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# Between Land and Sky—A Study of the Orientation of Roman Centuriations in Italy

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**Abstract:** The centuriations were public lands delimited and divided in regular lots by Rome as a result of the conquest but also the conceptual appropriation of new territories, which were transformed according to particular ideas of space. Despite previous works rejecting the astronomical hypothesis for the orientation of Roman centuriations, recent publications have supported the role of particular astronomical phenomena in the design of Roman land and urbanism in Italy. The aim of this work is to determine whether the orientation of the centuriations follows any pattern, and to determine the precepts, if any, underlying the election of privileged directions. We present a statistical study of the orientation of 67 centuriations in Italy—the largest sample of this type ever studied in this region—that considers the conditions of the surrounding environment together with a comparative analysis with a dataset of the same type that includes 52 Italian Roman towns. The results show interesting patterns shared by both centuriations and towns, some of them coinciding with relevant astronomical events in the Roman context, together with others in which differentrequirements would have been prioritized. In summary, we should consider the sky as an element involved in the creation of Roman urban and rural spaces.

**Keywords:** archaeoastronomy; Roman archaeology; Roman urbanism; centuriations; Roman landscape



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## 1. Introduction

During the Roman Republic and the Empire, a vast amount of land was conquered and incorporated into the Roman domains. As a consequence, it was felt necessary to establish boundaries and to assess lands for censuses and land taxes, as well as to divide the *ager publicus* for the development of the colonies. The formal act of colonization was known as *deductio* and it was in this context that Romans divided the land by creating regular patterns of squares or rectangles (called *centuriae*) marked out by diverse topographical features, boundary stones or different structures, such as roads. These *centuriae* had two main axes, called *cardo* and *decumanus*, that ran approximately north–south and east–west, respectively (Figure 1). Similar systems of land division (*limitatio*) were previously applied in Italy by Greeks, Oscans or Etruscans [1–3], but the Romans adopted unprecedented strategies in terms of scale and skill, and possibly, according to certain cultural elements referred to symbolic aspects, strongly reshaped the conquered territories.

Typical Roman orthogonal grids are characterized by squares with standard sizes, such as 20 × 20 *actus* (710 m side) or 16 × 16 *actus* (569 m side), although other modules were used depending on various factors, such as the local topographic configuration (Front. La. 11.3-6) [2,4]. These newly created landscapes defined property rights, designated common pasture and public areas, strengthened the administrative power in conquered areas and served to arrange structures. However, a central role of this division system was that it contributed to the conceptual and ideological appropriation of territory sustained by a religious background, in part expressed by the rituality involved in the land division processes, which was likely influenced by the Etruscans (Var., L.L., 7, 7; Front., *De limit.*, 9, 28-9).

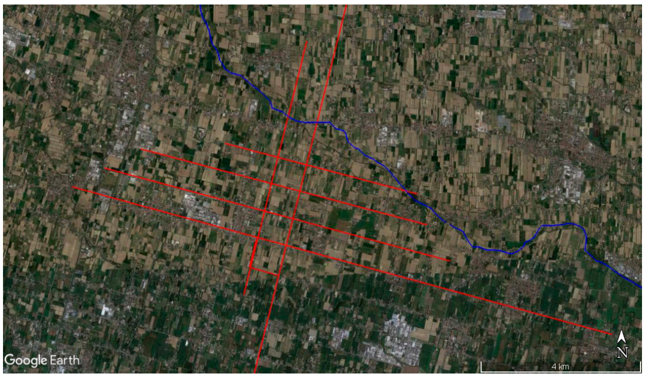


**Figure 1.** Reconstruction of the Roman grid of the Padova northeast centuriation over the remains of the *cardines* and *decumani* in the present territory. Satellite images from Google Earth.

Surveying tasks and land division were carried out by the *agrimensores*, who designed and registered the newly settled land, set out the borders of new colonies and advised in all kinds of land disputes [5]. They also were designated as *gromatici* for the *groma*, a surveying instrument that consisted of a stick with two horizontal cross bars connected by a bracket, which was used to set long straight lines at right angles with the great accuracy that was essential for the creation of *centuriae* [6].

After the Second World War, with the beginning of aerial archaeology, the study of centuriations increased appreciably since several of these structures started to be identified and various treatises that were collected mentioned a considerable number of centuriations [4]. Particularly, starting from the 1970s and during the 1980s, archaeomorphological research on centuriation experienced a significant development, in part by the French group of Besançon, which incorporated the photointerpretative study of the orientation and size of *centuriae* [7,8].

