Integrating Legacy and Modern Remote Sensing Data for the Study of Land-Use History on Samothrace

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Introduction

This paper emerged from an effort to restudy legacy intensive survey data collected on the Aegean island of Samothrace from 1985–1987 (fig. 1).[1] To contextualize the survey data, we sought to investigate the organization of the landscape during the period when the survey was conducted. In searching for this data, we realized that there was a robust dataset of historical imagery available to us. Therefore, we saw the opportunity to explore landscape and settlement change on other parts of the island using this legacy remote sensing data. This paper demonstrates the temporal resolution available from legacy and modern remote sensing data that can inform our understanding of the opportunities on the island for landscape exploitation, as well as what the history of that land use has been over the past 75 years. Through examination of these imagery datasets and comparisons to select archaeological and demographic data, we seek to characterize in what ways the island has been utilized over time, and to identify connections between these land-use practices and fluctuations in population.

Samothrace is a rugged island measuring 178 km² that is located in the northeast corner of the Aegean Sea.[2] The island lies roughly 40 km from the mainland, and at least 25 km from the nearest Aegean island.[3] Neither small nor lacking in natural resources, it appears that Samothrace never was settled intensely in antiquity, although little is known about the one polis-sized urban centre located on the island.[4] Instead, Samothrace features prominently in history because of the religious sanctuary, the Sanctuary of the Great Gods, located on the island's northwest coast, that attracted a number of monumental architectural dedications by Hellenistic kings.[5]

It has long been assumed that the topography of Samothrace was a major reason for the limited settlement on the island. Most of the island is mountainous, rising up to a height of 1,611 m to dominate the northeast Aegean. Such extreme topography provides limited opportunities for agriculture and settlement, except on the west coast where the terrain is less extreme. The prominence of the sanctuary and the easily arable terrain on the west and northwest part of the island has attracted the majority of archaeological investigation. In addition, Samothrace is without any natural harbours, and the creation of artificial moles and bays has been necessary to facilitate seafaring, fishing, and trade since antiquity.

Nevertheless, archaeological remains are prevalent throughout the island, and aerial photography and satellite imagery collected over the course of the past century reveals a high degree of activity, settlement, and change throughout the island. As the French geographer Elisée Reclus remarked after his visit to the island in the late 19th century,

Published in: Martin Bentz – Michael Heinzelmann (Eds.), Sessions 11–12 – Single Contributions | Poster Sessions. Archaeology and Economy in the Ancient World 56 (Heidelberg, Propylaeum 2023) 5–19.
DOI: *https://doi.org/ 10.11588/propylaeum.1036.c14121*

"there is only one village on the island now. Its inhabitants lead a secluded life, and the only strange faces they see are those of the sponge-fishers who frequent the island during summer. The entire absence of harbours, and the dangerous current which separates Samothrace from Imbro, keep off the mariner, and though the valleys are extremely fertile, they have not hitherto attracted a single immigrant from the neighbouring continent."[6]. Today, the island has a population of 2,859,[7] and many of its "extremely fertile" valleys are under cultivation. Such activity not only underscores the exploitability of these other parts of the island, but also demonstrates the markedly dynamic relationship between population, environment, and settlement. Moreover, these observations challenge assumptions about where traces of past human activity are likely to be preserved.

Historical Overview

The archaeological and historical record of Samothrace reveals long-term habitation by several cultural groups, highlighting the island as an important place of cultural contact in the Aegean. Fieldwork at Mikro Vouni on the western coast of the island has shown that the island was inhabited since the Late Neolithic.[8] This site also provides the most compelling evidence for Bronze Age activity, with some of the earliest Linear A and Cretan Hieroglyphic texts outside of Crete, and certainly the furthest examples of these scripts from the Minoan heartland.[9] The Iron Age archaeological record exhibits strong parallels to the ceramics and metalworking produced by contemporary populations on the nearby Thracian coast. Following the settlement pattern seen on the mainland, these sites cluster atop hills, occupying easily defensible positions in the landscape, and occasionally integrating additional fortifications.[10] This was the period when religious activity began at the Sanctuary of the Great Gods on the north coast of the island.[11] The earliest material evidence of worship at this site dates to the 7th century BC, with votive deposits exhibiting local Samothracian forms.[12] Hellenic influence is seen at the site by the 6th century, with the first Greek inscriptions and the rise to prominence of the mystery cult for which the site is known. A major urban centre developed adjacent to the sanctuary, known today as Paleopolis, which has yet to undergo systematic study. Hints of activity from the Archaic to Roman periods are found throughout the rest of the island, at sites like Phonias and Chora, but the lack of any published material precludes their integration in this narrative.[13] The Byzantine, Medieval, and Early Modern periods saw Samothrace changing hands between the Ottoman Empire, the Genoese Gattilusi family, the Venetians, and briefly the Russians. Recently, the island has been a point of contention between Greece and Turkey and still features a major Greek military presence.

