5-2018

Social Organization and Environmental Patterning at Tel Abu Shusha: An Integrated Spatial Approach to Survey Archaeology

Seth Price
University of Arkansas, Fayetteville

Social Organization and Environmental Patterning at Tel Abu Shusha:
An Integrated Spatial Approach to Survey Archaeology

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Arts in Anthropology

by

Seth Price
Grand Valley State University
Bachelor of Arts in Anthropology, 2014

May 2018
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

Dr. Kenneth Kvamme
Thesis Director

Dr. Benjamin Vining
Committee Member

Dr. Jami Lockhart
Committee Member

Abstract

Tel Abu Shusha, located in the Jezreel Valley of Palestine, is a large-scale archaeological site possibly identified as the cities of Biblical Gaba or Roman Gaba Hippaeon/Gaba Philippi. Surface archaeological survey of the surrounding area, conducted by the Jezreel Valley Regional Project during 2017, revealed extensive assemblages of visible settlement features dating primarily to middle and late Islamic periods. This research seeks to answer questions of settlement decision-making and societal organization, by integrating archaeological, textual, environmental, and geospatial data sources. In addition to visual interpretation, Kolmogorov-Smirnov nonparametric tests are used to gain insight on environmental settlement preferences; Ripley's K analysis aids in interpretation of multiscalar point patterning; and pure locational (k-means) and unconstrained clustering methods provide information regarding social organization, on both a larger scale and within four smaller case study areas. Results suggest that residential neighborhoods were often located with easy access to resources, in open areas to accommodate larger populations, and with some defensive advantages. Production centers, in contrast, were placed in high, flat areas with plentiful sunlight, likely near raw materials. Lifeways differed greatly, with a central residential hub centered on Abu Shusha, a northern region with intensive agricultural activity, and a more varied southern area with heavy production and a more household-based settlement style. Additionally, low-density magnetic susceptibility measurements were taken within the four focused case study areas, with mixed results. Local correlation methods aid in identification of settlement soils in certain areas, particularly near production centers, while other grid blocks exhibit more confused magnetic patterns.

Acknowledgements

This project would not have been possible without Dr. Ken Kvamme; I am beyond grateful for his guidance and friendship throughout this process, and he has been an understanding mentor throughout the past two years. Dr. Ben Vining and Dr. Jami Lockhart have both also been incredibly supportive, helping from the early stages to form this research into a more thoughtful final product. I would like to thank Dr. Wes Stoner for his assistance in forming a stronger theoretical background, Dr. Jarrod Burks for his advice on magnetic susceptibility methods, the Department of Anthropology at University of Arkansas for their continued support, and the graduate student community for all of the assorted guidance that has been given throughout my time here.

Fieldwork was made possible by the Jezreel Valley Regional Project, with special thanks to Dr. Matthew Adams, Dr. Robert Homsher, Dr. Yotam Tepper, Melissa Cradic, Adam Prins, Ryan Gardner-Cook, Kate Cescon, Karlene Shippelhoute, Mark Letteney, Erika Jecks, and Samantha Lindgren. Each of these individuals have contributed to this research in various ways, and have been caring friends and colleagues through difficult field seasons. Dr. Adams has been invaluable in helping to obtain the information needed to write this thesis. Lastly, Dr. Homsher and Adam Prins have gone out of their way to help with this project at every chance, to the point of hiking through brambles with me to collect data, and for this I am particularly grateful.

Table of Contents

INTRODUCTION

The Jezreel Valley in modern Israel has been a cradle of economic and military activity throughout Levantine history. Tel Abu Shusha (Figure 1), a mostly unstudied archaeological site, represents an addition to this history that may provide insight into settlement patterning and regional relationships in the valley. Previously, claims of ancient human occupation at this site have derived mostly from unprovenanced artifacts, textual accounts, and general landscape observations. However, organized archaeological survey completed during 2017 by the Jezreel Valley Regional Project (JVRP) advances our knowledge of human occupation at Abu Shusha. This project aims for greater understanding of this site through integration of surface survey data with multiple forms of spatial, archaeological, and historical data.

