

# Ancient land divisions in the territories of Hierapolis in Phrygia and Nicaea (Turkey): the contribution of multitemporal satellite images to the discovery and study

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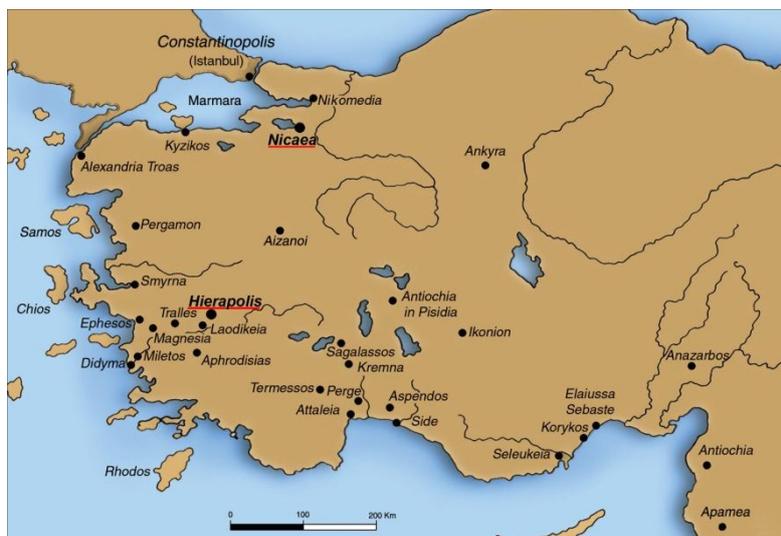
**Abstract.** During the archaeological research in the territory of Hierapolis of Phrygia (south-western Turkey), the integration of systematic field surveys and high resolution satellite remote sensing allowed to identify and document an ancient regular land division in the northern part of the Uzunpinar plateau (Province of Denizli). In particular, the visual analysis of multitemporal images acquired by satellites Corona KH-4A, Hexagon KH-9 and QuickBird-2 between 1968 and 2007 were fundamental for the identification of traces in the landscape that draw the remains of an orthogonal grid in the division of land, since the topographic maps available are not accurate and complete in reporting the boundaries of fields; moreover, aerial photographs of the area are not available. The archaeological surveys confirmed that the ancient land division was based on orthogonal axes consisting mainly of roads, canals and especially walls, built with irregular small stones. As a preliminary hypothesis, it is possible to date the land division to the Hellenistic period or to the early Imperial Roman age; to these periods, in fact, are dated the remains of rural settlements identified within and surrounding the investigated territory. The discovery is very important because this type of archaeological evidence is scarcely documented in the territory of modern Turkey. Moreover, applying the same research approach, other remains of possible ancient regular land divisions were identified in another small sector of the territory of Hierapolis itself and in the territory surrounding the ancient city of Nicaea, modern day Iznik (Province of Bursa, north-western Turkey).

**Keywords.** Landscape Archaeology, Ancient Regular Land Divisions, Multitemporal Satellite Images, Archaeological Survey, Turkey, Hierapolis of Phrygia, Nicaea.

## 1. Introduction

This study is a part of the archaeological study performed during last years on the territory of Hierapolis of Phrygia, in the modern Province of Denizli (south-western Turkey) (Fig. 1). The research project has allowed the acquisition of a lot of data for the reconstruction of the ancient settlement pattern of the territory from Prehistoric times to the Ottoman period [1]. Hierapolis was an important Hellenistic, Roman and Byzantine city and its remains are near the modern village of Pamukkale, in the ancient Region of Phrygia [2,3,4]. In this context (both the urban area and the surrounding territory), the Institute for Archaeological and Monumental Heritage of the National Research Council of Italy has conducted archaeological surveys as part of the research activities of the Italian Archaeological Mission; the surveys were aimed to the creation of the digital archaeological map of the area, integrated in a GIS platform. High-resolution satellite images were very useful in this research, because they integrate the scarce aerial photos available and the not updated and not detailed Turkish maps in 1:25,000 scale. So, the processing and visual analysis of the images allowed the identification of many buried ancient structures and palaeo-environmental elements; moreover, ortho-images, space-maps and topographic maps derived from satellite data were

produced and used during field works, for the discovery, documentation and location of the ancient remains, and in the GIS of the territory of Hierapolis, still in progress.