This review paints the picture of an island that experienced periods of dense island-wide habitation and exploitation, as well as periods of settlement contraction and

abandonment. Though this paper focuses on the settlement history and land-use of the past century, we argue that understanding changes occurring during that period can better inform our understanding of similar changes in the past. While the northern and eastern parts of the island were extensively occupied during the Byzantine periods, settlement during the subsequent centuries contracted to Chora in the foothills near the west coast. The settlement dispersal and population increase of the past century provide a valuable opportunity to track how these northern and eastern parts of the island were re-inhabited and more intensively exploited.

Data

To obtain a comprehensive record of aerial and satellite imagery that covers much of the past century, we drew on a variety of legacy and contemporary datasets, each with their relative advantages and drawbacks. The earliest of these datasets comes from extensive photographic aerial reconnaissance missions flown by Allied Forces during World War 2. The photos that cover Greece were given to the British School at Athens after the war. More than 30,000 images of Greece exist, many of them stereo pairs, and which cover about 60% of the Greek mainland and select Aegean and Ionian islands, including Samothrace. The scale of most of these photos is around 1:15,000. Flight paths have been mapped by the BSA and linked to an interactive map of Greece,[14] which we have used to request and obtain relevant images from August of 1944.

The second set of imagery comes from the CORONA spy satellite program, operated by the CIA between 1959 and 1972. Since 1995, the majority of images collected by this program have become declassified, providing an invaluable tool for archaeologists interested in studying landscapes prior to the expansion of urban settlements and intensive agriculture.[15] As with the RAF photos, CORONA images were also collected in stereo pairs. The images used for this study were collected in 1965, with a spatial resolution of approximately 2,75 meters.

The third set of imagery comes from the Landsat satellite program, which is the designation given to a series of satellite systems launched and maintained by NASA in order to provide a tool for the continuous monitoring of Earth's resources. With the first of these systems launched in 1972, the Landsat program has provided consistent monitoring of the planet with increasing spatial and spectral resolution. For the purposes of this paper, we focus on images collected by Landsat 4 and 5, which were operational from 1975 to 2013, and Landsat 7, which was launched in 1999 and remains operational today. Landsat 4 and 5 provided imagery in seven spectral bands, with a maximum resolution of 30 meters and a revisit time of 16 days, while Landsat 7 added a panchromatic band that allows resolution to be sharpened to 15 meters. From imagery collected by these sensors, we select images for 1985 and 2005, continuing the roughly 20-year interval between RAF and CORONA imagery.

The fourth set of imagery is provided by DigitalGlobe and comes from their WorldView-2 sensor, launched in 2009. WorldView data, acquired through a grant from the DigitalGlobe Foundation, provides the greatest spectral and spatial resolution of our datasets, with eight multispectral bands imaged at a resolution of 1,84 meters and a panchromatic band imaged at a resolution of 46 centimetres. Two sets of images were obtained for Samothrace, collected in September 2015 and May 2016 respectively.

Collectively, these four datasets provide a coarse but long-term perspective on changes in settlement and land-use on the island. While limitations clearly exist, not least in terms of spatial resolution and obscuration by clouds, these data nevertheless represent an important archive of information that can be employed to answer broad scale questions.

Methods

To integrate these datasets and create a narrative of Samothracian landscape change over the past 75 years, we georeferenced all available image sets and identified five areas of interest on the island, which we investigated for signs of continuity or change in land-use (fig. 1). These areas were selected according to three criteria. The first criterion was areas on the coast. While we would have liked to focus on more inland and mountainous areas, no ground-truthed archaeological data for these areas exists presently; features associated with pastoralist activities are either too small to appear in all but our highest resolution imagery, or even then are obscured by vegetation which is more prevalent at higher elevations. The second criterion was areas that were under cultivation and settled in our earliest imagery datasets. We considered these areas as baselines, from which we evaluate processes of expansion and abandonment. Conversely, one of our areas was chosen specifically because it is currently exploited, but was not settled or under cultivation in 1944. For this area, we are interested in tracking when activity began and the rate at which it progressed. The third and final criterion aimed to sufficiently sample the northern, southern, and eastern parts of the island, in order to compare with the activity taking place on the western part. These parts of the island can be considered marginal, when compared with the flatter and more agriculturally favourable areas on the west, such that their exploitation may reflect certain social or economic pressures.

Together, these criteria provide us with a means to address our two questions: what evidence is there for recent activity on other parts of the island, and what has the trajectory of settlement and land-use been on the island over the course of the past 75 years? Based on these findings, we have established a foundation for further research that integrates data from other parts of the island with the robust dataset coming from the well-studied western area. These data both stand on their own, providing novel insights into something of an archaeological lacuna, but also provide a critical regional