Figure 1. Tel Abu Shusha and surrounding landscape, with Kibbutz Mishmar-HaEmek visible adjacent. Photograph courtesy of Adam Prins and the JVRP.

Landscape

The Jezreel Valley lies between the southern Central Highlands and the northern hilly Galilee (Figure 2). The valley is a graben created by parallel faults formed in the Early Pliocene (Homsher et al. 2017:156), and contains predominantly alluvial sediment rich in organic matter, resulting in fertile soils that retain water well (Orni and Efrat 1964). At the center of the valley is alluvial plain with little relief known as the Esdraelon Plain, which has an average elevation of approximately 100 m above sea level. The valley approaches sea level to the west and 200 m below sea level to the east near the Jordan Valley (Homsher et al. 2017:155). Tel Abu Shusha itself resides in a hillier landscape with a high level of relief.

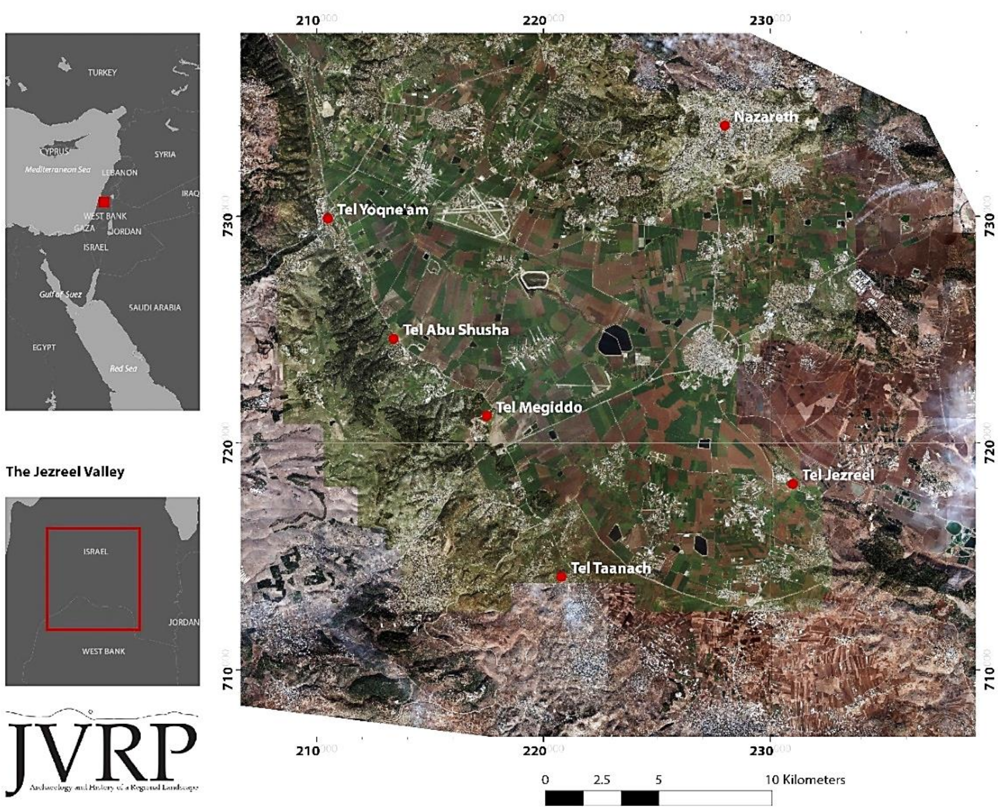


Figure 2. The Jezreel Valley. Image courtesy of the JVRP, with Israeli Transverse Mercator (ITM) coordinates.

