Pattern the Past: Symposium on Mathematical Methods in Archaeology, Amsterdam 1984*, Conseil de l'Europe, Strasbourg, 181 - 189.

Attwell, M. R. and M. Fletcher 1987. An Analytical Technique for Investigating Spatial Relationships, *Journal of Archaeological Science* 14(1), 1-11. doi: 10.1016/S0305-4403(87)80002-X

Barnes, T. J. 2003. The place of locational analysis: a selective and interpretive history, *Progress in Human Geography* 27 (1), 69-95. doi: 10.1191/0309132503ph419oa

Bintliff, J. L. 1992. Erosion in the Mediterranean lands: A reconsideration of pattern, process and methodology. In: J. Boardman and M. Bell (eds), *Past and Present Soil Erosion*, Oxbow Books, Oxford, 125-131.

Boserup, E. 1981. *Population and technological change. A study of long-term trends*, The University of Chicago Press, Chicago.

Brown, F.E. 1980. *Cosa: The Making of a Roman Town*, University of Michigan Press, Ann Arbor.

Buck, R. J. 1971. The Via Herculia, *Papers of the British School at Rome* 39, 66 - 87.

Buck, R. J. 1981. The ancient roads of northwestern Lucania and the battle of Numistro, *La Parola del Passato* 36, 317-347.

Capano, A. 1999. L'uso dell' acqua nella colonia Latina di Venosa. In: *Archeologia dell'acqua in Basilicata*, Soprintendenza Archeologica della Basilicata, Consiglio Regionale di Basilicata, 159-166.

Carrer, F. 2013. An ethnoarchaeological inductive model for predicting archaeological site location: A case-study of pastoral settlement patterns in the Val di Fiemme and Val di Sole (Trentino, Italian Alps), *Journal of Anthropological Archaeology* 32 (1), 54-62. doi: 10.1016/j.jaa.2012.10.001.

Casarotto, A. 2015. Location Preference Modeling alias Predictive Modeling for the study of archaeological contexts. In: G. Pizziolo and L. Sarti (eds), *Predicting Prehistory. Predictive models and field research methods for detecting prehistoric contexts. Proceedings of the International Workshop,Grosseto (Italy), September 19-20, 2013*, "Millenni" Studi di Archeologia Preistorica, 11, Museo e Istituto Fiorentino di Preistoria "Paolo Graziosi", Firenze, 35 – 46.

Casarotto, A., J. Pelgrom and T. D. Stek 2016. Testing settlement models in the early Roman colonial landscapes of Venusia (291 B.C.), Cosa (273 B.C.) and Aesernia (263 B.C.), *Journal of Field Archaeology*, 41 (5), 568-586. doi: 10.1080/00934690.2016.1211474.

Casarotto, A., T. D. Stek, J. Pelgrom, R. H. van Otterloo and J. Sevink 2017. Assessing visibility and geomorphological biases in regional field surveys: the case of Roman Aesernia, *Geoarchaeology, an International Journal*. doi: 10.1002/gea.21627.

Casarotto, A., J. Pelgrom and T. D. Stek (forthcoming). A systematic GIS-based analysis of settlement developments in the landscape of Venusia in the Hellenistic-Roman period.

Celuzza, M. G. and E. Regoli 1982. La Valle d'Oro nel territorio di Cosa. Ager Cosanus e Ager Veientanus a confronto, *Dialoghi di Archeologia* 4, 31-62.

De Guio, A. 2015. Nuove linee di ricerca fra archeologia pre-dittiva e post-dittiva, *Archeologia e Calcolatori* 26, 301-313.

De Neeve, P. W. 1984. *Peasants In Peril: Location And Economy In Italy In The Second Century BC*, JC Gieben, Amsterdam.

Drennan, R. D. 2009. *Statistics for Archaeologists: A Common Sense Approach*, Springer, New York.

Dyson, S. L. 1978. Settlement Patterns in the *Ager Cosanus*: The Wesleyan University Survey, 1974–1976, *Journal of Field Archaeology* 5 (3), 251-268. doi: 10.1179/009346978791489745

Eastman, J. R. 2012. *IDRISI Selva Manual (Manual Version 17.01)*, Clark Labs, Clark University, Worcester, MA.

ESRI 2014. How Aspect works. In *ArcGIS 10.2.2 Help*.

FAO 2006. *Guidelines for Soil Description* (4th edition), Food and Agriculture Organization of the United Nations, Rome.

FAO 2014. *World reference base for soil resources 2014. International soil classification system for naming soils and creating legends for soil maps* (Update 2015), Food and Agriculture Organization of the United Nations, Rome.

Fentress, E. 2000. What are we counting for? In: R. Francovich, H. Patterson and G. Barker (eds), *Extracting meaning from ploughsoil assemblages*, Oxbow Books, Oxford, 44 – 52.

Field, A. 2009. *Discovering Statistics using SPSS* (3rd edition), SAGE, London.

Frayn, J. M. 1979. *Subsistence Farming in Roman Italy*, Centaur Press Ltd, Fontwell, Sussex.

Garnsey, P. 1988. *Famine and food supply in the Graeco-Roman world: Responses to risk and crisis*, Cambridge University Press, Cambridge.

Given, M. 2004. Mapping and Manuring: Can We Compare Sherd Density Figures? In: S. E. Alcock and J. F. Cherry (eds), *Side-by-Side Survey, Comparative Regional Studies in the Mediterranean World*, Oxbow books, Oxford, 13 – 21.

Goodchild, H. 2007. *Modelling Roman Agricultural Production In The Middle Tiber Valley, Central Italy*, Ph.D. dissertation, University of Birmingham. *eTheses Repository* http://etheses.bham.ac.uk/175/.

Goodchild, H. and R. Witcher 2010. Modelling the agricultural landscapes of Republican Italy. In: J. Carlsen and E. Lo Cascio (eds) *Agricoltura e scambi nell'Italia tardo repubblicana*, Edipuglia, Roma and Bari, 187 – 220.

Haggett, P., A. D. Cliff and A. Frey 1977. *Locational Analysis in Human Geography* (2nd edition), Arnold, London.

Hodder, I. and C. Orton 1976, *Spatial Analysis in Archaeology*, Cambridge University Press, Cambridge.

Judge, W. J. and L. Sebastian (eds) 1988. *Quantifying the Present and Predicting the Past: Theory, Method, and Application of Archaeological Predictive Modeling*, US Bureau of Land Management, Denver.