**Figure 1.** Hierapolis of Phrygia and Nicaea in western Turkey.

One of the main result of the research was the identification of an ancient regular land division in the northern sector of the Uzunpinar plateau, about 17 km to the north of Hierapolis. The discovery was possible only thanks to the integration of archaeological field surveys and high resolution satellite remote sensing; in particular, only the analysis and interpretation of multitemporal satellite images allowed the identification of the axes of this land division surviving in the modern landscape, since the topographic maps available are not accurate and complete in reporting the field boundaries; moreover, any aerial photographs of the area are available. Later, the archaeological surveys, performed with the aim to verify the remote sensing documentation, clarified that the ancient orthogonal field boundaries amount to roads, canals and walls built with small stones. The field works also made it possible to acquire data for dating the land division to the Hellenistic age or the early Roman Imperial period. The same research approach was applied to the entire territory of Hierapolis, i.e. the eastern sector of the valley of the Çürüksu river (ancient Lykos river, a tributary of the Meander), where the remains of the city lies, and the plateaus of Uzunpinar and Çal, to the north of the city. In this way, the remains of another possible ancient regular land division were identified in the sector of the Lykos plain located about 1.5 km to the west of Hierapolis.

The archaeological evidence documented in the territory of Hierapolis is strictly linked to the problem of identification of ancient regular land divisions in regions, such as Anatolia, where the essential tools for this type of research (i.e. large scale maps and aerial photographs, in addition to literary sources and epigraphic documents) are not available. For this reason, until today the ancient regular agrarian divisions identified in Turkish territory are very few, while it is estimated that land divisions and territory assignments were performed in this region at least in the Hellenistic and Roman periods. This research highlighted the importance of high-resolution satellite images as fundamental tools in the study of ancient land divisions. In fact, applying the same approach and using multitemporal satellite images, other remains of a regular agrarian division, probably of Hellenistic times, were discovered in the territory surrounding the ancient city of Nicaea, modern day Iznik, in the Province of Bursa, the ancient Bithynia Region (north-western Turkey) (Fig. 1). The city was founded in Hellenistic times and, despite the changes of the Roman, Byzantine and Ottoman periods, the urban layout of the modern town is still strongly influenced by the orthogonal structure built by Lysimachus in 301 BC and minutely described by Strabo (*Geographica*, XII, 565). He writes that Nicaea had the form of a square, with perpendicular road axes and two main streets that crossed in the center of the city; along them, four gates opened in the walls [5,6,7].

## 2. Methods and data set

First of all, the research was based on the visual analysis of multitemporal satellite images, acquired both from the recent civil platforms (Ikonos-2, QuickBird-2, WorldView-2) and from the United States reconnaissance satellites (Corona KH-4 and KH-4A, Hexagon KH-9) of 1960s and 1970s; the images have a best spatial resolution between 9 to 0.5 m. The first type of images (both panchromatic and multispectral) was processed using the usually methodology (such as data fusion, colour composite RGB, etc.); in the case of the territory of Hierapolis, some of these images were also orthorectified and used as base maps during field surveys and in the georeferentiation of the archaeological features. In both the case study, very useful were the space photos of the U.S. spy satellites, because they document the study areas before recent transformations and destructions due to urbanization and agricultural works.

In particular, in the case of the Uzunpinar plateau in the territory of Hierapolis the data set is: i) two space photos taken from a Corona KH-4A satellite on February 4, 1968; ii) four images taken from Hexagon KH-9 satellites on July 21, 1973, August 15, 1976, May 29, 1979, and September 28, 1980; iii) three QuickBird-2 images taken on July 17, 2005, October 26, 2006, and April 10, 2007. In the case of the Lykos valley, also in the territory of Hierapolis, the data set is: i) the same Corona KH-4A and Hexagon KH-9 images of the Uzunpinar plateau; ii) two Ikonos-2 images (April 24, 2004; March 27, 2010); iii) four QuickBird-2 images (April 30, 2002; March 25, 2005; April 10, 2007; December 14, 2009); iv) two WorldView-2 images (June 28, 2011; July 7, 2012). The analysis of the multitemporal images have highlighted the presence of many field boundaries that document the remains of an orthogonal grid in the territory. The subsequent field surveys have verified these axes and have documented their typologies: country roads, canals and walls built with small irregular stones deriving from the cleaning of fields, in which the bank emerging is often calcareous. Moreover, the field works have also allowed to identify the modulus of the land divisions (i.e. the distance between the main axes) and to acquire data for their dating to the Hellenistic period or to the early Roman Imperial age; in fact, in particular for the Uzunpinar plateau, to these periods are dated the small rural settlements identified within the investigated territory and the various large ancient villages arranged along the margins of the land division.

In the case of Nicaea and its surrounding territory, the data set is: i) two Corona KH-4 space photos taken on July 19, 1963; ii) two WorldView-2 images (July 6, 2011; November 5, 2012). In this case the study was based only on remote sensing data, without ground verify, and the modulus of the land division was identified thanks measurements in Google Earth; in fact, in the territory of Nicaea the orthogonal grid of the field boundaries stands out very clearly and seems strictly linked to the regular Hellenistic city plan.