Territorial signs of these cultural landscapes from different periods are still present in the regions that belonged to the Roman Empire and in Italy in particular. The aim of this paper is to present the results of a project for the study of the role of astronomy in the design of Roman landscapes, both rural and urban. Specifically, here we show the preliminary results of a statistical analysis of the orientations of Roman centuriations in Italy and a comparison with the patterns found in a sample of orientations of Roman towns in the same region. This first approach offers some clues for the understanding of Roman concepts of space organization and the role that different factors such as astronomy and topographic features might have had in the shaping of landscapes. Furthermore, including the colonial settlements and the wider territory in the analysis allows for better comprehension of Roman colonization and its impact on the society and the environment. This is in line with more recent perspectives regarding the origin, development and exploitation of these rural Roman landscapes, as well as the role of nonurban settlements in Roman administrative structures [3,9].

*Ancient Sources and Previous Works*

One of the main sources of Roman ideas about land surveying is the *Corpus Agrimensorum*, an extant collection of short works in Latin from the Republic and the Empire, which was assembled in the late fourth century CE and which can be considered as containing the primary written records of Roman land surveying. These treatises contain plenty of information about the surveying practices, their origin and evolution and further technical issues regarding land demarcation and distribution. In various texts, some authors mentioned the use of astronomical observations in order to define the orientation of the *cardines* and the *decumani*, in particular relative to the position of the sun (e.g., Frontinus, *De limit*., 10.20–11.6 Th; 11.9–14 Th; see [10] for a recent review). However, ancient writers such as Vitruvius prioritized wind avoidance at defining the orientation of the urban axes (*de Architectura* I, 6), and Strabo also remarked on the convenience of considering meteorological features (Strabo, 5. 2. 5. 1). Nonetheless, the former stressed that the architect should manage astronomy in order to proceed correctly (1. 1. 3).

Earlier studies have rejected the idea of astronomical orientations [11,12], stating that the axes of both the centuriations and towns were established *secundum natura*, that is, that topographical and environmental conditions, such as a mountain slope or a coastline, prevailed over astronomical ones [13].

Alternatively, hypotheses such as the use of right-angled triangles have been suggested for both centuriations and towns [12,14], sometimes supporting that there were not any special criteria for the orientations [12]. Nonetheless, works such as that of Le Gall [11]—who mentioned the existence of nine methods for the orientation of centuriations *secundum naturae*—used azimuths extracted from maps according to the magnetic, not the real, north and compared the values from a wide range of latitudes, which makes it difficult to make a comparison with the positions of celestial objects.

During recent decades, several researchers on Roman archaeoastronomy have offered a completely different view, by showing that the orientation patterns of several Roman settlements and monuments across the Empire are far from random (see, e.g., [15,16]).

At present, more than 300 towns have been already measured in Western Europe [10,16,17], the Near East [18] and the Maghreb [19], and astronomical patterns were identified in all regions, some of them shared among different provinces together with regional particularities. In Italy specifically, several Roman towns were studied [20,21], including Rome itself [22], together with the masterpiece of Roman engineering that is the Via Appia [23,24], which is a clear example of the integration of astronomical phenomena in Roman land organization. In addition, the implementation of a particular geometrical technique (the *varatio*) for the orientation of the main axes was explored in Roman towns in the Iberian Peninsula, leading to the conclusion that geometry might have also been used with possibly astronomical purposes [25]. These works prompted us to study the case of the centuriations in a similar way. The hypothesis we aim to test is whether a statistically significant sample of centuriation orientations does or does not show concentrations that might be related either to astronomical targets or to purely topographic restrictions.

## 2. Materials and Methods

This work includes an analysis of the azimuths of the main axes of 67 Roman centuriations in Italy (Figure 2). The centuriations included here represent approximately 80% of the known centuriations listed in the compilation made by S. Settis [26], who collected a significant corpus of more than 120 Roman land divisions in different regions of the Empire, mostly in Italy. Additionally, other grids extracted from later research were identified and included in the sample, as indicated in the data of Tables S1 and S2. In the present work, no specific chronological or geopolitical criteria were followed at the time of selecting the places studied, since the main aim in this case was to collect a sample as wide as possible within a particular territory. Nonetheless, the periods of development for each centuriation and town are indicated in the data of Tables S1 and S2 for all cases in which we could find this information. Using this method, our aim is to have the opportunity to analyse whether certain orientation patterns were privileged during particular historical processes and, if so, to figure out why.

The dataset for this study includes the azimuths and the declination for a horizon with altitude 0°, of the *cardo* and the *decumanus* at each site, since a reference point from where to determine the altitudes of the horizon could not be found in all places. According to Hyginus Gromaticus (Hyg. Grom., *De limitibus constituendis*, p. 181, ed. Lachmann), this point (the *locus gromae*) should be the centre of the grid or of the town if present, and supposedly the central point of territorial systematization, but it cannot be assumed that all centuriations were contemporary to the corresponding colonies; they could be later developments, a possibility which has been suggested at least for the earliest Latin colonies [27,28]. Furthermore, in towns that had more than one centuriated system, these usually had different orientations and not all of them encompassed the urban area.