Research Objectives

With this unexcavated site, a combination of archaeological and environmental approaches allows us to best utilize the available datasets. This project focuses on study and interpretation of surface features dating primarily to middle and late Islamic period settlements. As it is difficult to distinguish time periods based on material culture at this point, it will be most productive to interpret the full survey area as a single aggregate behavioral pattern. These analyses seek to add supplemental interpretations to a larger project run by the JVRP. With Tel Megiddo as a focal point, this group looks at regional relationships within the valley through remote sensing, large-scale surface surveys, and small-scale excavations to test survey results. Three surveys have been completed to date, each one approximately 5-10 km^2, with the most recent survey covering Abu Shusha and the surrounding landscape (Figure 3).

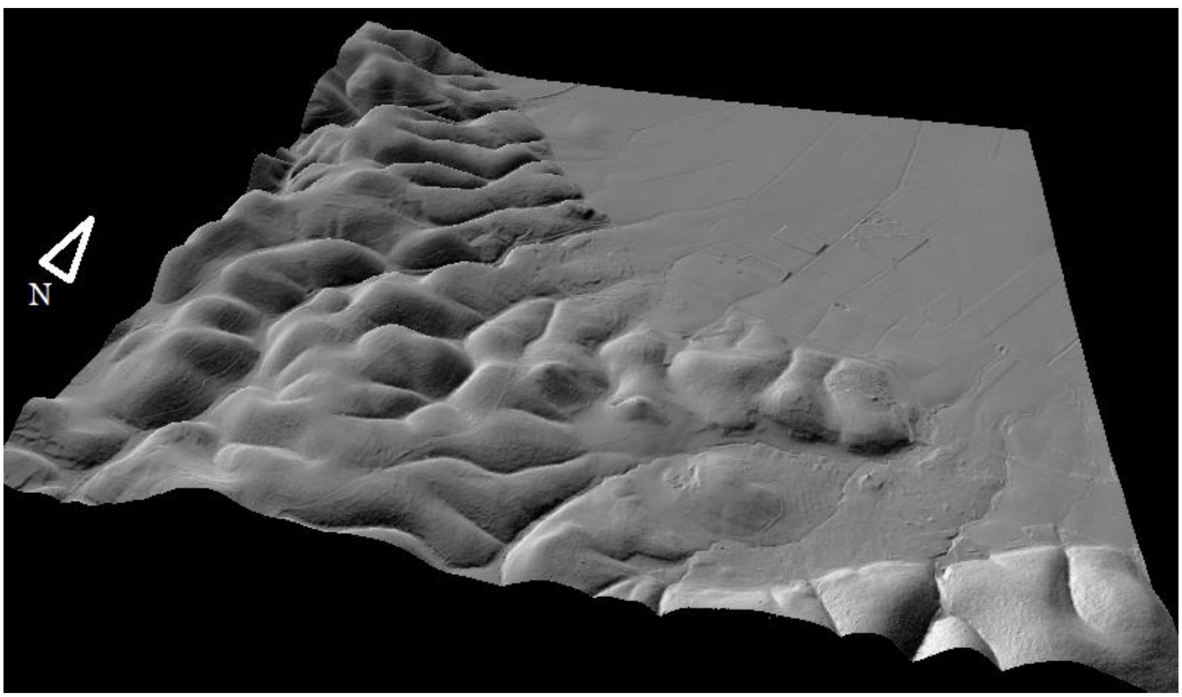


Figure 3. Landscape surrounding Tel Abu Shusha, three-dimensional elevation model overlaid with a hillshade image. Area measures approx. 25 km^2.