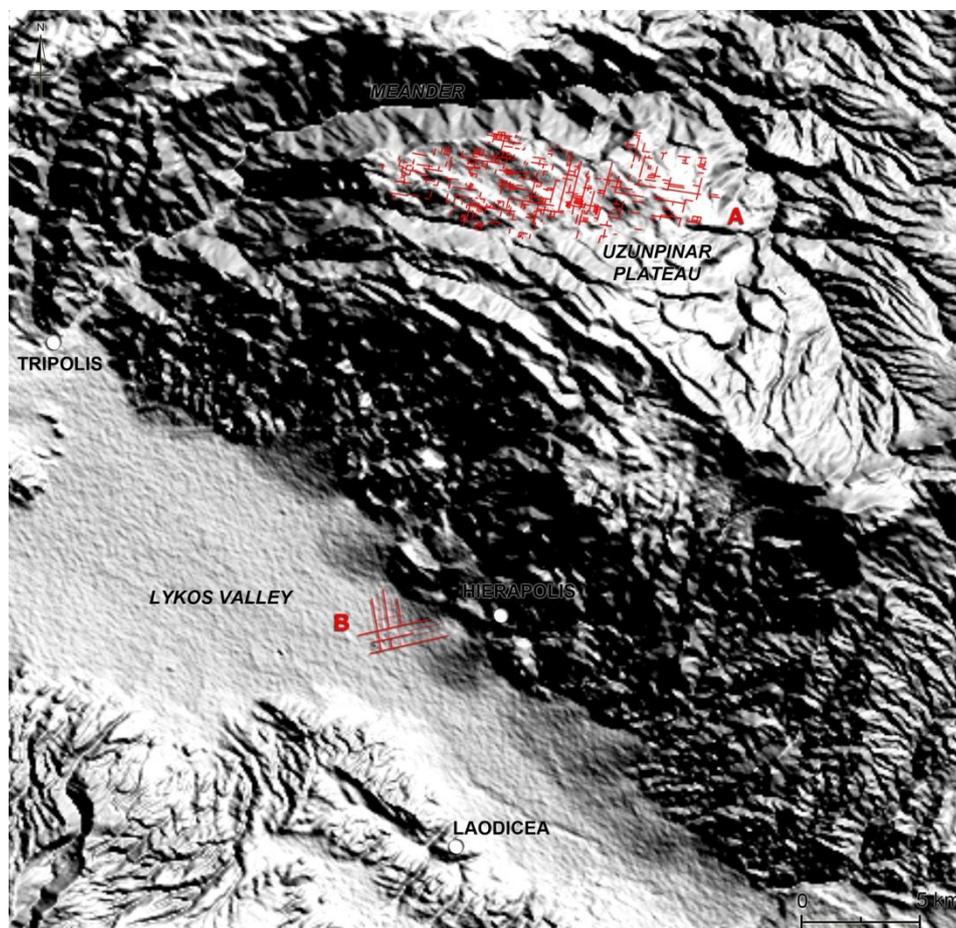
Moreover, very useful both during the research and in the presentation of results were some DEMs, on which the archaeological evidence of the land divisions are georeferenced. They were processed from ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) data and SRTM (Shuttle Radar Topography Mission) data.

## 3. Results

### 3.1. *The Uzunpinar plateau and the Lykos valley in the territory of Hierapolis*

In the northern sector of the Uzunpinar plateau (Fig. 2, A), which is at a lower altitude than the southern one and is rather flat and sloping slightly towards the north (where it is bordered by the steep slope that descends to the course of the Meander river), the archaeological surveys have documented a peripheral distribution of the rural villages of the Hellenistic, Roman and Byzantine periods. They are absent in the central part of the territory, up to 12 km wide from east to west and

up to 4 km in the north-south axis; this area, where the remains of some small ancient farms are present, was evidently intended for agricultural exploitation. In fact, a regular ancient land division was identified in this area thanks to the visual analysis of multitemporal satellite images (Fig. 3).