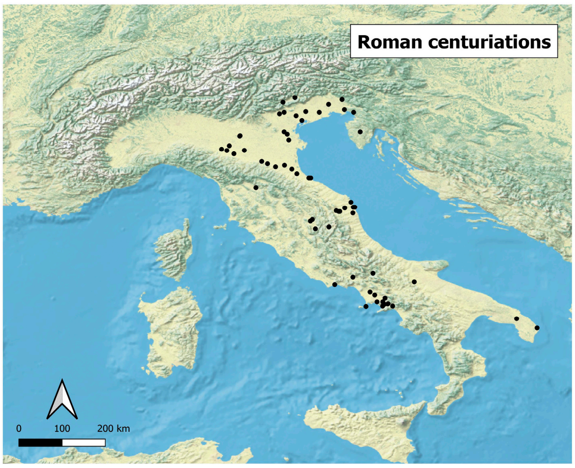


**Figure 2.** Map with the 67 Roman centuriations included in the sample.

Even in the absence of a *locus gromae*, the astronomical declination was calculated for each azimuth, considering an altitude of the horizon equal to 0°. This magnitude is independent of the latitude and it allows a direct comparison of the positions of the sun with dates—in this case with the proleptic Gregorian calendar—and incorporates the influence of the surrounding horizon in the visibility of astronomical phenomena. Due to the inclination of the Earth's rotation axis with respect to the plane that contains the orbit around the sun, the rising and setting positions of the sun over the horizon (and thus its declination value) vary every day. In particular, the solar declination at the equinoxes is 0° (although there are other definitions of equinox [29]) and the declination of the sun at the solstices is ±23.4° today, whereas due to variations in obliquity, the latter value was ±23.7° in Roman times.

In this sense, declination values for an altitude of 0° allow an analysis of the orientations that considers how latitude affects the observation of the positions of specific celestial objects and can provide insight into the purposes behind the transformation of a territory. Declination is defined as

$$\sin \delta = \sin h \sin \varphi + \mathrm{con}\, h \cos \varphi \cos A \quad (1)$$

with δ being the astronomical declination, h the altitude of the horizon, φ the latitude of the location and A the azimuth, considered as the angle from north, clockwise.

The first step for the data acquisition was performing a selection and identification of previously known centuriations in Italy [26,30], which were the first candidates to be georeferenced and studied. Our own observations of the grids in the present-day ground, together with the corroboration of their Roman origin, were some of the main limitations of our research. Despite the fact that many more centuriated systems are currently being studied, we have limited our sample to those grids that we were able to observe directly on aerial imagery or from which we could find the orientation data in the literature. In most cases, the Roman origin of each centuriation was checked and supported using a related bibliography and, whenever possible, the modules of the observed grids were measured in order to check that their sizes followed one of the Roman standards, such as 20 × 20 *actus* (approximately 710 × 710 m) or 16 × 16 *actus* (569 × 569 m), although modules different to these were used as well [31]. The aim of this procedure was to corroborate that the grids were not remains from previous or later divisions, since similar land division procedures were practiced at various moments in history; even different Roman traces are sometimes superimposed, which makes centuriations notoriously difficult to date [3]. Finally, once the traces of the grids were identified using aerial or satellite images, the orientation of their main axes was measured using Google Earth Pro (7.3.3, 7.3.4). This was performed on 51 sites, and a bibliography was also required in areas without visual signs of the centuriations on the present-day terrain but where their existence was previously attested and their remains studied. In particular, in a number of places there are modern structures, such as roads or water channels, that follow the axes of the Roman grids today, for example in South Padova [32] or in Fermo [13,33] (Figure 2). The source of the data is specified in the column of comments in Table S1, with "GE" (for Google Earth data) or the bibliographical references consulted for the centuriations that are not identified in the satellite and aerial images.

We have avoided data obtained only from cartography, and only azimuths measured using either orthophotography or satellite images, as well as in situ, were selected. In particular, this last data source refers to the abovementioned centuriation of the Pontine marshes, which was studied by one of the authors [23,24]. For some centuriations, both bibliographic and Google Earth data could be contrasted, and in general the resultant values differed by no more than 2°. In these cases, the Google Earth values were selected in order to produce a more homogeneous data sample.

Even though not all Google Earth Pro images have the same spatial resolution, a general intrinsic error in azimuth of ±1° was estimated for data obtained by this procedure according to previous studies [19].