This project addresses questions of behavioral patterning and social organization of ancient humans from an intra-site perspective, with archaeological concepts of environment and landscape used to interpret the relationship between past humans and the natural and built environment. Additionally, theories of urbanism bring up the possibility of isolating spatial and social "units" of settlement in the area, which enables interpretation of small-scale social organization. As studies of past Islamic culture in modern Israel are relatively rare, identification of analogous sites to inform interpretations is difficult and will be used sparingly. It is important to note that the concept of the archaeological "site" is relative and used loosely in this project, as definitive site boundaries for this area may appear differently at various scales (see Ebert 1992). This is a problem inherent to all archaeological practice, as site boundaries are ultimately the result of modern human interpretations. In this case, the study area includes Abu Shusha and surrounding hinterlands, measuring a total of 7,745.18 m^2, and is examined at multiple scales to reduce bias.

While the dearth of archaeological and historical data at Abu Shusha is problematic, the use of spatial and environmental analyses to supplement cultural interpretations allows us to discuss its cultural organization and environmental patterning. Specifically, this research addresses three anthropological and methodological questions:

1. What cultural and natural motivations were driving settlement decisions at this site, and what environmental considerations may have impacted this? These factors may enable or constrain human activity, and can provide insight into cultural behavior and feature use.
2. How were settlements organized at a household and neighborhood level, particularly in terms of communal behavior, cooperation, and social integration?

3. How effective are magnetic susceptibility studies for locating anthropogenically enhanced soils and contributing to interpretation of organizational patterning in this landscape, and to what degree do these data align with archaeological surface feature distribution?

The nature and high quality of spatial data available for this site provides an unusual opportunity to investigate these intra-site questions, despite limited historical and chronological data. Chapter I provides cultural, theoretical, and methodological background information, and Chapter II presents analyses of large-scale factors contributing to settlement decisions using Light Detection and Ranging (LiDAR) data, LiDAR derived images, and survey data. Chapter III then focuses on smaller-scale, household-level organization at four study blocks measuring 9 ha in size. Chapter IV assesses the results of magnetic susceptibility surveys within these four study areas and examines their correlation with surface features. Lastly, Chapter V presents discussion and conclusions.

Data Overview

During the summer of 2017, the JVRP completed surface survey at Abu Shusha and the surrounding region, documenting 2,743 archaeological features with ESRI's Collector software (Figure 4). Based on user descriptions and photographs, each feature was given a classification in the field: “wall”, “architectural element”, “built structure”, “built installation”, “unclassified built”, “cut structure”, “cut installation”, “unclassified cut”, “quarry”, “press”, “burial”, “cave”, or “unclassified”. Ceramics and lithics were also collected, but spatial data for these assemblages are limited. Satellite imagery is available, as well as 4.25 x 4.25 cm resolution orthophotos