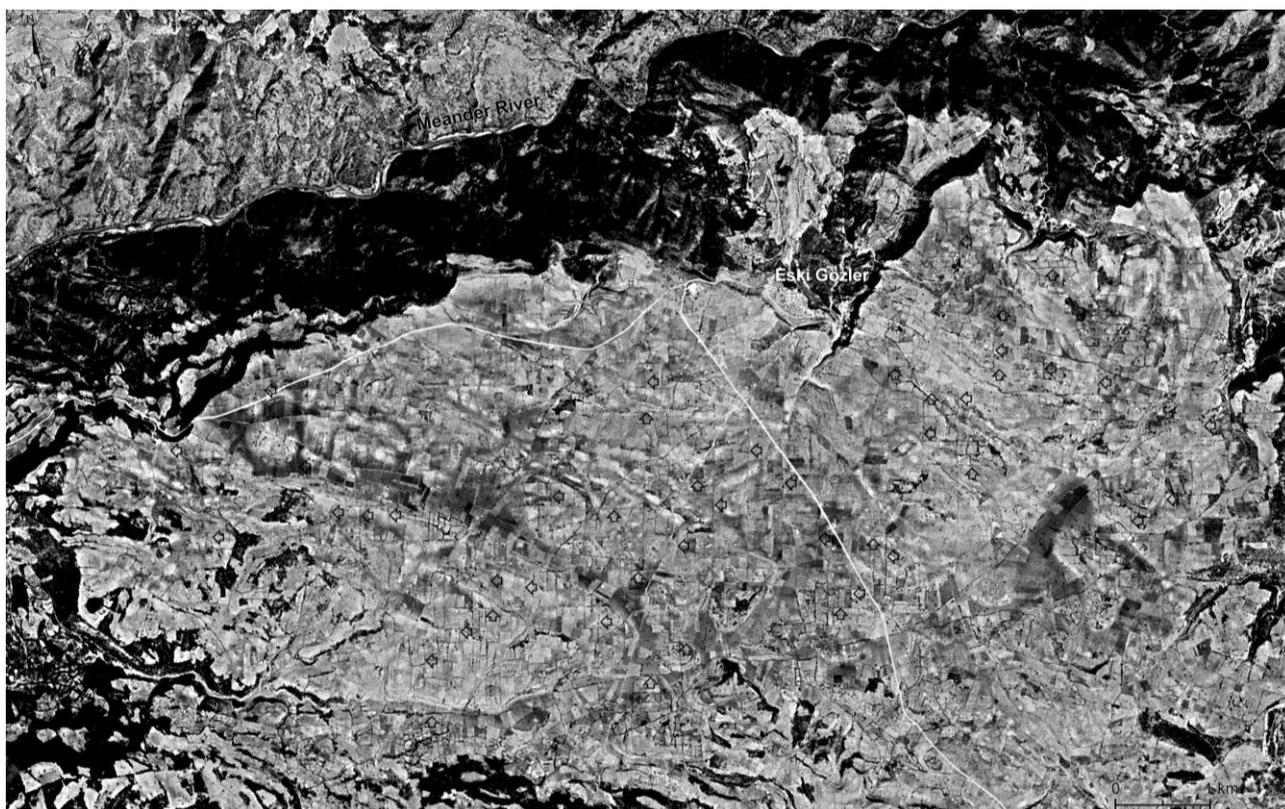


**Figure 2.** DEM of the territory of Hierapolis based on ASTER data, on which the preserved axes of possible ancient regular land divisions on the Uzunpinar plateau and in the Lykos valley are georeferenced.



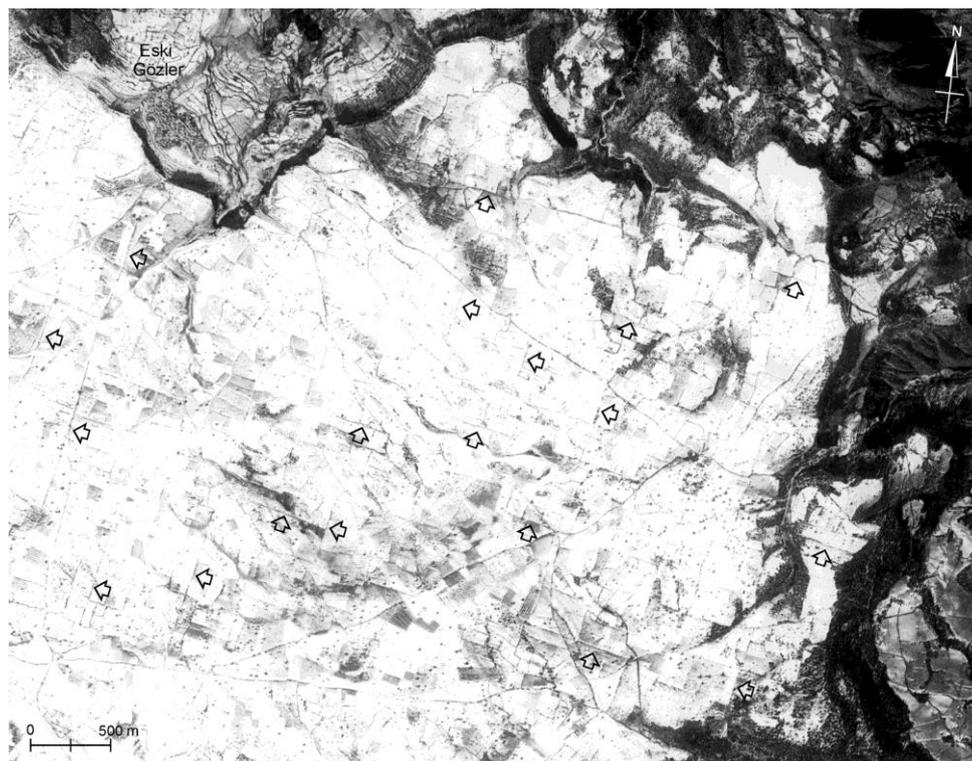
**Figure 3.** DEM of the northern sector of the Uzunpinar plateau based on ASTER data, on which the remains of an ancient regular land division in the area of Yeni Gözler (Y.G.) and Eski Gözler (E.G.) are georeferenced; they cover a large surface of the territory, around which the ancient villages are located.