The same value was considered for the declinations, since all were calculated for an altitude of 0°, meaning this is an acceptable first approach to the real data to within an accuracy of ±1°; this means approximately 3 days for dates close to the equinoxes and almost 20 days for dates around the solstices. However, a more conservative error of ±2° should be estimated for the data extracted only from bibliographic sources, where no structures of the centuriations were observable. As mentioned previously, these centuriations are indicated in the data table (Table S1) with the corresponding references. For the analysis of the orientation of towns, the altitude of the horizon was obtained to calculate the declination with the virtual tool HeyWhatsThat [34], as will be discussed later.

Ideally, all the orientations should have been measured in situ, but the size of the sample, the state of preservation of a great part of these structures and many other logistic issues made it difficult to carry out fieldwork at the present stage of the study.

## 3. Results

### *3.1. Orientation of Centuriations*

The data are presented in curvigrams, in particular using a probability density function with a Gaussian kernel, one of the most commonly used, and the results are normalized by the mean value of the relative frequency. This means that the values of the peaks indicate their distance above the mean.

In the different declination curvigrams, a horizontal red-dashed line marks the 3σ level of significance, which indicates that 99.7% of the values of a binomial distribution fall within three standard deviations from the mean, so that that particular value can be considered statistically significant. Despite the fact that 3σ is a significant general convention in many disciplines, bearing in mind the size and nature of the sample analysed in this paper, data above the 2σ level (which includes 95.5% of the values) can be considered significant. In addition, peaks below these limits should not be underestimated since they can actually represent either minoritarian or local orientation practices.

Figure 3 shows the curvigram of the declination towards the east of the 67 centuriations, for an altitude of the horizon equal to 0° using a Gaussian kernel and a passband of 2°. This value was selected considering the nature and size of the dataset and in order to appreciate the main clusters, avoiding distributions that are too sharp or smooth [35]. Since the altitude of the horizon is 0° for the declination values, due to the orthogonality of the axes the western values offer a mirror image.

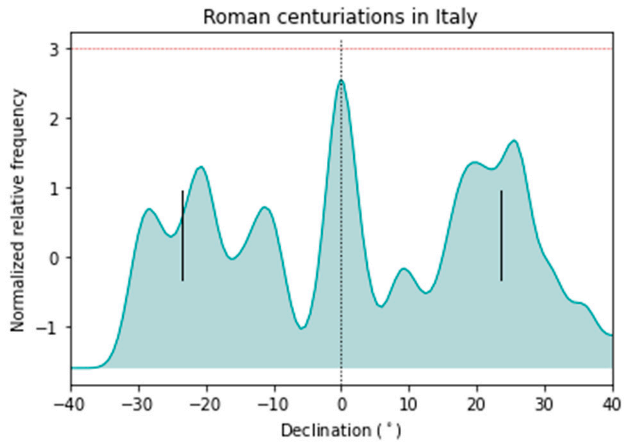


**Figure 3.** Declination curvigram of 67 centuriations in Italy considering an altitude of the horizon of 0°. The black solid vertical lines indicate the extreme positions of the rising sun, on the solstices, and the vertical dashed line marks the solar declination on the equinoxes. More details are presented in the main text.

The declination curvigram shows various concentrations and 70% of the data fall within the solar rising range of declinations (Figure 3), limited by the black solid vertical lines at +23.75° and −23.75° (the solar declinations for the summer and winter solstices, respectively). There is one main maximum above the 2σ level towards the sunrise at the equinoxes (12 centuriations) and various secondary peaks. There is a widely spread group of declinations around the summer solstice value, subdivided in two subpeaks. Interestingly, regarding the azimuths, the subgroup around δ = 26° (of 7 centuriations) could respond to the use of the Pythagorean triple 3:4:5 for Italian latitudes and that of δ = 17° to the use of 5:12:13. Other minor peaks are centred around δ = −22° (the beginning of December and mid-January) and δ = −12° (mid-February and the end of October), and there is one value out of the solar arc centred around δ = −30°.

Exploring the Role of Topography

In a second analysis, the possible role of topography in the layout of the axes of a centuriation was explored, since in areas with abrupt orography or that are appreciably affected by water flows and floods, the grids would have inevitably been drawn *secundum natura*. In particular, and as is attested by many ancient and contemporary authors, water management was a primary feature to attend to at the time of designing and dividing lands—for example, for canalization and irrigation projects required for agriculture and pastures—since it was essential for their administration and productive use. Examples where this seems to be prioritized are mentioned for some centuriations along the Via Aemilia [36] as well as in towns developed in former marshy areas, such as Capua [37] or Acerrae [38].

Undoubtedly, surveyors had to cope with a variety of geographical settings, so in order to identify likely environmental restrictions in the tracing of the main axes, the centuriations were classified into three categories: "topographic", "possibly topographic" and "non-topographic". According to this categorization, the majority of centuriations would be potentially affected by environmental conditions, but it should be noted that this classification is not exempt from subjectivity, since it is essentially based on the accounts and impressions of other authors (for the "topographic" ones) and on personal estimations of the influence of the surrounding terrain, made using observations of the local topography at present and in Roman times; there are mentions in the ancient texts describing the territory, as there are in recent works discussing environmental land reconstructions.