Judson, S. 1963. Erosion and Deposition of Italian Stream Valleys during Historic Time, *Science* 140 (3569), 898-899. doi: 10.1126/science.140.3569.898

Kamermans, H. 2000. Land evaluation as predictive modelling: a deductive approach. In: G. Lock (eds), *Beyond the Map: Archaeology and Spatial Technologies*, IOS Press, Amsterdam, 124 - 146.

Kamermans, H. and M. Wansleeben 1999. Predictive Modelling in Dutch Archaeology, Joining Forces. In: J. A. Barceló, I. Briz and A. Vila (eds), *New Techniques for Old Times*. CAA98. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 26th Conference, Barcelona, March 1998 (BAR International Series 757), Archaeopress, Oxford, 225-230.

Kvamme, K. L. 1990a. The fundamental principles and practice of predictive archaeological modelling. In: A. Voorrips (eds), *Mathematics and Information Science in Archaeology: a Flexible Framework*, Holos, Bonn, 257-295.

Kvamme, K. L. 1990b. One-sample tests in regional archaeological analysis: new possibilities through computer technology, *American Antiquity* 55(2), 367-381. doi: 10.2307/281655

Kvamme, K. L. 2006. There and back again: revisiting Archaeological Locational Modeling. In: M.W. Mehrer and K. L. Wescott (eds), *GIS and Archaeological Site Location Modeling*, CRC press, Taylor & Francis Group, New York, 3 – 38.

Kvamme, K. L. 2011. Archaeological Predictive Modeling in the USA. In: S. Gelichi and C. Negrelli (eds), *A piccoli passi, archeologia predittiva e preventiva nell'esperienza cesenate*, All'Insegna del Giglio, Firenze, 19-26.

Lefèvre, D., J. P. Raynal, G. Vernet, G. Kieffer and M. Piperno 2010. Tephro-stratigraphy and the age of ancient Southern Italian Acheulean settlements: the sites of Loreto and Notarchirico (Venosa, Basilicata, Italy), *Quaternary International* 223 - 224, 360 - 368. doi: 10.1016/j.quaint.2010.02.020

Lloyd, J. A. and G. Barker 1981. Rural settlement in Roman Molise: problems of archaeological surveys. In: G. Barker and R. Hodges (eds), *Archaeology and Italian Society*, British Archaeological Reports, International Series 102, Oxford, 289 - 304.

Marchi, M. L. 1991. Venosa: ceramica di tradizione non romana. In: M. Salvatore (eds), *Il Museo Archeologico Nazionale di Venosa*, IEM editrice, Matera, 86-91.

Marchi, M. L. 2000. Effetti del processo di romanizzazione nelle aree interne centro-meridionali. Acquisizioni, innovazioni ed echi tradizionali documentati archeologicamente, *Orizzonti* I, 227 - 242.

Marchi, M. L. 2004. Fondi, Latifondi e proprietà Imperiali nell'*Ager Venusinus*, *Agri centuriati 1*, 129 – 156.

Marchi M. L. 2010. *Ager Venusinus II (IGM 175 II SO; 187 I NO; 187 I SE; 188 IV NO; 188 IV SO)* (Forma Italiae 43), Leo S. Olschki editore, Firenze.

Marchi M. L. and G. Sabbatini 1996. *Venusia (IGM 187 I NO / I NE)* (Forma Italiae 37), Leo S. Olschki editore, Firenze.

Marchi, M. L. and M. Salvatore 1997. *Venosa: forma e urbanistica* (Città antiche in Italia 5), «L'Erma» di Bretschneider, Roma.

Orton, C. 2004. Point Pattern Analysis Revisited, *Archeologia e Calcolatori* 15, 299-315.

Palmisano, A. 2013. Zooming Patterns Among the Scales: A Statistics Technique to Detect Spatial Patterns Among Settlements. In: G. Earl, T. Sly, A. Chrysanthi., P. Murrieta-Flores, C. Papadopoulos, I. Romanowska and D. Wheatley (eds) *Archaeology in the Digital Era*, *CAA 2012*,Amsterdam University Press, Amsterdam, 348–356.

Pelgrom, J., M. L. Marchi, G. Cantoro, A. Casarotto, A. Hamel, L. Lecce, J. García Sánchez and T. D. Stek 2014. New approaches to the study of village sites in the territory of Venosa in the Classical and Hellenistic periods, *Agri centuriati* 11, 31-59. doi: 10.1400/233577

Pelgrom, J. and C. Tetteroo 2015. Preliminary results from the Ager Venusinus project. Fieldreport of the 2013 and 2014 campaigns (Internal Report for the Soprintendenza Archeologica della Basilicata).

Potter, T. W. 1976. Valleys and settlement: some new evidence, *World Archaeology* 8(2), 207-219.

Potter, T. W. 1979. *The Changing Landscape of South Etruria*, Paul Elek, London.

Rathbone, D. W. 1981. The Development of Agriculture in the 'Ager Cosanus' during the Roman Republic: Problems of Evidence and Interpretation, *The Journal of Roman Studies* 71, 10–23. doi: 10.2307/299493

Rathbone, D. W. 2008. Poor Peasants And Silent Sherds. In: L. De Ligt and S. J. Northwood (eds), *People, Land and Politics. Demographic Developments And The Transformation Of Roman Italy, 300 B.C.–A.D. 14*, BRILL, Leiden, 305–332.

Rosa, A., T. Sileno and P. Deanna Vernetti 2016. *Mappe della memoria: fontane e fontanili a Venosa*, Catalogo della Mostra, Castello Pirro del Balzo, Venosa 23 Ottobre 2015 – 8 Gennaio 2016, Soprintendenza belle arti e paesaggio della Basilicata.

Sabbatini, G. 2001, *Ager Venusinus I. Mezzana del Cantore (IGM 175 II SE)* (Forma Italiae 40), Leo S. Olschki editore, Firenze.

Salmon, E.T. 1969, *Roman Colonization under the Republic*, Thames and Hudson, London.

Salvatore, M. (eds) 1984. *Venosa: un parco archeologico ed un museo. Come e perchè*, Mediterraneo tardoantico e medievale. Scavi e ricerche, 2, Editrice Scorpione, Taranto.

Settis, S. (eds) 1984. *Misurare la terra: centuriazione e coloni nel mondo romano*, Edizioni Panini, Modena.