During the research particularly useful were the Corona KH-4A and Hexagon KH-9 images taken between 1968 and 1980 (Figs. 4-5), because they show a territory closer to its ancient appearance and less altered by modern transformations, due to agricultural works and urbanization (Fig. 6). In fact, from the end of 1980s the village of Yeni Gözler was built in the central part of the study area, as consequence of the destruction of Eski Gözler, located just north, along the slope that descends to the Meander, due to an earthquake occurred in August 19, 1976. Therefore, some ancient axes of the land division, that now are not preserved, are well visible in the Corona KH-4A and Hexagon KH-9 images (Fig. 7).



**Figure 4.** Hexagon KH-9 image of the northern sector of the Uzunpınar plateau taken on September 28, 1980: the arrows indicate the main remains of an ancient regular land division.

The ground verify of the evidence visible in the satellite documentation allowed to note that the ancient land divisions based on orthogonal axes that constituted by country roads, canals and mostly in dry stone walls built using the material deriving from the cleaning of the fields, where the first substrate consists of limestone bed. These orthogonal roads, canals and walls trace the ancient ones and document a regular grid based on about 30 north-south axes crossed by around 16 east-west axes; generally the first ones are best preserved, probably because they also had a function of surface water drainage in direction of the northern limit of the plateau and the valley of the Meander river. The distance between the main north-south axes is about 330 or 660 m, equivalent to 11 and 22 plethra, that is a Greek measurement unit corresponding to 100 Attic feet (around 30 m); the main east-west axes are about 240 or 480 m (equivalent to 8 and 16 plethra) away between them. According the denser grid (330 x 240 m) the territory was divided into rectangles with an area of 7.92 hectares; this surface is slightly higher than the 6.45 hectares (equivalent to 50 schoinoi) of the rectangular allotments on which was based the ancient land division of the territory of Magnesia on the Meander, that was reconstructed on the base of an inscription dated to the beginning of the 3rd century BC [8].



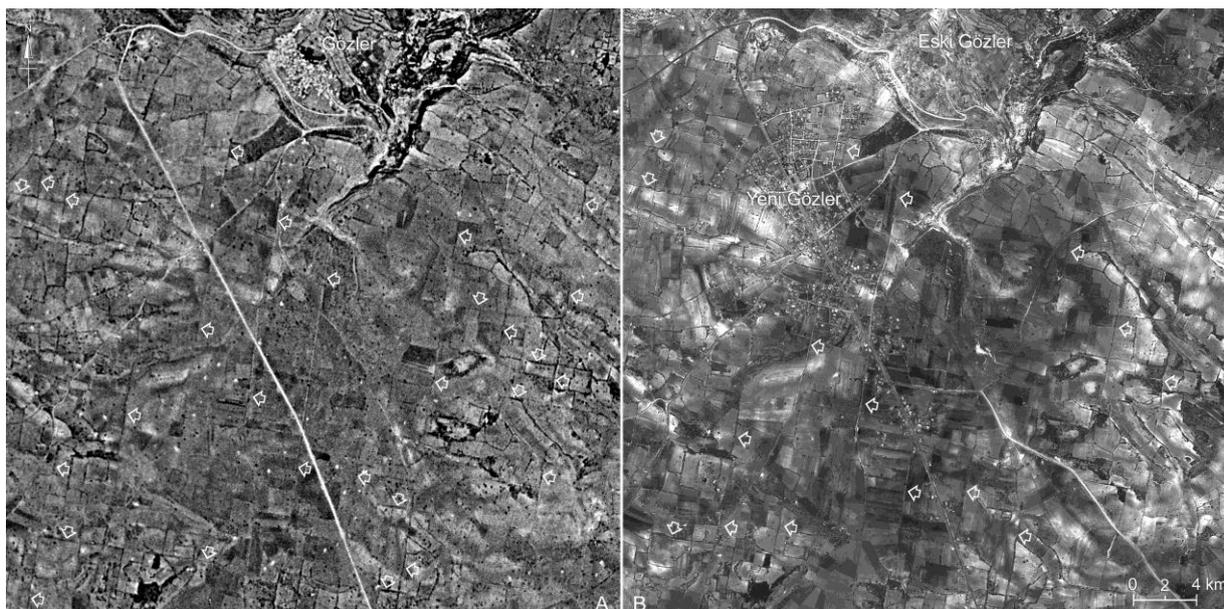
**Figure 5.** A detail of a Corona KH-4A space photo taken on February 4, 1968: many remains of ancient axes of a regular land division are visible in the central and eastern sectors of the northern part of the Uzunpinar plateau, that at the moment of the acquisition was covered by snow.