By this classification, 53 grids in the sample could have potentially been affected by the shape and conditions of the terrain, e.g., the presence of mountains, slopes, marshes or coastlines, risks of flooding, etc. These are the "topographic" (21 grids) and "possibly topographic" (32 grids) centuriations, from which 38 values (70%) fall within the solar range of declination. The declination distribution of the 53 grids is likely affected by diverse environmental factors, as shown in Figure 4, and in Figure 5 the data of the 21 "topographic" centuriations are displayed. As expected, both distributions present concentrations that coincide with the main ones found for the full sample but with different levels of significance, in part due to the size of each dataset. The data of the "topographics" (Figure 5) seem more dispersed and present more and lower peaks, with the exception of a great concentration of values that are approximately between −24° and −10°.

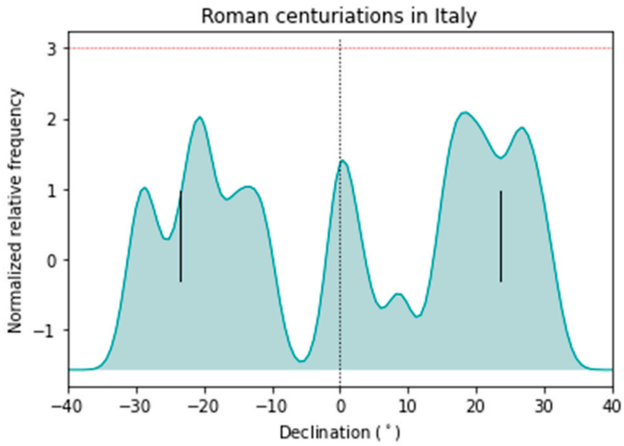


**Figure 4.** Declination curvigram considering an altitude of the horizon equal to 0° of the 53 centuriations where topography or water management may have affected the orientation ("topographic" and "possibly topographic"). The black solid vertical lines indicate the extreme positions of the rising sun on the solstices, and the vertical dashed line marks the solar declination on the equinoxes.

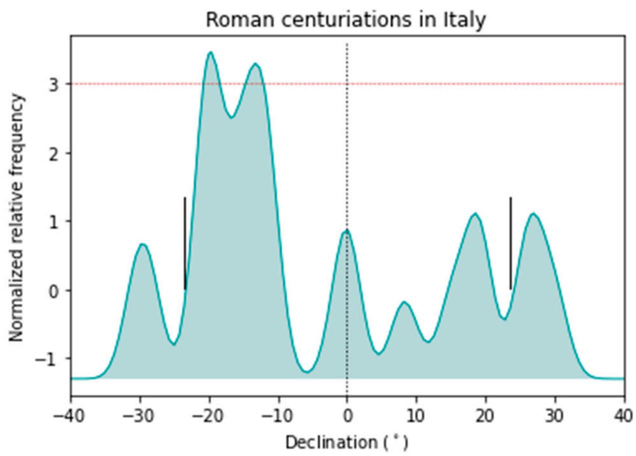


**Figure 5.** Declination curvigram of 21 centuriations likely affected by the natural environment ("topographic"), considering an altitude of the horizon equal to 0°.

Included in this group are a number of grids developed along the Via Aemilia, in present-day Emilia Romagna, that some authors assumed were traced *secundum natura* to favour drainage and irrigation of fields; for example, in Mutina, Regium Lepidi [36] and Bononia [39]. The Via Aemilia was one of the main consular roads in the region. Its construction started in the late second century BCE under the rule of the Roman consul Marcus Aemilius Lepidus and it traversed the area between Ariminum (Rimini) and Placentia (Piacenza), being a key element for the appropriation of the Cispadana area and the creation of several urban centres throughout. The two cardinal centuriations are Feltria—on irregular terrain in the course of the Cordeville river [40]—and one in Capua that belonged to the Ager Campanus and was possibly affected by the presence of marshes in the area [37].

Finally, in Figure 6 the 21 "topographic" centuriations are discarded. In contrast to the curvigrams of Figures 4 and 5, this diagram presents less and more defined maxima, with 70% of the centuriations within the solar arc and mostly grouped around the sunrise on the equinoxes (11 grids) and both solstices, with the exception of a minor cluster around −11° (late October and mid-February). A similar percentage of solar-compatible orientations appears for the "non-topographic" centuriations (60%), which are mostly concentrated around the equinoxes and around δ = 26°, so that they could have been obtained by using a triangle 3:4:5 or they might possibly correspond to summer solstice orientations for local altitudes of the horizon different from 0°.