Sevink, J. 1985. Physiographic soil surveys and archaeology. In: C. Malone and S. Stoddart (eds), *Papers in Italian archaeology IV. Part 1: the Human Landscape,* BAR International Series, 243, Oxford, 41-52.

Shennan, S. 1988. *Quantifying Archaeology*, Edinburgh University Press, Edinburgh.

Siegel, S. 1956. *Nonparametric statistics for the behavioral sciences*, McGraw-Hill, New York.

Spurr, M. S. 1986. *Arable cultivation in Roman Italy c. 200 B.C. - c. A.D. 100* (Journal of Roman Studies Monographs, 3), Society for the Promotion of Roman Studies, London.

Stek, T. D. 2012. Review of: Marchi M. L. (2010) Ager Venusinus II. Forma Italiae 43, *BaBesch* 87, 243-244.

Stone, G. D. 1996. *Settlement ecology, the social and spatial organization of Kofyar Agriculture*, The University of Arizona Press, Tucson.

Tarquini, S., I. Isola, M. Favalli, F. Mazzarini, M. Bisson, M. T. Pareschi and E. Boschi 2007. TINITALY/01: a new Triangular Irregular Network of Italy, *Annals of Geophysics* 50 (3), 407 - 425. doi: 10.4401/ag-4424

Tarquini, S. and L. Nannipieri 2017. The 10 m-resolution TINITALY DEM as a trans-disciplinary basis for the analysis of the Italian territory: Current trends and new perspectives, *Geomorphology* 281, 108-115. doi: 10.1016/j.geomorph.2016.12.022

Tarquini, S., S. Vinci, M. Favalli, F. Doumaz, A. Fornaciai and L. Nannipieri 2012. Release of a 10-m-resolution DEM for the Italian territory: Comparison with global-coverage DEMs and anaglyph-mode exploration via the web, *Computers & Geosciences* 38 (1), 168-170. doi: 10.1016/j.cageo.2011.04.018

Van Leusen, P. M. and H. Kamermans (eds) 2005. *Predictive Modelling for Archaeological Heritage Management: a research agenda*. Nederlandse Archeologische Rapporten, vol. 29, Rijksdienst voor het Oudheidkundig Bodemonderzoek, Amersfoort.

Verhagen, P. 2002. Some Considerations on the Use of Archaeological Land Evaluation. In: P. Attema, G. J. Burgers, E. van Joolen, M. van Leusen and B. Mater (eds), *New Developments in Italian Landscape Archaeology: Theory and methodology of field survey, Land evaluation and landscape perception, Pottery production and distribution. Proceedings of a three-day conference held at the University of Groningen, April 13-15, 2000*, BAR International Series 1091, Archaeopress, Oxford, 200-204.

Verhagen, P. 2007. *Case Studies in Archaeological Predictive Modelling*. ASLU 14. Leiden University Press, Leiden.

Vink, A. P. A. 1975. *Land Use in Advancing Agriculture*, Springer – Verlag, Berlin Heidelberg New York.

Vinson, P. 1972. Ancient roads between Venosa and Gravina, *Papers of the British School at Rome* 15, 58-90.

Vinson, P. 1979. Il percorso della via Appia tra Venosa e Palazzo S. Gervasio, *Lucania Archeologica* 3, 15-18

Vita-Finzi, C. 1969. *The Mediterranean Valleys. Geological Changes in Historical Times*, Cambridge University Press, New York.

Vogel, S., M. Märker, D. Esposito and F. Seiler 2016. The ancient rural settlement structure in the hinterland of Pompeii inferred from spatial analysis and predictive modeling of *Villae Rusticae*, *Geoarchaeology, an International Journal* 31, 121 – 139. doi: 10.1002/gea.21560

Wheatley, D. 2004. Making space for an archaeology of place, *Internet archaeology* 15. doi: 10.11141/ia.15.10

Wheatley, D. and M. Gillings 2002. *Spatial Technology and Archaeology. The Archaeological Applications of GIS*, Taylor and Francis, London & New York.

White, K. D. 1970. *Roman Farming*, Thames and Hudson, London.

Witcher, R. 2016. Agricultural production in Roman Italy. In: A. E. Cooley (eds), *A companion to Roman Italy*, Wiley-Blackwell, Chichester, 459-482.

Wood, J. 2009. The LandSerf Manual. http://www.staff.city.ac.uk/~jwo/landserf/landserf230/doc/landserfManual.pdf

Anita Casarotto
Faculty of Archaeology
Leiden University
PO Box 9514
2300 RA Leiden
The Netherlands
a.casarotto@arch.leidenuniv.nl

Appendix I

Here, one example of the results obtained for each statistical test is offered. Significant differences and/or correlations are highlighted in red, whereas absence of differences and/or correlations is highlighted in green.

1. Assessing differences in settlement distributions

a. ANOVA and t-tests: by using these tests in this example it is explored whether the distribution of pre-Roman 801 – 2000 sq m settlements is significantly different from the distribution of Republican 801 – 2000 sq m settlements with respect to the distance from the town of Venusia. As displayed in the tables below, there seems to be a significant difference between two groups of settlements: *i.e.* pre-Roman and new Republican settlements, and pre-Roman and Republican settlements ($\alpha = 0.05$).

Distance from the town of Venusia (m)			
n	Pre-Roman settlements	New Republican settlements	Republican settlements
1	11114.2	11368.3	11114.2
2	10932.7	15748.5	11368.3
3	11377.4	12028.1	11776.1
4	11776.1	7698.84	15748.5
5	12163.5	9472	12028.1
6	12241.5	6345.47	7698.84
7	8716.25	5486.93	9472
8	13490.3	4026.51	6345.47
9	10256.9	5411.12	5486.93
10	9624.6	5515.89	4026.51
11	5697.87	6265.99	5411.12
12	4537.15	12372.7	5515.89
13	5904.05	9900.07	6265.99
14	16273.2	10592.8	13490.3
15	16058	12113.9	12372.7
16	13049.5	8630.98	9900.07
17	12393.1	8419.06	10592.8
18	11034.4	7957.42	10256.9
19	11090.8	7304.42	9624.6
20	11093.3	6725.21	12113.9
21	12354.9	7041.77	8630.98
22	15381.7	7509.7	8419.06
23	15185.9	7420.55	7957.42
24	15206.3	8327.71	7304.42
25	15405.2	7363.97	6725.21
26	7743.95	6954.28	7041.77
27	7258.35	4288.89	7509.7
28	3020.55	5257.09	7420.55
29	2586.52	5849.62	8327.71
30	5125.44	4384.27	7363.97