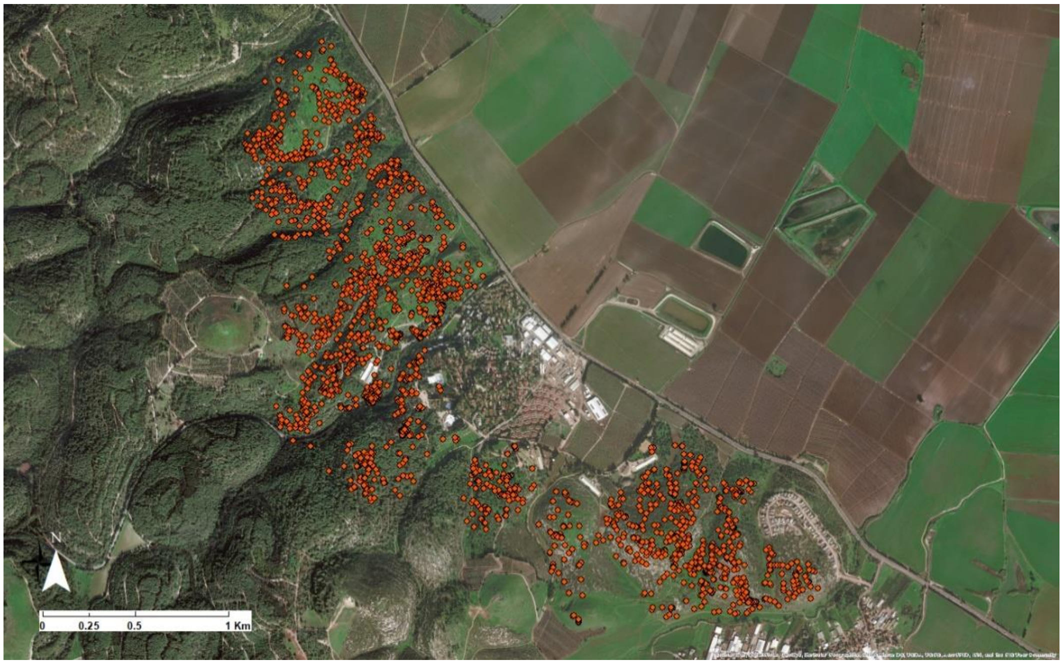


Figure 4. Tel Abu Shusha and surrounding landscape, overlaid with archaeological point features documented through surface survey.

computed through drone photogrammetry by Adam Prins. LiDAR bare-earth elevation data was collected for the Jezreel Valley at 1 x 1 m resolution, and DEM derived maps were computed from this.

Magnetic susceptibility surveys were also completed, focused on clusters of surface features. A Bartington MS2D single coil field sensor was used, with a depth penetration of 10 cm, and coordinates were recorded using an Arrow RTK GNSS system with approximately 1 cm measurement accuracy. These vector points were then interpolated using inverse distance weighting, and a low-pass filter was applied to create smoother images. The purpose of these large-scale, low density surveys was to capture general trends in soil magnetism and cultural activity, rather than isolating smaller subsurface features. Geographic Information Systems (GIS) processing and statistical analyses were computed using Clark Lab's TerrSet (Clark Labs 2017), ESRI's ArcGIS (Environmental Systems Research Institute 2017), R statistical software (The R Foundation 2016), and Relief Visualization Toolbox software (Kokalj et al. 2011).

CHAPTER I: BACKGROUND

Regional Cultural History

Understanding the broader historical context is critical to interpretating spatial data. Hominin presence in ancient Palestine, modern Israel, is apparent as far back as the Stone Age, but this study will restrict itself to eras and sub-regions relevant to this research (Table 1). The Jezreel Valley, part of the cultural sphere in which Abu Shusha operated, has a long history of both prosperity and conflict due to its strategic importance. Located on a primary land route connecting Egypt in the south to Mesopotamia, Phoenicia, and Anatolia in the north, the valley controls this vital trade corridor and has been host to military forces throughout history. While the background of the site of Abu Shusha is mostly unknown, the cultural history of the Jezreel Valley in general is well studied, and Abu Shusha's location and size suggest at least partial settlement motivations analogous to those of nearby Megiddo: strategic military location and control over trade routes.

Table 1. Chronology of ancient Palestine, adapted from Rast (1992).

Period	Dates
Early Bronze Age	3300-2000 B.C.E.
Middle Bronze Age	2000-1500 B.C.E.
Late Bronze Age	1500-1200 B.C.E.
Iron Age	1200-586 B.C.E.
Neo-Babylonian	586-539 B.C.E.
Persian	539-332 B.C.E.
Hellenistic	332-63 B.C.E.
Roman	63 B.C.E.-360 C.E.
Byzantine	360-640 C.E.
Early Islamic	640-1291 C.E.
Early Crusader	1099-1187 C.E.
Late Crusader	1187-1291 C.E.
Late Islamic	1291-1918 C.E.