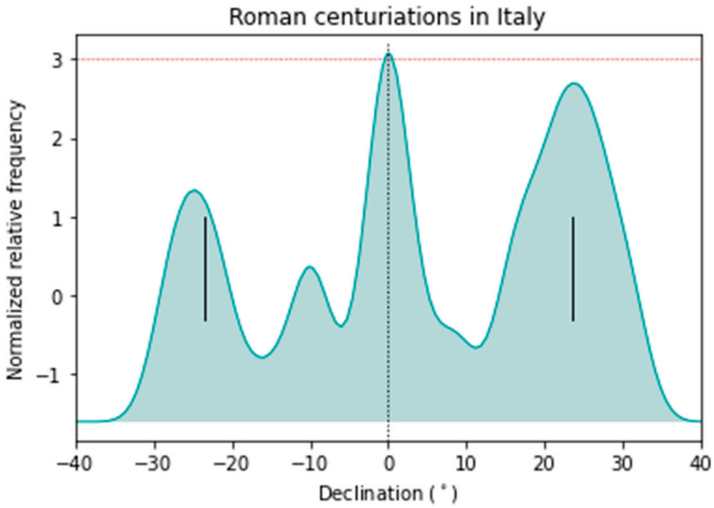


**Figure 6.** Declination curvigram with altitude of the horizon 0° of 47 centuriations where topography does not seem to have been a restriction and where there is a possibility that orientation was related to water management ("non-topographic" and "possibly topographic").

### *3.2. Orientation of Roman Towns*

In a final step, the declination of the centuriations was compared with those of a number of Roman towns in Italy and three in the Roman province of Illyria (present-day Croatia), since the centuriation of Histria is included in the sample. In particular, this dataset includes 42 declinations from 39 towns (Figure 7), since in Tergeste (modern Trieste) there are three grids developed in different constructive processes (see Table S2). From these, 24 towns were inserted in the centuriations of the sample and the remaining azimuths were extracted from other publications [16] or measured using satellite images by the authors of this paper, except at Augusta Praetoria Salassorum (modern Aosta), whose orientation was obtained in situ by one of the authors [21].

The altitudes of the horizon were obtained by using a digital terrain model with the web application HeyWhatsThat [34]. Since altitude data have now been introduced, in this case the estimated error for the declinations is ±1.5°, the same considered in a previous analysis of a sample of Roman towns obtained using these methods [16].


**Figure 7.** Map with the 42 Roman towns studied in Italy.

In Figure 8, the declination curvigram of Roman towns is displayed, where 76% of the declinations are within the solar rising arc. As was the case for the previous curvigrams for the centuriations, a Gaussian kernel was used with a passband of 2.5°, taking into consideration a larger margin of error introduced by the measurement of the altitudes and in order to differentiate the maxima. The distribution of towns approximately shares the general trend present in the orientation of the centuriations (Figure 3) to cluster around the equinoxes, mostly avoiding values around −8° and +8°. The diagram presents maxima above the 2σ level grouped in a spread around −18° and 27°, slightly to the right of the summer solstice value (Figure 8). However, the data of the centuriations are in general more dispersed than those of the towns.

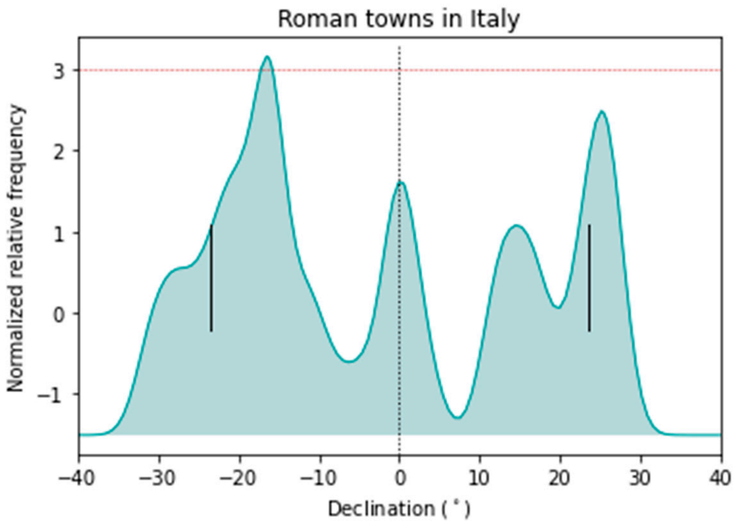


**Figure 8.** Declination curvigram of 42 *decumani* of Roman towns in Italy, created using a Gaussian kernel.

The coincidental orientations between centuriations and towns make sense because out of the 24 towns inserted in the centuriations studied, 16 have conformal grids (i.e., their urban axes follow the same direction as their corresponding centuriation) and in some places the centres of towns could have been the points from which centuriations were developed, i.e., the *locus gromae*. This coincidence is present in illustrations in the *Corpus Agrimensorum Romanorum*, in which the *territorium* would represent an extension of the urban axes. In other cases, however, the rural systems were organized according to different topographical features or pre-existing pathways, and did not follow the urban streets [2].