Distance from the town of Venusia (m)			
n	Pre-Roman settlements	New Republican settlements	Republican settlements
31	7977.63	2934.93	6954.28
32	10113.4	5098.28	4288.89
33	10360.3	3606.12	5257.09
34	10491.4	7950.37	5849.62
35	10586.2	5550.23	4384.27
36	10290.8	5958.14	2934.93
37	10316	14359.4	5697.87
38	10129.3	13794.9	5098.28
39	10203.2	19875.7	3606.12
40	10238.9	15949.3	4537.15
41	10458.6	15912.8	7950.37
42	10469.3	16102.7	5550.23
43	10576.6	17304.1	5958.14
44	10729.4	15626.1	14359.4
45	10662.9	10853.3	13794.9
46		16495.7	19875.7
47		16716.1	15949.3
48		18014.8	15912.8
49		20144.5	16058
50		18514.2	16102.7
51		15807.2	17304.1
52		15389.3	15626.1
53		12431.5	10853.3
54		15114.9	16495.7
55		19109.1	16716.1
56		19597.6	18014.8
57		19517.7	20144.5
58		19658.6	18514.2
59		19541.7	15807.2
60		2065.84	15389.3

Distance from the town of Venusia (m)			
n	**Pre-Roman settlements**	**New Republican settlements**	**Republican settlements**
61		2564.7	12431.5
62		3106.01	15114.9
63		3180.22	19109.1
64		3877.69	19597.6
65		1420.56	19517.7
66		2371.24	19658.6
67		1712.83	19541.7
68		560	2065.84
69		526.972	2564.7
70		612.699	3106.01
71		687.968	3180.22
72		652.993	3877.69
73		731.095	3020.55
74		966.488	1420.56
75		2912.47	2371.24
76		7816.55	1712.83
77		5950.6	560
78		5877.25	526.972
79		4399.06	612.699
80		1475.74	687.968
81		1856.91	652.993
82		2443.93	731.095
83		1761.82	966.488
84		2269.74	2912.47
85		2870.05	5125.44

Distance from the town of Venusia (m)			
n	**Pre-Roman settlements**	**New Republican settlements**	**Republican settlements**
86		3200.25	7816.55
87		3645.85	5950.6
88		5444.24	5877.25
89		3893.44	4399.06
90		3020.35	1475.74
91		2462.19	1856.91
92		6846.76	2443.93
93		8814.65	1761.82
94		5925.96	2269.74
95		5502.45	2870.05
96		2130.38	3200.25
97			3645.85
98			5444.24
99			10113.4
100			10316
101			10458.6
102			3893.44
103			3020.35
104			2462.19
105			6846.76
106			8814.65
107			5925.96
108			5502.45
109			2130.38

SUMMARY

Samples	Count	Sum	Average	Variance
Pre-Roman settlements	45	471697.56	10482.168	10107288
New Republican settlements	96	770269.275	8023.63828	34107923
Republican settlements	109	891858.385	8182.18702	31756273

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Samples	209286932.8	2	104643466	3.632917	0.027862	3.032361
Within Samples	7114650838	247	28804254.4			
Total	7323937770	249				

t-Test	Pre-Roman settlements	New Republican settlements
Mean	10482.168	8023.638281
Variance	10107288.02	34107923.31
Observations	45	96
Pooled Variance	26510599.91	
Hypothesized Mean Difference	0	
df	139	
t Stat	2.643005103	
P(T<=t) one-tail	0.004580305	
t Critical one-tail	1.655889868	
a: P(T<=t) two-tail	0.009160609	
b: P(T<=t) two-tail (Bonferroni's correction)	0.016666667	
t Critical two-tail	1.977177724	
If a< b, significant difference exists	TRUE	

t-Test	Pre-Roman settlements	Republican settlements
Mean	10482.168	8182.187018
Variance	10107288.02	31756272.68
Observations	45	109
Pooled Variance	25489461.33	
Hypothesized Mean Difference	0	
df	152	
t Stat	2.57100583	
P(T<=t) one-tail	0.005550097	
t Critical one-tail	1.654940175	
a: P(T<=t) two-tail	0.011100195	
b: P(T<=t) two-tail (Bonferroni's correction)	0.016666667	
t Critical two-tail	1.975693928	
If a< b, significant difference exists	TRUE	

t-Test	New Republican settlements	Republican settlements
Mean	8023.638281	8182.187018
Variance	34107923.31	31756272.68
Observations	96	109
Pooled Variance	32856798.84	
Hypothesized Mean Difference	0	
df	203	
t Stat	-0.197615997	
P(T<=t) one-tail	0.421771627	

t-Test	New Republican settlements	Republican settlements
t Critical one-tail	1.65239446	
a: P(T<=t) two-tail	0.843543254	
b: P(T<=t) two-tail (Bonferroni's correction)	0.016666667	
t Critical two-tail	1.971718848	
If a< b, significant difference exists	FALSE	

b. Kolmogorov-Smirnov two-sample test: by using this test in this example it is assessed whether the distribution across variable categories (in this case, subsequent distance bands from the town of Venusia) of pre-Roman 801-2000 sq m settlements significantly differs from the distribution of new Republican 801-2000 sq m settlements.

Kolmogorov-Smirnov test. Critical value 0.246 (α = 0.05)

Distance band from the town of Venusia	Pre-Roman settlements	Proportion of pre-Roman settlements	Cumulative proportion of pre-Roman settlements (a)	New Republican settlements	Proportion of New Republican settlements	Cumulative proportion of new Republican settlements (b)	Difference = |a - b|
0-2 km	0	0	0	12	0.125	0.125	0.125
2.1-4 km	2	0.044	0.044	18	0.188	0.313	0.268
4.1-6 km	4	0.089	0.133	17	0.177	0.490	0.356
6.1-8 km	3	0.067	0.200	14	0.146	0.635	0.435
8.1-10 km	2	0.044	0.244	6	0.063	0.698	0.453
10.1-12 km	22	0.489	0.733	3	0.031	0.729	0.004
12.1-14 km	6	0.133	0.867	5	0.052	0.781	0.085
14.1-16 km	4	0.089	0.956	8	0.083	0.865	0.091
16.1-18 km	2	0.044	1	4	0.042	0.906	0.094
18.1-20 km	0	0	1	8	0.083	0.990	0.010
> 20 km	0	0	1	1	0.010	1	0
Tot.	45	1		96	1		

c. Chi-squared two-sample test: by using this test in this example it is assessed whether the distribution across variable categories (in this case, soil types) of pre-Roman 101-400 sq m settlements significantly differs from the distribution of new Republican 101-400 sq m settlements. A very small p value (in this case, p = 0.00027) indicates that a significant difference exists. In this case (df = 11 ; α = 0.001) the critical value to reject the null hypothesis of no difference between the two samples is 31.26 (see Siegel 1956: 249). However, it should be noted that in this example there are many expected frequencies of sites below five; the Chi-squared test might not be the most appropriate method to be used in this case (see Siegel 1956, 110).