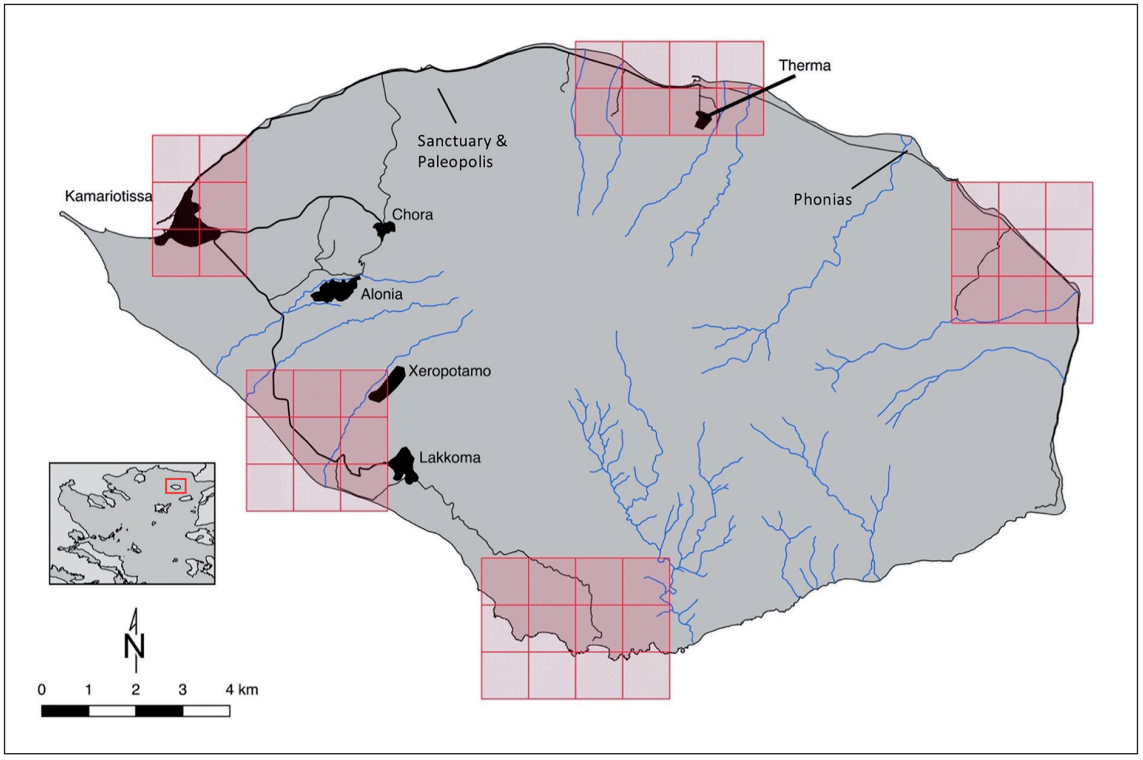

Fig. 1: Map of Samothrace with major urban centers and areas of interest.

context within which to better situate the questions asked of the western part of the island.

Trends in Samothracian Land-Use

The most notable change apparent from the satellite imagery was the expansion of settlement to other parts of the island and the construction of harbour facilities on the coasts at several of these new settlements. Across the island, there is a concerted pattern of settlement dispersal, with areas on the north and east coast becoming progressively settled over the course of the 20th century. These changes are best contextualized by reference to population and economic data for the past 75 years. From 1830 to the end of the 19th century, as recorded in Ottoman census records, the island's population was no larger than 500.[16] In any case, by the first Greek census of the island in 1940, immediately before the occupation of the island by the Bulgarian army, the island's population had risen to 4,000. The following decade experienced another period of growth, as the population rose to 4,564 inhabitants by 1951. Subsequent decades, however, have seen a general population decline on the island, with numbers steadily decreasing to 3,000 in 1971, and remaining near that figure until the present day.

This trend of population decline contrasts with the sharp rise of tourism on the island by domestic and international visitors. While the Samothracian economy of the 19th and first half of the 20th century was dominated by local agro-pastoral production, documented both in historical literature and the archaeological record of the recent past, tourism now serves as the major driving force of the island's economy. Like other Aegean islands, visitor numbers peak in the summer months, with between 8 and 11 thousand individuals transported to the island during summer months in 2016 and 2017.[17] A good deal of the island's tourist population camps on the north side of the island, taking advantage of the touristic amenities in Therma, plentiful camping areas, as well as visiting the island's waterfalls, forests, hiking trails, and beaches. Nevertheless, while agricultural and pastoral economics have been supplanted by tourism as the major economic drivers on the island and the large tourist population has necessitated the importation of food from the Greek mainland and EU, a population of some 90–100,000 goats are still herded on the island and common Mediterranean crops are still farmed across the island.[18]

These figures provide us with a perspective toward the island as a whole, but further nuances can be seen in our five case studies. The first area that we examine is Kamariotissa: the area that has become the island's major port and main centre of habitation and infrastructure (fig. 2). In 1944, the area was almost devoid of buildings, with clear evidence of the exploitation of this fertile landscape for farming, likely by inhabitants of the village of Chora a few kilometres inland. By 1965, a settlement had expanded and a harbour with an artificial mole was constructed to provide a safe place for ships to dock in rough seas. By 1985, the settlement had expanded further, continuing to encroach on coastal farmland. The harbour and mole were expanded in 2005 to allow for large Aegean ferries to dock on the island, but the settlement and farmland around it largely stagnated in terms of change. Some additional structures were built, but the urban footprint remains roughly the same. In 2015, the western and southern extents of the town remained as they were in 2005, but noted expansion was observed to the northeast, where additional touristic amenities (such as hotels and pools) are clearly visible.