Additionally, the curvigram of towns presents a peak approximately around δ = +13° that coincides with a minimum in the different subsamples of the centuriations (Figures 3–6). It is interesting to note that this value corresponds to the declination of the sun rising on April 25th, a date close to a relevant moment for the Roman calendar: the anniversary of the mythical foundation of Rome on April 21st. This is among the errors considered for these data.

## 4. Discussion

The analysis presented here encompasses the biggest dataset of orientations of centuriations in Italy, and it is the first statistical comparison with the data of Roman cities from the same region. At first glance, regarding the orientation patterns displayed in the different curvigrams, we can identify that 70% of the declinations coincide with values for the rising sun. In addition, some maxima may correspond to the practice of astronomical observations or the application of simple geometrical techniques such as the *varatio*—previously studied for Roman towns in Hispania [25,41]—together with more dispersed data that could be explained by diverse environmental restrictions of the terrain where centuriations were located.

Regarding the potential effects of the surrounding environment in these results, as expected, the main maxima present in the general sample of centuriations are restricted both within the declination curvigrams that display "topographic" centuriations (Figure 6) and when only "topographic" and "possibly topographic" grids were considered (Figure 4). In both cases, more than half of the values are in the solar arc of the sunrise, although some maxima and their significance differ among samples. When the "topographic" grids are ignored (Figure 6), the values appear more clustered around the cardinal directions, the summer solstice and slightly to the left of the winter solstice. The 21 "topographic" declinations (Figure 5) appear to be spread more along the eastern sector (which may be also an effect of the smaller dimensions of this dataset) and from this sample and regarding Figure 4, the use of Pythagorean triangles could be inferred even in the presence of certain topographic constraints; in particular, the 5:12:13 triangle ($\delta \approx \pm 17°$ for latitude 42°) could have been used.

It should be noted that there is subjectivity in the classification of the centuriations for the study of the role of topography, which is largely based on the accounts of ancient writers, the considerations of other authors and personal impressions, so the possibility of other motivations cannot be fully discarded. Furthermore, recent studies have shown the impact of anthropogenic activities, such as deforestation and even centuriation, on the environment during Roman times; the effects of these activities included increases in flooding [42]. These events may suggest a lack of proper maintenance of the territory in periods of political turbulence or during strong rainfall episodes, but also that the processes of land division could sometimes have conflicted with the local hydrological conditions if motivations other than strictly practical motivations (e. g., following special, sacred directions) were prioritized at the time of establishing the *limites*, at least in certain moments in Roman history. In addition, meteorological changes from climate stability to periods of drought and increasing rainfall, for example during the triumviral and Augustan ages, would have influenced the design of the centuriated lands as observed at the alluvial plains of Luni and Lucca [42].

Nevertheless, even though topography would have been an unavoidable central feature that conditioned the orientation of the axes of various centuriations, different factors related to state authority (e.g., certain divisions, assignations and uses of lands) and ritual practices may have played a role in the designing and setting of boundaries. This is suggested by the predominantly solar pattern with maxima clusters around relevant moments such as the equinoxes and probably the solstices, considering the margin of error and the fact that the real influence of the surrounding horizon is unknown at the moment. Both acted as temporal landmarks which were commonly considered transition moments on the solar cycle and were accompanied with festivities and rituals in the Mediterranean and Roman traditions [43–45], as well as in many other cultures throughout history. In fact, both orientations are present in several Roman towns in different provinces and from specific moments in Roman history [16,21,22], sometimes probably relating to the pre-Roman traditions of the local cultures [18]. Interestingly, Roman author Vitruvius stressed the importance of architects having knowledge of astronomy (1.1.3), as well as knowing the principles of the heavens, the equinoxes, the solstices and the course of the stars (1.1.10).

The Roman calendar underwent several modifications before Julius Caesar reformed it in 45 BCE. The Roman year started in January in Republican times (as attested in *Fasti Antiates Maioris*), but ancient sources mention that the first Roman calendar established by Romulus (the legendary founder of Rome) started in March during the spring equinox (Macrobius, Sat. 13.3) and festivities were associated with this moment [29].