Soil unit	Pre-Roman settlements (O_β)	New Republican settlements (O_γ)	Totality	Expected Pre-Roman settlements (E_β)	$(O_\beta-E_\beta)^2/E_\beta$	Expected New Republican settlements (E_γ)	$(O_\gamma-E_\gamma)^2/E_\gamma$
14.2	10	33	43	13.277	0.809	29.723	0.361
14.3	1	1	2	0.618	0.237	1.382	0.106
9.2	1	3	4	1.235	0.045	2.765	0.020
7.3	9	17	26	8.028	0.118	17.972	0.053
11.1	38	105	143	44.154	0.858	98.846	0.383
6.3	5	0	5	1.544	7.737	3.456	3.456
14.5	0	2	2	0.618	0.618	1.382	0.276
14.1	0	1	1	0.309	0.309	0.691	0.138
12.1	1	4	5	1.544	0.192	3.456	0.086
11.2	17	19	36	11.116	3.115	24.884	1.391
14.7	1	12	13	4.014	2.263	8.986	1.011
6.4	5	0	5	1.544	7.737	3.456	3.456
Tot.	88	197	285	88	24.036	197	10.737
						Chi-square = 34.773	

2. Assessing correlations between factors and settlement distributions: the one-sample Chi-Squared, Kolmogorov-Smirnov, and Attwell-Fletcher tests

By applying either the Chi-squared (for nominal variables) or the Kolmogorov-Smirnov test (for ordinal variables), it is possible to assess whether there are significant differences between the frequency distribution of observed and expected settlements with respect to certain landscape factors. In the first example (a), the chi-squared test is used to assess whether Imperial settlements are equally distributed across the various soil types. This does not seem to be the case ($p < 0.001$); subsequently, the Attwell-Fletcher test is used to point out possible correlations with soil types. In the second example (b), we focus instead on the Republican 0-100 sq m settlements and on how these settlements are placed with respect to a water source. First the Kolmogorov-Smirnov test is used to assess whether a divergence exists from equality in distribution with respect to water distance bands and subsequently, the Attwell-Fletcher test is applied to highlight both favored and avoided distance bands to water.

a. *Chi-squared and Attwell-Fletcher tests*

Chi-squared test. Critical value 23.68 (df = 14 ; $\alpha = 0.05$)

Soil unit	Area (sq m)	%	Observed settlements (O)	Expected settlements (E)	$(O - E)^2/E$
14.4	2542200	0.366	2	2.172	0.014
14.6	15408200	2.216	7	13.164	2.886
14.2	61494600	8.845	88	52.537	23.939
14.3	8919300	1.283	7	7.620	0.050
9.2	15808800	2.274	33	13.506	28.137
7.3	67255200	9.673	84	57.458	12.261
11.1	279720100	40.231	212	238.973	3.044

Chi-squared test. Critical value 23.68 (df = 14 ; α = 0.05)

Soil unit	Area (sq m)	%	Observed settlements (O)	Expected settlements (E)	(O - E)²/E
6.3	13156400	1.892	11	11.240	0.005
14.5	9745700	1.402	6	8.326	0.650
14.1	28993500	4.170	12	24.770	6.583
12.1	23297100	3.351	14	19.903	1.751
11.2	135817200	19.534	92	116.033	4.978
7.5	7361700	1.059	2	6.289	2.925
14.7	19072200	2.743	19	16.294	0.449
6.4	6690000	0.962	5	5.715	0.090
Tot.	695282200	100	594	594	Chi-square = 87.762

Attwell-Fletcher test

number of settlements = 594 ; number of simulations = 200

Soil unit	N of settlements	Expected proportion	Observed proportion	Category weight	More sites than expected	Fewer sites than expected
14.4	2	0.00	0.00	0.06		
14.6	7	0.02	0.01	0.04		
14.2	88	0.09	0.15	0.11		
14.3	7	0.01	0.01	0.06		
9.2	33	0.02	0.06	0.16		
7.3	84	0.10	0.14	0.10		
11.1	212	0.40	0.36	0.06		
6.3	11	0.02	0.02	0.07		
14.5	6	0.01	0.01	0.05		
14.1	12	0.04	0.02	0.03		
12.1	14	0.03	0.02	0.05		
11.2	92	0.19	0.15	0.05		
7.5	2	0.01	0.00	0.02		
14.7	19	0.03	0.03	0.08		
6.4	5	0.01	0.01	0.06		

95th percentile = 0.14 +- 0.007 ; 5th percentile = 0.00 +- 0.000

b. Kolmogorov-Smirnov and Attwell-Fletcher tests

Kolmogorov-Smirnov test. Critical value: 0.105 (α = 0.05)

Water distance band	Area (sq m)	Proportion of area	Expected Cumulative proportion (E)	N of settlements	Proportion of settlements	Observed Cumulative proportion (O)	Difference = |E - O|
0 – 200 m	175648200	0.253	0.253	45	0.268	0.268	0.015
201 – 400 m	164570200	0.237	0.489	62	0.369	0.637	0.148
401 – 600 m	127113900	0.183	0.672	34	0.202	0.839	0.167
601 – 800 m	89448700	0.129	0.801	20	0.119	0.958	0.158
801 – 1000 m	56637100	0.081	0.882	3	0.018	0.976	0.094
> 1000 m	81864100	0.118	1	4	0.024	1	0
Tot.	695282200			168			

Attwell-Fletcher test

number of settlements = 168 ; number of simulations = 200

Water distance band	N of settlements	Expected proportion	Observed proportion	Category weight	More sites than expected	Fewer sites than expected
0 – 200 m	45	0.25	0.27	0.21		
201 – 400 m	62	0.24	0.37	0.31		
401 – 600 m	34	0.18	0.20	0.22		
601 – 800 m	20	0.13	0.12	0.18		
801 – 1000 m	3	0.08	0.02	0.04		
> 1000 m	4	0.12	0.02	0.04		
95th percentile = 0.25 +- 0.002 ; 5th percentile = 0.09 +- 0.008						

Appendix II

The tables below report the results of the statistical analysis. Significant differences and/or correlations are highlighted in red, whereas absence of differences (*i.e.* presence of similarity) and/or correlations is highlighted in green.