We turn now to the town of Therma on the island's north central coast, another area that has seen a good deal of infrastructural development over the past 75 years (fig. 3). This area, known since antiquity for its hot sulfuric springs (perhaps related to worship of Asclepius), was a very limited settlement in 1944 and was surrounded by extensive farmland. A road from the island's west, hugging the coast, terminated at Therma, making this the most accessible part of the eastern part of the island by automobile. No change was seen in the area in 1965, where we continued to record a small cluster of buildings and a series of intensively farmed grain fields. The first major development is recorded in the imagery from 1985, where we noted the road expanding further to the east (toward the area of Kipos Beach on the island's southeast), a noted expansion in the settlement of Therma, as well as a clear contraction of exploited farmland. In the imagery from 2005, in the same period when the harbour at Kamariotissa

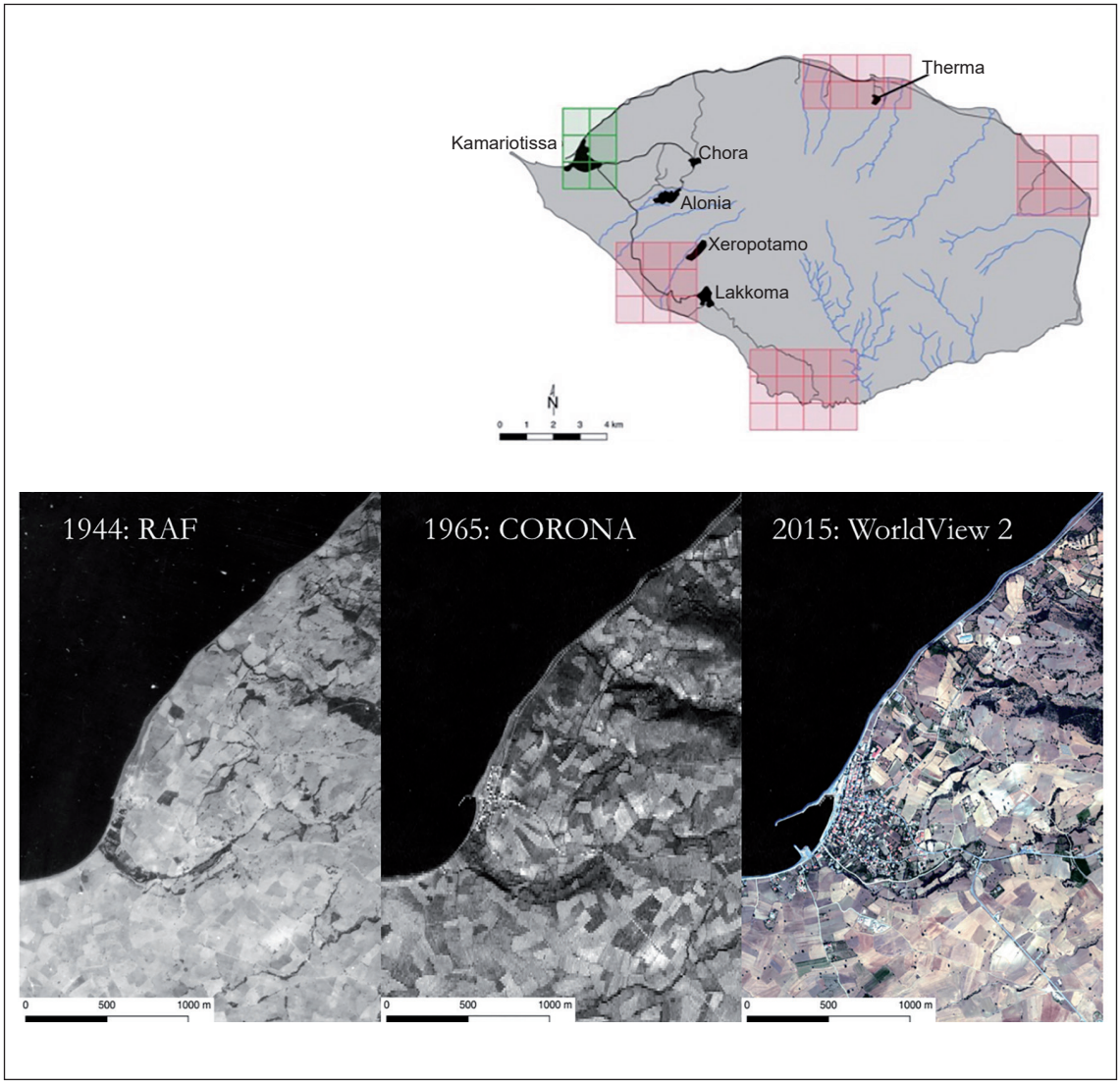

Fig. 2: Case study 1: Kamariotissa.