The winter solstice was also a central point of the natural and ritual Roman year (coinciding with the longest night, after which days start to become longer) that was embodied in the orientations identified in Rome itself [22], several towns across the Empire [10,15] and, particularly, in towns founded during the reign of Emperor Augustus. The first Roman emperor incorporated Capricorn and the winter solstice into his imperial propaganda as symbols of political renewal [16,21]. Although today the sun is in the constellation of Sagittarius during the winter solstice, in Roman times the "host" constellation was Capricorn. In other words, the stars of Capricorn were behind the sun at the moment in which the daily hours of light started to increase. In parallel, during this period the autumn equinox became a central date because it coincided with Augustus' birthday, and this can also be observed in the orientation patterns of numerous cities founded by him.

Similar patterns to those of the centuriations are present as well in the Roman urban examples in Italy included in this paper, a result that supports the study's interest in astronomical motivations behind the land division practices. At first glance, the data of the towns appear less dispersed (Figure 8), possibly due to the greater land extensions covered by the centuriations that would have been more affected by environmental constrictions than the less extensive urban centres. Furthermore, towns and centuriations may not necessarily be contemporary, but the latter could be post-dated according to the necessities and circumstances of colonization. Ultimately, the pre-Roman origins of various urban centres [28] and, possibly, of some of the land divisions should be borne in mind [27]. However, the comparison of the two permits a better understanding of the colonial settlement organization as a whole and its impact on the wider environmental and local society. Regarding this, we found some parallels between the orientation patterns of towns and centuriations, mainly at the equinoxes and at dates around the summer solstice. In addition, towns presented a maximum for the declination towards the rising sun on an important day known as the *Dies Natalis* of Rome, which was previously identified in the urbanism in further regions of the Roman Empire as well as in such a notable structure of Roman architecture as the Pantheon in Rome [46].

Finally, the use of geometry should not be dismissed either, as suggested by the maxima around $\delta \approx +26^\circ$ and $\delta \approx +17^\circ$ in the centuriations' curvigram of declination (Figure 3), which are compatible with the use of the Pythagorean triangles 3:4:5 and 5:12:13, respectively, for null altitudes of the horizon and medium Italian latitudes. The role of geometry in the layout of land has been explored in several studies on Roman land and urban design across the Empire, with both practical and symbolic intentionality [14,25,41,47] and, in addition to hypothetical direct observations of particular astronomical phenomena (such as sunrises on special dates), astronomy was also required for the implementation of particular geometric relations to the cardinal axes by using a *gnomon* (see, e.g., [25]).

## 5. Conclusions

It is indisputable that Roman surveyors had to account for several environmental and topographical issues when establishing new colonies and for the reorganization, division and exploitation of land [6]. The transformation of the territory and the modification of water courses were essential for productive activities but also for favouring the conditions of the terrain necessary for the development of settlements. However, in addition to adaptations to physical and natural constraints, at some points in Roman history strategic and defensive motivations may have been prioritized in determining the location of colonies, and even certain political contexts and necessities would have left footprints in the landscape transformations [48] that can now be identified in elements such as the preference for specific directions in the layout of the axes of a new urban or agrarian project.

The results of this study suggest that, even without considering the altitudes of the horizon, we should not discard either the existence and application of special practical guidelines for the orientation of the axes of centuriations or the possibility that those precepts involved some forms of astronomical observations and symbology (as stated in various ancient texts already mentioned). In fact, prior research has shown how the azimuth patterns could indicate the presence of astronomical considerations in the orientation of Roman structures [20,25]. It is especially suggestive to find the main maxima around the equinoxes and the solstices, more appreciably when the centuriations clearly conditioned by topography ("topographic") were discarded (Figure 6). In other words, the rising sun at important dates for Roman political and religious life may have been be chosen by surveyors in the absence of strong geographic limitations.

Furthermore, the parallels between the declinations of the centuriations and those of the cities—mainly at the equinoxes and towards the summer solstice—together with the group of towns facing the sunrise on the day of the mythical foundation of Rome could be exhibiting the relevance of specific astronomical events together with such an important festivity in the Roman calendar as was the celebration of the mythical foundation of the mothertown, on April 21st. Moreover, the similarity of these results with the outcomes found in Roman towns across the Empire [15,17] and in Rome [46] once again reaffirms the existence of some kind of astronomical connection between the sky and the Roman landscapes.

All these findings support an astronomical hypothesis that proposes the existence of some form of surveying practices that involved the observation and knowledge of particular astronomical events in the layout of both the urban and rural Roman landscapes, combined with the necessary consideration of environmental features for productive activities and salubrity; these practices were also subject to diverse political processes and changes. In conclusion, there is not a single interpretation, but rather there are more complex interpretations of such an ambitious project, as it relates to the creation and implementation of new political and ideological orders in a vast land over centuries.

**Supplementary Materials:** The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/su15043388/s1: Table S1: Orientation and description of the centuriations in Italy included in the sample. Bibliographical references are in the References section in the main text of the article. title; Table S2: Orientation of the Roman towns in Italy included in the sample. References [32,33,40,49–98] are cited in the Supplementary Materials.

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