For the one-sample tests, the yellow fields indicate that only one out of two tests detected a correlation. The symbol "+" indicates more sites than expected (positive correlation), whereas "-" indicates that fewer sites than expected are located in a certain land unit (negative correlation). Positive and negative correlations are separated by a semicolon. The ordinal numbers indicate the classes/bands/units where the correlations occur (see also the correspondent Figures).

1. ANOVA and t-tests

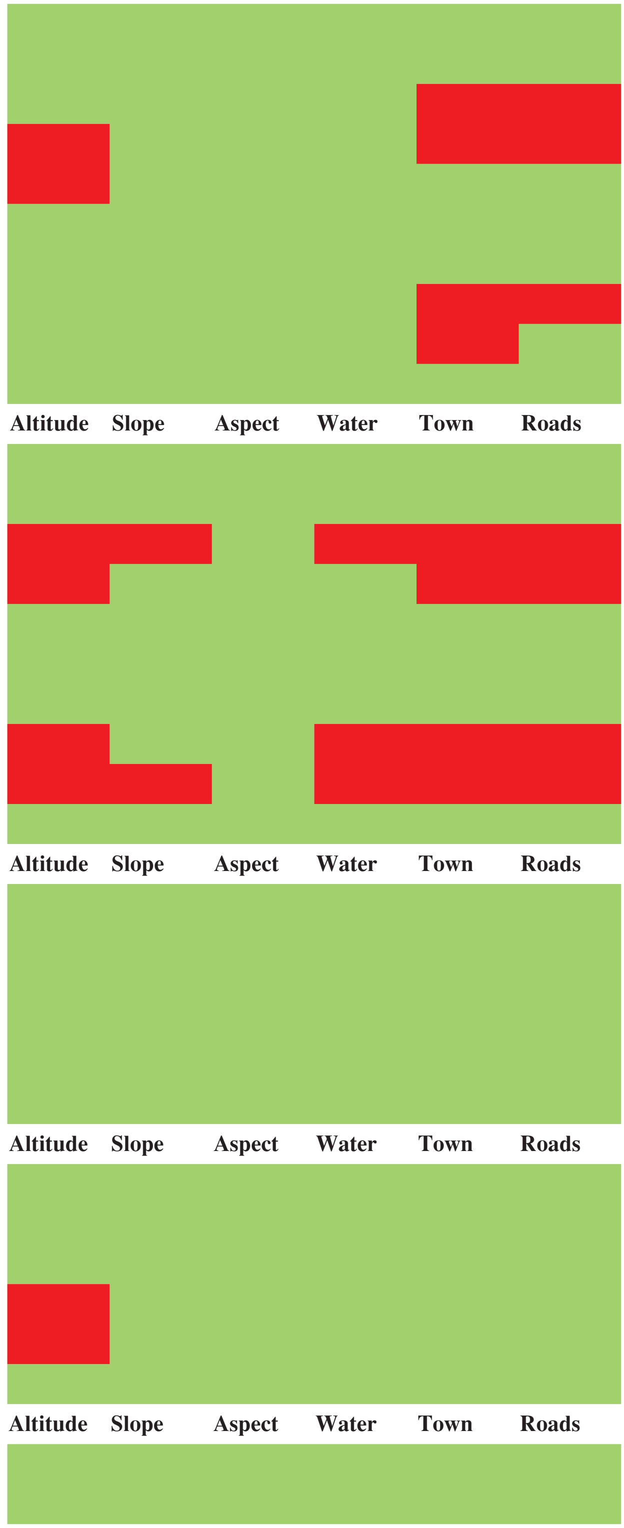
Pre-Roman and early colonial period settlement comparison	**ANOVA and t-tests**					
0-100 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Pre-Roman vs. inherited pre-Roman settlements						
Pre-Roman vs. new early colonial period settlements						
Pre-Roman vs. early colonial period settlements						
Inherited pre-Roman vs. new early colonial period settlements						
Inherited pre-Roman vs. early colonial period settlements						
New early colonial period settlements vs. early colonial period settlements						
101-400 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Pre-Roman vs. inherited pre-Roman settlements						
Pre-Roman vs. new early colonial period settlements						
Pre-Roman vs. early colonial period settlements						
Inherited pre-Roman vs. new early colonial period settlements						
Inherited pre-Roman vs. early colonial period settlements						
New early colonial period settlements vs. early colonial period settlements						
401-800 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Pre-Roman vs. new early colonial period settlements						
Pre-Roman vs. early colonial period settlements						
New early colonial period settlements vs. early colonial period settlements						
801-2000 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Pre-Roman vs. new early colonial period settlements						
Pre-Roman vs. early colonial period settlements						
New early colonial period settlements vs. early colonial period settlements						
> 2000 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Pre-Roman vs. new early colonial period settlements						
Pre-Roman vs. early colonial period settlements						
New early colonial period settlements vs. early colonial period settlements						

Pre-Roman and Republican settlement comparison	ANOVA and t-tests					
0-100 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Pre-Roman vs. inherited pre-Roman settlements						
Pre-Roman vs. new Republican settlements						
Pre-Roman vs. Republican settlements						
Inherited pre-Roman vs. new Republican settlements						
Inherited pre-Roman vs. Republican settlements						
New Republican vs. Republican settlements						
101-400 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Pre-Roman vs. inherited pre-Roman settlements						
Pre-Roman vs. new Republican settlements						
Pre-Roman vs. Republican settlements						
Inherited pre-Roman vs. new Republican settlements						
Inherited pre-Roman vs. Republican settlements						
New Republican vs. Republican settlements						
401-800 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Pre-Roman vs. new Republican settlements						
Pre-Roman vs. Republican settlements						
New Republican vs. Republican settlements						
801-2000 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Pre-Roman vs. new Republican settlements						
Pre-Roman vs. Republican settlements						
New Republican vs. Republican settlements						
> 2000 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Pre-Roman vs. new Republican settlements						
Pre-Roman vs. Republican settlements						
New Republican vs. Republican settlements						