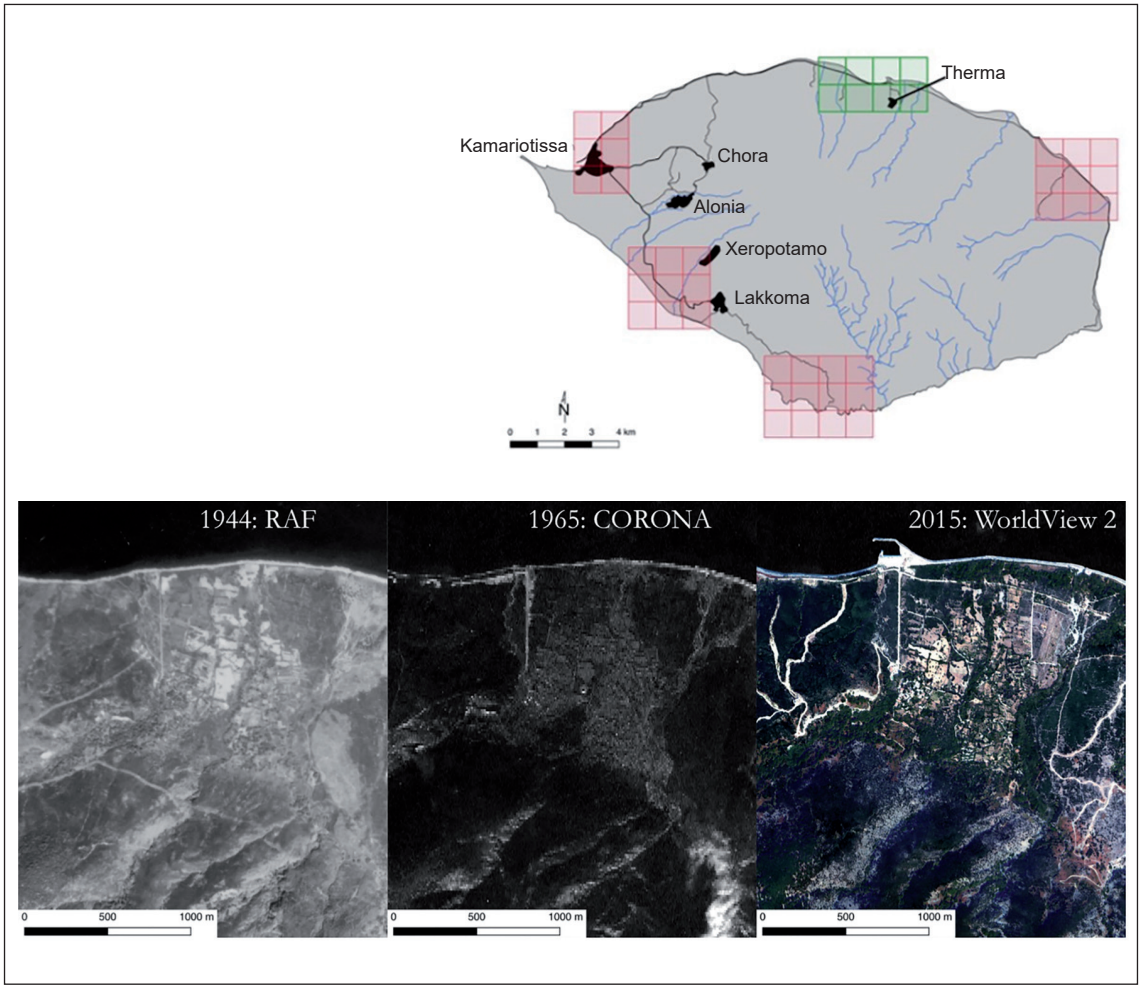

Fig. 3: Case study 2: Therma.

is expanded, we see the construction of an artificial harbour at Therma alongside the continued abandonment of farmland around the village. However, little change is apparent at the site between 2005 and 2015. Therma still receives the majority of the island's tourist visitors, who camp at the free camping sites on the island's north coast, but this has not resulted in significant change in the past decade.

This same pattern of gradual agricultural reduction, increased settlement, and the construction of amenities for tourism is not an island-wide phenomenon. The area downriver from the village of Ano Meria is notable as one of the most fertile parts of the island away from the west. This trait is exhibited by the 1944 imagery, which shows extensive farmland and the furrows of deep-plough agriculture (fig. 4). While the village to the west grew and contracted over time, these fields and others in the area remained in constant cultivation between 1985 and 2005, throughout periods of road construction and economic reorganization. In 2015, a period when there is noted growth in the nearby village of Ano Meria, we noted very little change in the agricultural landscape, field divisions, or means of cultivation.

A similar pattern is witnessed at the area on the outskirts of the village of Makrilies, at the southern end of the coastal plain on the island (fig. 5). In a similar form to the area near Ano Meria on the northeast, the area was extensively farmed in the 1940s, and the subsequent decades saw little change in the use of this area. However, a new road and some new homes were constructed toward the sea and in the nearby village during this time. In 2015, this area persists as the south-eastern boundary of intensive agricultural production, delimited – in all periods – by the Xeropotamos river.

Finally, the area of Pachia Ammos is not only the finest beach on the island, but is also one of the only accessible parts of the island's south coast which is otherwise dominated by steep cliffs covered in scree and vegetation (fig. 6). Select, albeit small-scale, farming takes place in the area around the beach, with individual fields and some terraces noted since the 1940s. However, with the construction of a road from the west in the decades between 1985 and 2005, we witnessed the development of small touristic beach installations that have grown in the past decade. A clifftop church has remained in use since 1887, but a taverna that hangs over the cliff toward the sea and beach now neighbours this older religious architecture. Examination of the high-resolution World-View imagery shows us that the beachside amenities continue to grow, and that the scattered and small-scale farming persists.