**Figure 6.** The central and eastern sectors of the northern part of the Uzunpinar plateau in a QuickBird-2 image of 2005, on which the remains of an ancient regular land division are highlighted; the ancient villages are also located.

There are not many data to be able to offer a dating of the land division identified in the Uzunpinar plateau, which documents a rational and intensive exploitation of the territory; moreover, the epigraphic and literary sources, regarding the ancient agrarian organization of the region of Hierapolis, are very few. According the modulus of this land division, based on Greek measurement units, and considering the strict connection between some axes and the surrounding ancient villages, it is possible to suppose that it dating to the Hellenistic age or the early Roman Imperial period; this

is also the chronology of the more ancient phase of the rural settlements of the area. Moreover, the considerable extension of the area affected by the agrarian division (about 4,800 hectares) leads to the hypothesis that it is an intervention promoted by the central government or by Hierapolis, but it seems rather unlikely that it happened by instigation of local communities. Therefore, we can suppose that this agrarian division was a consequence of land allocations in subsequent of one of the main events that mark the history of Hierapolis: the arrival of the Greek-Macedonian settlers, who founded the city in the 3rd century BC; the passage of the territory of Hierapolis by the Seleucid kingdom to the kingdom of Pergamon after the Peace of Apamea in 188 BC; the Roman conquest and the institution of the Province of Asia in 133 BC; the main events of the 1st century BC, such as the Mithridatic Wars (88-63 BC) or the battles of Philippi (42 BC) and Actium (31 BC).



**Figure 7.** The area of Yeni Gözler (Uzunpınar plateau) in a Hexagon KH-9 image of 1976 (A) and in a QuickBird-2 image of 2007 (B): the arrows indicate the main remains of an ancient regular land division.

The sector of the Uzunpınar plateau affected by the orthogonal agrarian division is the most fertile and flat, still today characterized by an intense agricultural exploitation; any regular land division is in the southern sector of the plateau, that has a morphology more rugged and less fertile, so much so that even today it is mostly covered by woods and exploited for sheep farming rather than for agriculture. But it is possible to suppose that a regular land division, with characteristics similar to that found on the Uzunpınar plateau, could exist even in the Lykos valley; about this matter, the late Hellenistic and early Imperial-Roman literary sources, such as Strabo (*Geographica*, XIII, 4, 14) and Vitruvius (*De architectura*, VIII, 3), remembered that the fertile alluvial plain was occupied by vegetable gardens and cultivated fields. Here, the modern intense agricultural exploitation and the transformations of recent decades (also due to reclaim and building of canals) have profoundly altered many fields' boundaries; moreover, these limitations, unlike those of the northern part of the Uzunpınar plateau, have characteristics that do not guarantee a long duration in time, since they do not consist of dry stone walls. But, around 1.5 km west of Hierapolis, in the sector of the Lykos plain between the modern villages of Develi and Akköy (Fig. 2, B), the analysis of satellite images allows to identify the remains of a regular land division, probably dating to ancient times, based on one of the most important road that descends by the city in direction of the river. In particular, a Corona KH-4A space photo taken in 1968 (Fig. 8) shows better than recent satellite images, due to the transformations produced by agricultural works, a regular grid in the fields' limitations, based on squares with sides about 390 m long (equivalent to 13 plethra); the axes consist in country roads, canals, rows of trees and simple limits of cultivation.



**Figure 8.** The territory to the west of Hierapolis (Lykos plain) in a Corona KH-4A space photo taken in 1968: the circle highlights an area characterized by a regular land division, of uncertain chronology, that is based on a country road of ancient origin (indicated by arrows).

However the dating of this land division is uncertain; moreover, satellite images show that the area, close to the river, is characterized by high residual humidity and cannot be excluded that the agrarian division visible today is made in the first half of 20th century for the reclamation of the territory, as well as in other sectors of the Lykos plain.