Republican and LR-Triumviral settlement comparison	ANOVA and t-tests					
0-100 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Republican vs. inherited Republican settlements						
Republican vs. new Republican settlements						
Republican vs. LR-Triumviral settlements						
Republican vs. new LR-Triumviral settlements						
Inherited Republican vs. new Republican settlements						
Inherited Republican vs. new LR-Triumviral settlements						
Inherited Republican vs. LR-Triumviral settlements						
New Republican vs. New LR-Triumviral settlements						
New Republican vs. LR-Triumviral settlements						
New LR-Triumviral vs. LR-Triumviral settlements						

Republican and LR-Triumviral settlement comparison	ANOVA and t-tests					
101-400 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Republican vs. inherited Republican settlements						
Republican vs. new Republican settlements						
Republican vs. LR-Triumviral settlements						
Republican vs. new LR-Triumviral settlements						
Inherited Republican vs. new Republican settlements						
Inherited Republican vs. new LR-Triumviral settlements						
Inherited Republican vs. LR-Triumviral settlements						
New Republican vs. New LR-Triumviral settlements						
New Republican vs. LR-Triumviral settlements						
New LR-Triumviral vs. LR-Triumviral settlements						
401-800 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Republican vs. new Republican settlements						
Republican vs. LR-Triumviral settlements						
Republican vs. new LR-Triumviral settlements						
New Republican vs. new LR-Triumviral settlements						
New Republican vs. LR-Triumviral settlements						
New LR-Triumviral vs. LR-Triumviral settlements						
801-2000 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Republican vs. new Republican settlements						
Republican vs. LR-Triumviral settlements						
Republican vs. new LR-Triumviral settlements						
New Republican vs. new LR-Triumviral settlements						
New Republican vs. LR-Triumviral settlements						
New LR-Triumviral vs. LR-Triumviral settlements						
> 2000 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Republican vs. new Republican settlements						
Republican vs. LR-Triumviral settlements						
Republican vs. new LR-Triumviral settlements						
New Republican vs. new LR-Triumviral settlements						
New Republican vs. LR-Triumviral settlements						
New LR-Triumviral vs. LR-Triumviral settlements						

Republican and Imperial settlement comparison	ANOVA and t-tests					
0-100 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Imperial vs. Inherited Republican settlements						
Imperial vs. new Imperial settlements						
Imperial vs. Republican settlements						
Imperial vs. new Republican settlements						
Inherited Republican vs. new Republican settlements						
Inherited Republican vs. new LR-Triumviral settlements						
Inherited Republican vs. Republican settlements						
New Imperial vs. new Republican settlements						
New Imperial vs. Republican settlements						
New Imperial vs. Imperial settlements						
101-400 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Imperial vs. Inherited Republican settlements						
Imperial vs. new Imperial settlements						
Imperial vs. Republican settlements						
Imperial vs. new Republican settlements						
Inherited Republican vs. new Republican settlements						
Inherited Republican vs. new LR-Triumviral settlements						
Inherited Republican vs. Republican settlements						
New Imperial vs. new Republican settlements						
New Imperial vs. Republican settlements						
New Imperial vs. Imperial settlements						
401-800 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Imperial vs. new Imperial settlements						
Imperial vs. Republican settlements						
Imperial vs. new Republican settlements						
New Imperial vs. new Republican settlements						
New Imperial vs. Republican settlements						
New Imperial vs. Imperial settlements						
801-2000 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Imperial vs. new Imperial settlements						
Imperial vs. Republican settlements						
Imperial vs. new Republican settlements						
New Imperial vs. new Republican settlements						
New Imperial vs. Republican settlements						
New Imperial vs. Imperial settlements						
> 2000 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
Imperial vs. new Imperial settlements						
Imperial vs. Republican settlements						



Republican and Imperial settlement comparison	**ANOVA and t-tests**
Imperial vs. new Republican settlements	
New Imperial vs. new Republican settlements	
New Imperial vs. Republican settlements	
New Imperial vs. Imperial settlements	

LR-Triumviral and Imperial settlement comparison	**ANOVA and t-tests**					
0-100 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
LR-Triumviral vs. inherited LR-Triumviral settlements						
LR-Triumviral vs. new LR-Triumviral settlements						
LR-Triumviral vs. Imperial settlements						
LR-Triumviral vs. new Imperial settlements						
Inherited LR-Triumviral vs. new LR-Triumviral settlements						
Inherited LR-Triumviral vs. new Imperial settlements						
Inherited LR-Triumviral vs. Imperial settlements						
New LR-Triumviral vs. new Imperial settlements						
New LR-Triumviral vs. Imperial settlements						
New Imperial vs. Imperial settlements						
101-400 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
LR-Triumviral vs. inherited LR-Triumviral settlements						
LR-Triumviral vs. new LR-Triumviral settlements						
LR-Triumviral vs. Imperial settlements						
LR-Triumviral vs. new Imperial settlements						
Inherited LR-Triumviral vs. new LR-Triumviral settlements						
Inherited LR-Triumviral vs. new Imperial settlements						
Inherited LR-Triumviral vs. Imperial settlements						
New LR-Triumviral vs. new Imperial settlements						
New LR-Triumviral vs. Imperial settlements						
New Imperial vs. Imperial settlements						
401-800 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
LR-Triumviral vs. new LR-Triumviral settlements						
LR-Triumviral vs. Imperial settlements						
LR-Triumviral vs. new Imperial settlements						
New LR-Triumviral vs. new Imperial settlements						
New LR-Triumviral vs. Imperial settlements						
New Imperial vs. Imperial settlements						
801-2000 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
LR-Triumviral vs. new LR-Triumviral settlements						
LR-Triumviral vs. Imperial settlements						

LR-Triumviral and Imperial settlement comparison	**ANOVA and t-tests**					
LR-Triumviral vs. new Imperial settlements						
New LR-Triumviral vs. new Imperial settlements						
New LR-Triumviral vs. Imperial settlements						
New Imperial vs. Imperial settlements						
> 2000 sq m settlement samples	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**
LR-Triumviral vs. new LR-Triumviral settlements						
LR-Triumviral vs. Imperial settlements						
LR-Triumviral vs. new Imperial settlements						
New LR-Triumviral vs. new Imperial settlements						
New LR-Triumviral vs. Imperial settlements						
New Imperial vs. Imperial settlements						