A transition toward complexity and urbanism began during the Early Bronze Age, though the area trailed behind much of Mesopotamia in this regard. Unknown circumstances cause a decline around 2000 B.C.E., then we see a revitalization of city building during the Middle

Bronze Age (Mazar 1990:151). This continued through the Late Bronze Age, in which the city of Megiddo in the Jezreel Valley emerged as a regional power (Cline 2000:42). A mass collapse happened throughout the Near East at the end of this era, followed by a brief dark age. During the subsequent Iron Age, the Philistines and Hebrews settled in the region, and the Hebrew tribes united under David at the end of the eleventh century B.C.E. (Mazar 1990:368). This unity was soon fractured, and the nation split into the northern Israelites and the southern Judahites. The Babylonians, with a reputation for cruelty and oppression, assaulted these nations numerous times before the kingdom of Judah was finally destroyed in 586 B.C.E. (Mazar 1990:548). The situation changed when the Achaemenid Empire conquered the kingdom of Babylon in 539 B.C.E., as Cyrus the Great and the Persians were known for forgiveness and leniency. Textual accounts suggest that the Persian's subjects were encouraged in reconstruction and development projects (Rast 1992:145). Ancient Palestine was in an especially precarious position from the Iron Age onward, balanced between the powerful lands of Mesopotamia and Egypt. The Jezreel Valley in particular has experienced sporadic warfare, with at least thirty-four battles occurring over the past four-thousand years, including the famous battle of Megiddo between Pharaoh Thutmose III and the Canaanites in 1479 B.C.E. (Cline 2000:7).

Persian control in the Levant soon ended due to Alexander the Great's swift conquest of the region. When Alexander died, Palestine fell under the control of the Seleucid family. Archaeological remains from Hellenistic Palestine are sparse, leaving relatively little known of this era, and Megiddo was not permanently occupied again after the conquests of Alexander (Rast 1992:155). A battle occurred in 218 B.C.E. at Mount Tabor in the Jezreel Valley between Antiochus III, sixth ruler of the Seleucids, and Ptolemy IV, Macedonian ruler of Egypt. Two more battles would be fought in the same area in 55 B.C.E. between the Hasmonean Alexander and the incoming Romans, and in 67 C.E. as part of a Jewish rebellion against general Vepasian of Rome (Cline 2000:106). This is the rebellion written about by Josephus Flavius, in which he mentions the city of Gaba Hippaeon, possibly identified as Abu Shusha. These wars were centered around the city of Atabyrium, administrative capital of the Jezreel Valley at the time (Cline 200:104). The Romans defeated this rebellion, and later stationed the sixth Roman Legion in the valley just a few kilometers from both Megiddo and Abu Shusha. This seems to have been sufficient to ensure relative peace in the immediate area throughout the Roman and Byzantine periods, until the coming of Islamic forces (Cline 2000:115). These periods left a massive impact on Palestine, with widespread evidence of Roman and Byzantine city building and infrastructural innovation.

A new era began with the invasion of Islamic forces in the seventh century C.E. (Table 2), and violence broke out in the Jezreel Valley once again. At least three clashes occurred over the next few centuries, involving the Ikhshidids, the Abbasids, the Hamdanids, the Byzantines, and the Fatimids (Cline 200:117). The Umayyads created a regional capital at Damascus, which was later moved to Baghdad by the Abbasids, and in 969 C.E. the Fatimid Caliphate took control over Egypt and Palestine (Rast 1992). This dynasty was characterized primarily by pillaging rather than administration, and multiple large-scale revolts occurred by the various Arab tribes living in the Levant (Edde 2010:167). The well-documented crusades began soon after and a series of wars between Crusader and Islamic forces occurred, with seven battles taking place in the

Table 2. Islamic period chronology in Palestine, adapted from Rast (1992).

Period	Dates
Umayyad Dynasty	661-750 C.E.
Abbasid Dynasty	750-1258 C.E.
Fatimid Dynasty	969-1169 C.E.
Crusader Period	1099-1291 C.E.
Ayyubid Dynasty	1169-1252 C.E.
Mamluk Dynasty	1252-1517 C.E.
Ottoman Empire	1517-1918 C.E.