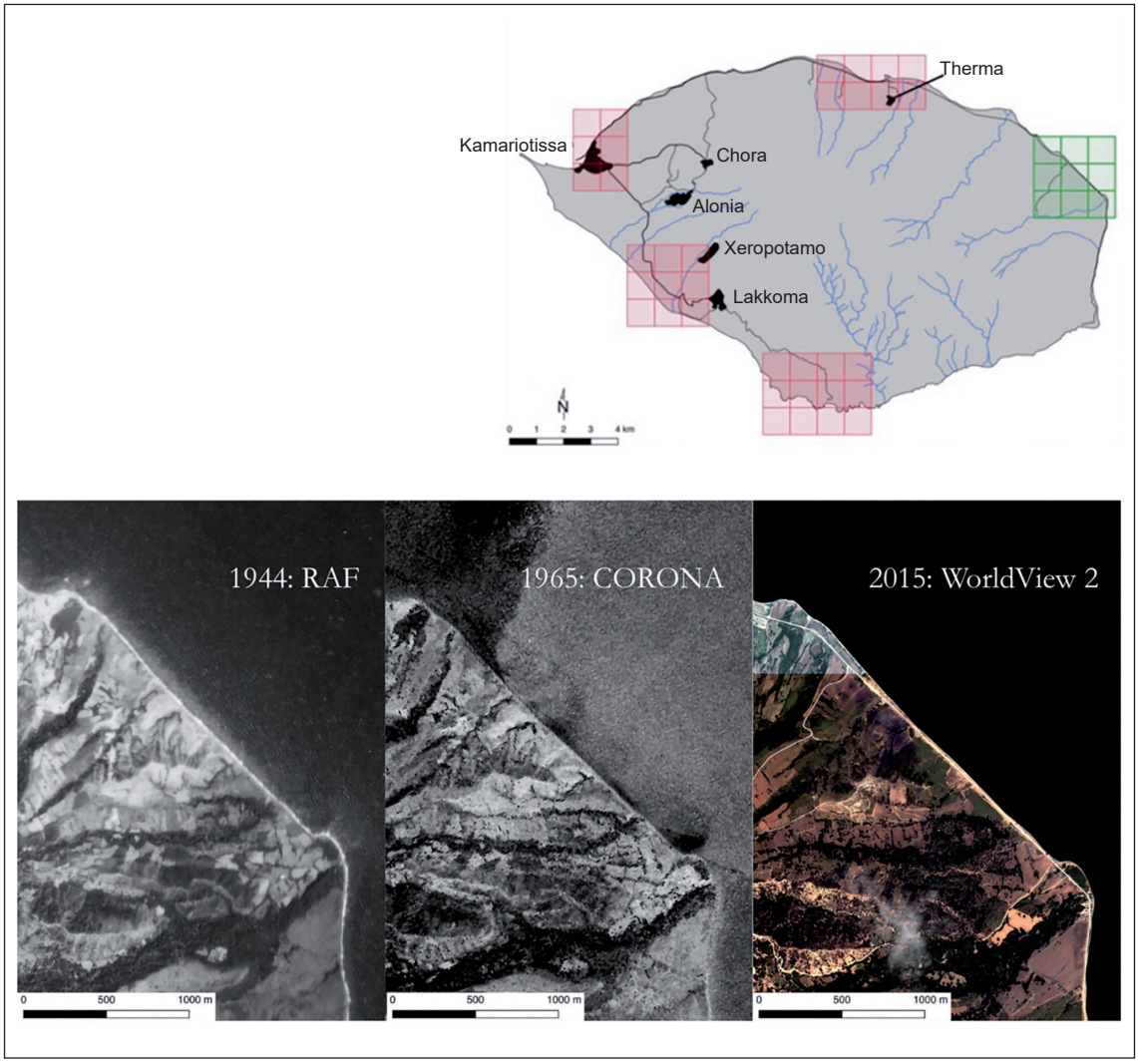

Fig. 4: Case study 3: Ano Meria.