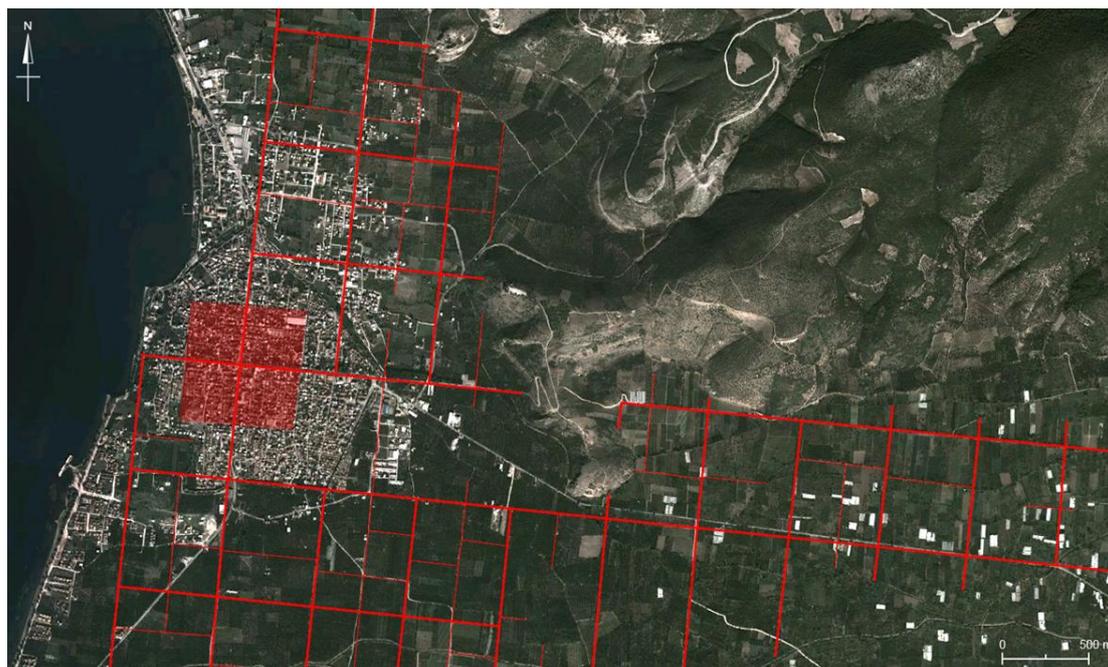
### 3.2. *The territory of Nicaea*

The difficulty to propose a dating for the regular land divisions identified in the territory of Hierapolis is due to the scarcity of comparisons in Asia Minor and in particular in Anatolia, where the state of research on this type of archaeological evidence is still far behind. This situation is not due to the lack of ancient actions of this kind, that were aimed at the rational allocation and use of land and the existence of which in some cases is suggested by epigraphic and literary sources; but it rather derives from the near impossibility of having some fundamental research tools, i.e. mainly large scale maps that provide a complete representation of the territories and aerial photographs. So, only the recent wide availability of high-resolution satellite images (also with the possibility to use the space photos taken in 1960s and 1970s, that can be defined “historical” documentation) has made it possible to develop this line of research with a more accurate and methodologically correct approach. Therefore, it is likely that a careful examination of the territories of the Greek and Roman cities of Asia Minor will provide many more examples of regular agricultural divisions, with the possibility to compare different forms and solutions, even in a diachronic perspective.

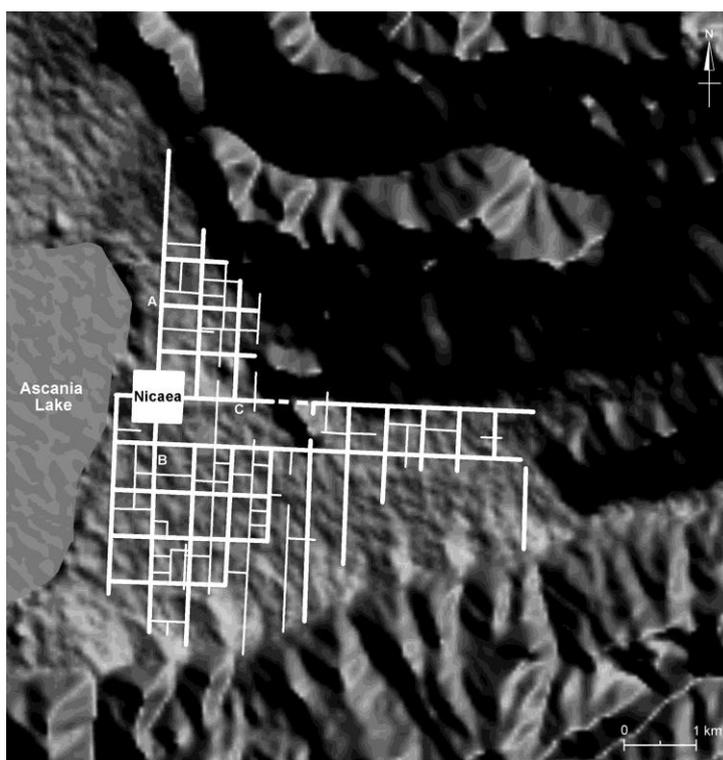
It is important, in this regard, the example offered by the territory of Iznik, the ancient Nicaea, for which the multitemporal satellite images show very clearly the remains of a regular land division (not considered and not examined in previous studies) strictly linked to the Hellenistic structure of the city. In particular, two Corona KH-4 space photos taken in 1963 document many ancient axes that survive in the modern fields' boundaries (Fig. 9). The same images also show (before recent transformations and urban expansion) the layout of the modern town, that appears strongly influenced by the Hellenistic orthogonal city planning; so, it is possible to reconstruct the form of Nicaea as it was described by Strabo, i.e. square shape, with sides of around 710 m and with city walls that had a perimeter of 16 stadia (about 2,840 m), along which four gates were opened and crossed by the two main streets that intersected in the centre of the town. Today the Hellenistic city walls are not preserved, but the fortifications now visible (around 4,427 m long) were built in the Byzantine period, partly following the route of the Roman walls built by emperor Hadrian after an earthquake in 120 AD.