2. Kolmogorov-Smirnov and Chi-squared two-sample tests

	Kolmogorov-Smirnov test						**Chi-squared test**	
Pre-Roman and early colonial settlement comparison	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**	**Soil**	**Ridges/ Peaks**
0-100 sq m settlement samples								
Pre-Roman vs. new early colonial period settlements								
101-400 sq m settlement samples								
Pre-Roman vs. new early colonial period settlements								
401-800 sq m settlement samples								
Pre-Roman vs. new early colonial period settlements								
801-2000 sq m settlement samples								
Pre-Roman vs. new early colonial period settlements								
> 2000 sq m settlement samples								
Pre-Roman vs. new early colonial settlements								

	Kolmogorov-Smirnov test						**Chi-squared test**	
Pre-Roman and Republican settlement comparison	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**	**Soil**	**Ridges/ Peaks**
0-100 sq m settlement samples								
Pre-Roman vs. new Republican settlements								
101-400 sq m settlement samples								
Pre-Roman vs. new Republican settlements								
401-800 sq m settlement samples								
Pre-Roman vs. new Republican settlements								
801-2000 sq m settlement samples								
Pre-Roman vs. new Republican settlements								
> 2000 sq m settlement samples								
Pre-Roman vs. new Republican settlements								

	Kolmogorov-Smirnov test						Chi-squared test	
Republican and LR-Triumviral settlement comparison	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**	**Soil**	**Ridges/ Peaks**
0-100 sq m settlement samples								
Republican vs. new LR-Triumviral settlements								
101-400 sq m settlement samples								
Republican vs. new LR-Triumviral settlements								
401-800 sq m settlement samples								
Republican vs. new LR-Triumviral settlements								
801-2000 sq m settlement samples								
Republican vs. new LR-Triumviral settlements								
> 2000 sq m settlement samples								
Republican vs. new LR-Triumviral settlements								

	Kolmogorov-Smirnov test						Chi-squared test	
Republican and Imperial settlement comparison	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**	**Soil**	**Ridges/ Peaks**
0-100 sq m settlement samples								
Republican vs. new Imperial settlements								
101-400 sq m settlement samples								
Republican vs. new Imperial settlements								
401-800 sq m settlement samples								
Republican vs. new Imperial settlements								
801-2000 sq m settlement samples								
Republican vs. new Imperial settlements								
> 2000 sq m settlement samples								
Republican vs. new Imperial settlements								

	Kolmogorov-Smirnov test						Chi-squared test	
LR-Triumviral and Imperial settlement comparison	**Altitude**	**Slope**	**Aspect**	**Water**	**Town**	**Roads**	**Soil**	**Ridges/ Peaks**
0-100 sq m settlement samples								
LR-Triumviral vs. new Imperial settlements								
101-400 sq m settlement samples								
LR-Triumviral vs. new Imperial settlements								
401-800 sq m settlement samples								
LR-Triumviral vs. new Imperial settlements								
801-2000 sq m settlement samples								
LR-Triumviral vs. new Imperial settlements								
> 2000 sq m settlement samples								
LR-Triumviral vs. new Imperial settlements								

3. One-sample Chi-squared, Kolmogorov-Smirnov and Attwell-Fletcher tests

Pre-Roman settlements	0-100 sq m	101-400 sq m	401-800 sq m	801-2000 sq m	>2000 sq m	Totality
Altitude	+ 5th ; - 1st	+ 4th ; - 1st				+ 4th ; - 1st
Slope						
Aspect						
Soil	+ unit 6.3	+ unit 6.4	+ unit 14.3	+ unit 14.3		+ units 6.3, 6.4
Ridges/Peaks						+ on ridges/ peaks
Water	+ 2nd ; - 6th	+ 2nd ; - 6th				+ 2nd ; - 6th
Town	+ 3rd , 4th	+ 6th		+ 6th		+ 4th , 6th; - 1st , 11th
Roads		+ 3rd				+ 3rd ; - 8th

Early colonial-period settlements	0-100 sq m	101-400 sq m	401-800 sq m	801-2000 sq m	>2000 sq m	Totality
Altitude	+ 4th	+ 4th				+ 4th ; - 1st
Slope		+ 1st				+ 1st
Aspect						- 7th
Soil						
Ridges/Peaks						
Water	+ 2nd	- 5th				+ 2nd
Town	+ 1st	+ 1st		+ 1st		+ 1st
Roads			+ 4th			

Republican settlements	0-100 sq m	101-400 sq m	401-800 sq m	801-2000 sq m	>2000 sq m	Totality
Altitude	+ 4th ; - 1st	+ 3rd				+ 3rd ; - 5th
Slope						
Aspect						
Soil						
Ridges/Peaks				+ on ridges/ peaks		+ on ridges/ peaks
Water	+ 2nd ; - 5th , 6th	- 6th				+ 2nd ; - 5th , 6th
Town	+ 1st , 2nd ; - 7th–9th, 11th	+ 1st , 2nd ; - 7th, 8th, 11th		+ 1st , 2nd		+ 1st , 2nd ; - 7th–9th, 11th
Roads	+ 1st , 2nd			+ 1st		+ 1st , 2nd ; - 8th

LR-Triumviral settlements	0-100 sq m	101-400 sq m	401-800 sq m	801-2000 sq m	>2000 sq m	Totality
Altitude	+ 4th ; - 1st			+ 3rd	+ 1st	+ 3rd
Slope						
Aspect						
Soil						+ unit 14.2
Ridges/Peaks		+ on ridges/ peaks		+ on ridges/ peaks		+ on ridges/ peaks
Water						- 6th
Town	+ 1st, 3rd	+ 1st, 2nd	+ 1st, 2nd	+ 1st		+ 1st–3rd ; - 6th–9th, 11th
Roads		+ 2nd				+ 1st, 2nd

Imperial settlements	0-100 sq m	101-400 sq m	401-800 sq m	801-2000 sq m	>2000 sq m	Totality
Altitude	+ 5th ; - 1st				+ 1st	
Slope						
Aspect						
Soil	+ unit 9.2					+ unit 9.2
Ridges/Peaks	+ on ridges/ peaks	+ on ridges/ peaks	+ on ridges/ peaks	+ on ridges/ peaks		+ on ridges/ peaks
Water	- 6th					+ 2nd ; - 6th
Town	+ 2nd	+ 1st ; - 11th	+ 1st	+ 3rd		+ 1st–3rd ; - 8th, 11th
Roads						+ 1st