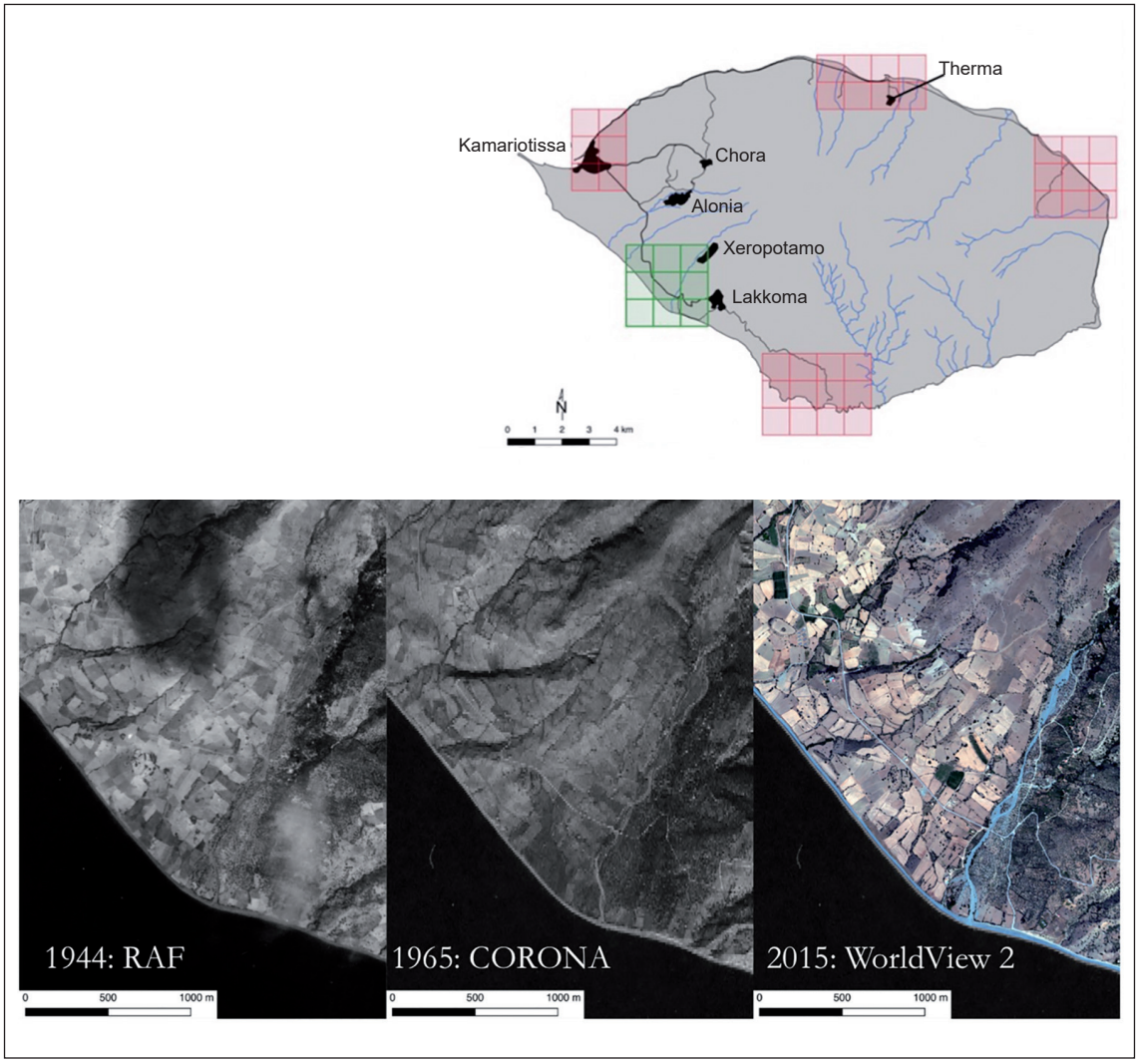

Fig. 5: Case study 4: Makrilies.