**Figure 9.** Mosaic of two space photos of the territory of Iznik-Nicaea taken in 1963 by a Corona KH-4 satellite: the arrows indicate the main remains of an ancient regular land division and the gray square replaces the area of the Hellenistic town; in the detail of the city, the arrows indicate the Byzantine fortifications.



**Figure 10.** The area of Iznik-Nicaea in a WorldView-2 image taken in 2012, on which the preserved axes of an ancient regular land divisions are georeferenced and the square area of the Hellenistic town is highlighted.



**Figure 11.** DEM of the territory of Iznik-Nicaea based on SRTM data, on which the remains of an ancient regular land division are georeferenced.

Nicaea is located at the western end of a very fertile alluvial plain (Figs. 10-11), with a roughly triangular shape that narrows towards the east, bounded on the north and south by mountains and bordered to the west by the shores of Lake Ascania (now Lake Iznik). The regular land division preserved in the plain is planned on the suburban continuation (in north, east and south directions) of the two main roads of the urban layout (Fig. 11, A-B-C). The division covers all the plan surface available and is characterized by north-south and east-west axes that are respectively 540 and 660 m

(equivalent to 18 and 22 plethra) away between them; the last measure corresponds to the distance between the main north-south axes in the land division of the Uzunpınar plateau according the wide mesh grid. The chosen modulus (a grid with rectangles of 396 plethra or 330 schoinoi, i.e. 35.64 hectares) and the close relationship with the urban layout, wanted by Lysimachus in 301 BC, suggest a dating to the Hellenistic period of the agrarian division. Moreover, even the Byzantine city walls, which were partly set on the Roman fortifications, seem built after the land division of the territory surrounding Nicaea; in fact, in some points their course takes into account and follows pre-existing axes (such as in the south-eastern stretch), and in other sector (such as in the north-eastern one) it cuts obliquely some limits (fields' boundaries and an axis corresponding to a road).

Thanks to the analysis of satellite images, we can suppose a reconstruction of the land division of Nicaea. To the north of the city, the street that comes from the northern gate (Istanbul Gate), which is the ancient road to Nicomedia, continues straight for approx. 2.3 km (Figs. 9 and 11, A), and in the narrow sector of territory, between the street itself and the hills that enclose the plain to the east, there are two other north-south axes, still quite well preserved; in this area it is also possible to reconstruct four east-west axes. To the east of the city, the street coming out of the eastern gate (Gate of Lefke) is preserved with a straight path (which also goes beyond a small hill) for 4.5 km, until the eastern boundary of the plain (Figs. 9 and 11, B), flanked to the south by another parallel axis well preserved, which the modern road partially overlaps; further south, the remains of at least four other main east-west axes are visible in particular in the western sector of the territory, while in the eastern part they are less preserved, probably due to the presence of the modern village that may have influenced the surrounding fields' boundaries. Lastly, the road coming out of the south gate (Gate of Yenişehir) still remains straight for 2.6 km, first as a street and then as a limit of fields, until the southern boundary of the plain (Figs. 9 and 11, C); parallel to it, to the east are also visible survival of at least 9 north-south axes, while another one could be to the west, where the plain widens slightly.

#### 4. Conclusions

The analysis of multitemporal and high-resolution satellite images allowed the identification of an ancient land division in the territory of Hierapolis of Phrygia, in the northern sector of the Uzunpınar plateau. The archaeological surveys confirmed that it was based on orthogonal axes consisting mainly of roads, canals and especially walls, built with irregular small stones; the field works also acquired archaeological evidence that allowed assuming that these land divisions can be dated to the Hellenistic period or to the early Roman Imperial age. Remains of another possible ancient land division were found also in the plain immediately to the west of Hierapolis, in the Lykos valley, using the same method. The role of satellite images in these discoveries was fundamental, since the aerial photographs of the territory are not available and the topographic maps are not accurate and complete in reporting the fields' boundaries.

Therefore, the research in the territory of Hierapolis highlights the importance of satellite images for the identification and study of ancient regular land divisions in regions, such as Anatolia, where some fundamental tools for this type of research (in particular large scale maps and aerial photos) are often not available. For this reason, until today the ancient regular agrarian divisions identified in Turkey are very few. However, it is estimated that in the future, applying the same research approach (based on the integration of field surveys and remote sensing data), it will be possible to identify other ancient land divisions of the Hellenistic and Roman periods that could be preserved in other Anatolian territories; this hypothesis is confirmed, for example, by the orthogonal grid identified in the plain of Nicaea (in ancient Bithynia Region), that is possible to date to the Hellenistic period.

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