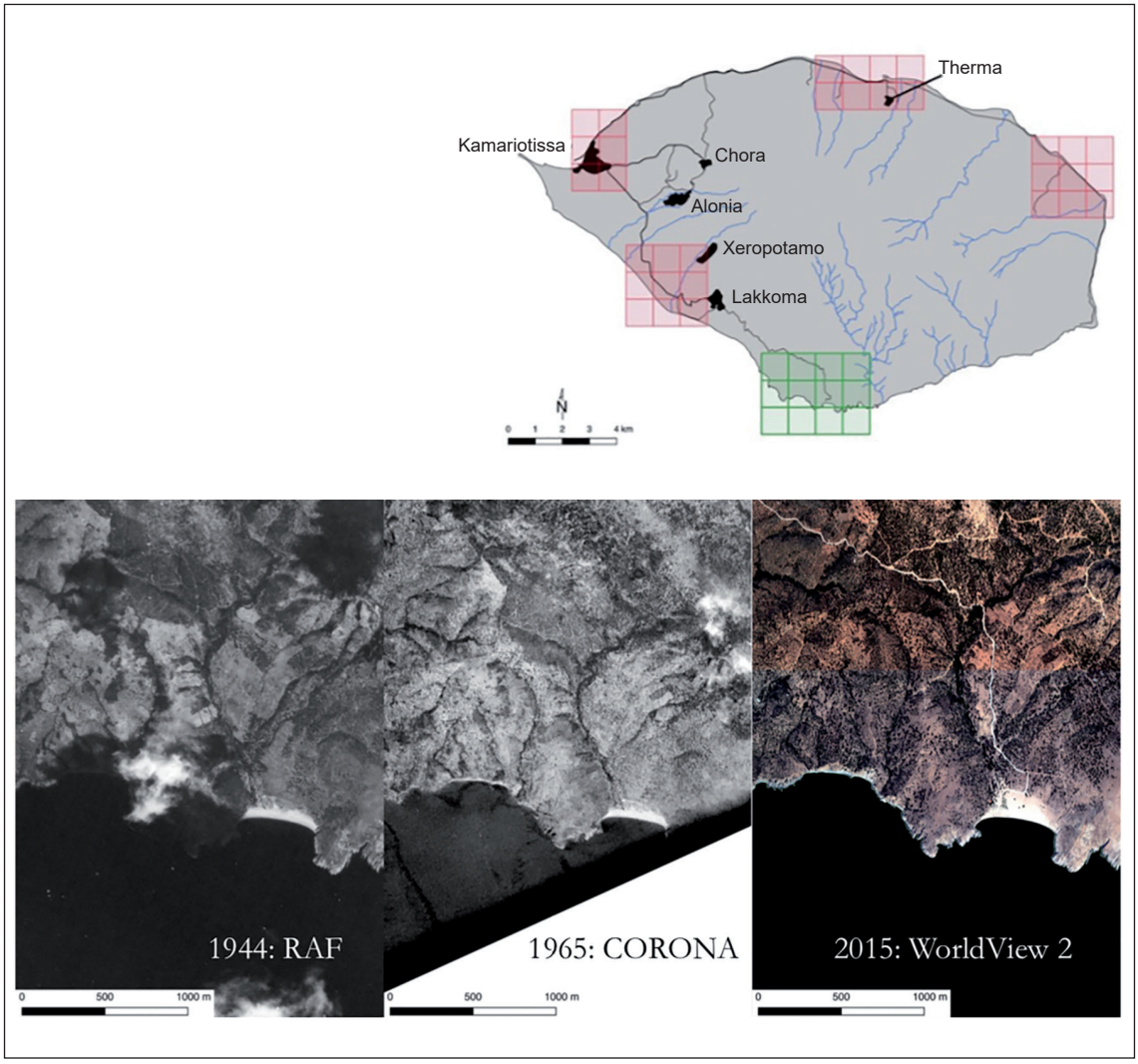

Fig. 6: Case study 5: Pachia Ammos.

Conclusion

We set out to investigate, through remote sensing, how land-use and settlement patterns on the island have changed over the course of the past 75 years. We recognized that archival, ethnographic, and archaeological data can substantially inform our understanding of these processes. For example, goat pastoralism is a major component of the Samothracian economy, with more than 90,000 goats managed relative to 3,000 inhabitants. While we can evaluate agriculture through remote sensing, signatures of pastoralism are much less pronounced in remote sensed imagery. Nevertheless, obtaining an extensive and long-term perspective on agriculture is a vital component to understand pastoral practices on the island, as many farmers also practice pastoralism. As such, we demonstrated the utility of archival and legacy remote sensing data as an additional line of evidence and complementary to these other forms of inquiry.

Beginning in the middle of the 20th century, a highly centralized population on the west side of the island, particularly around the settlement of Chora and its agricultural fields, progressively dispersed across the island. These groups increasingly exploited areas in the east, where there is also evidence of extensive Byzantine and Late Medieval settlement. It is interesting to note that a place like Kamariotissa, which was likely one of the small ancient harbours of the island, remained largely abandoned until the second half of the 20th century. Other places on the island, however, such as those around Phonias on the east coast, where there is extensive archaeological evidence for past occupation, remain uninhabited today. Instead, the primary centre for settlement on the east coast is further to the south, near the village of Ano Meria.

This study can inform archaeological research design by emphasizing discontinuities within the landscape. Even over the relatively short term, we may exhibit visual evidence that areas settled today are not necessarily those that were intensely settled in the past, and, conversely, areas that are abandoned today may have experienced settlement and exploitation in the recent past. Furthermore, the motivations for settlement and land-use are themselves a complex combination of internal and external factors, depending as much on local climate, environment, and social organization as on wider economic and political factors. We hope that by drawing attention to these data sources and the ways in which they can be utilized together, this excellent source of legacy data can continue to be utilized by archaeologists to explore changes in the recent past, shedding light on landscapes over the long-term.

Notes

[1] The authors would like to express their thanks to Bonna Wescoat & and the Samothrace excavations, Dimitris Matsas and Chryssa Keradima-Matsa, Christopher Witmore and the Texas Tech University Department of Classical & Modern Languages & Literatures, The British School at Athens and the wonderful

staff at the BSA library, DigitalGlobe & the DigitalGlobe Foundation. We would also like to thank Brown University, the Joukowsky Institute for Archaeology and the Ancient World, and the Brown University Graduate School. Finally, many thanks to the organizers of AIAC.

[2] Biel et al. 2014, 18.

[3] Syrides et al. 2009, 14.

[4] Matsas 2001.

[5] Lehmann 1998, see also <samothrace.emory.edu/bibliography> (08. 06. 2020) for a consistently updated bibliography of publications stemming from and related to this project.

[6] Reclus 1883, 95.

[7] This figure is according to the 2011 Greek census.

[8] Matsas 1991/1995; Syrides 2009.

[9] Davis 1992.

[10] Matsas 2007.

[11] Graham 2002.

[12] Lehmann 1952, 36.

[13] The single exception is a very interesting Hellenistic amphora workshop in the island's east coast, found during the construction of the main road and published by Karadima et al. 2002.

[14] This interface is available at <bsa.ac.uk/resources/raf> (08. 06. 2020).

[15] Ur 2003; Casana et al. 2013.

[16] Karpat 1985.

[17] Saos Ferries 2017.

[18] Biel et al. 2014, 29.

Image Credits

All figures by authors.

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