Jezreel Valley. Islamic fortresses in the valley were besieged numerous time by Crusader armies, until they were eventually forced to retreat. Finally, Saladin drove the Fatimids out of Egypt and the Crusaders withdrew, and Saladin and his Ayyubid descendants ruled the region for a brief time (Rast 1992:199). Despite this, there was still consistent raiding within Palestine, conflict between Levantine provinces, and recurring war between Franks and Arabs (Edde 2010). Global trade expanded as well, including the Levant, Eastern Asia, Northern Africa, the Mediterranean, and Russia (Edde 2010:192).

The Mamluk Dynasty took over for the following several centuries, defending the Jezreel Valley from the Mongols and defeating Crusader forces twice. This sultanate had a more formalized organization focused on military, and it still dealt with consistent internal strife and inter-factional struggles (Levanoni 2010:249). In 1516/17 C.E., the Ottoman Turks marched through the valley and defeated the Mamluks, incorporating Palestine into their expansive territory (Cline 2000:152). The Levant became centrally controlled. Agricultural lands were divided into tax units, each assigned to a loyal cavalryman, which were in turn divided into districts under a military commander who could mobilize cavalrymen in the area (Masters 2010:415). Four more battles took place in the Jezreel Valley during the Ottoman Empire, until the British General Edmund Allenby, mimicking the strategy of Thutmose III, marched on Ottoman-controlled Megiddo and achieved victory during World War I in 1918 (Cline 2000:15). In addition to sedentary populations in Palestine, there existed relatively powerful nomadic tribes, such as the Bedouin and the Turcoman, throughout much of the second millennium.

Tel Abu Shusha Cultural History

Abu Shusha has been suggested as the location of the city of Gaba (Geba, Geva), first mentioned in the Canaanite period as a conquered city by Thutmose III, inscribed on the temple at Karnak (Giveon 1988). This could represent the same city as the later Roman/Byzantine Gaba Hippaeon or Gaba Philippi. However, the distinction between these three city names is unclear, and these could be alternate names for the same one or two cities. Past work suggests that Gaba Hippaeon and Gaba Philippi existed as separate settlements (Barag 1988), but the support for this assertion is tentative. Evidence for this comes mostly from the writings of Josephus Flavius, a Jewish scholar and military commander of the Galilee during the Great Revolt of 66 C.E., who later joined the Roman cause. His autobiographical account of the revolt mentions Gaba Hippaeon as located near the Galilee on the border of Akko, near Mount Carmel, 20 stadia (3.7 km) from the city of Besara, modern Beth She'arim (Flavius 2000:77). The city of Gaba Hippaeon discussed by Flavius was supposedly founded by Herod the Great as a colony for demobilized cavalrymen and occupied during the rebellion. Siegelmann (1985) suggests Abu Shusha as the location of Gaba Hippaeon, but this is problematic as Abu Shusha is approximately 10 km from Beth She'arim as the crow flies. While Flavius' account provides hints to this city's identification, as an autobiographical text it is a relatively untrustworthy source on which to fully rely. Identification of this site with Gaba Philippi, a prominent Roman city that continued to exist into the Byzantine period, is also a realistic possibility.

Limited archaeological evidence contributes to this debate. Before the JVRP's 2017 survey, very little excavation or survey work was completed at this site. Processing installations and large constructions in the area suggests some degree of large-scale society, complexity, and cooperation, but most of these features cannot be reliably dated to Roman or Byzantine periods.

Ceramic assemblages indicate settlements at this site during these periods, but this does not narrow down their specific identities. However, two lead weights were excavated from an oil press at the foot of Abu Shusha. Greek inscriptions on the first weight state the name "*Gabe*" on the first line, the date "*218*" on the second line, and the weight on the third line (Siegelmann 1989:15). While this certainly lends support to the identification of this site with one of the cities bearing "Gaba" in its name, a single artifact of this type, seemingly with little documentation or contextual evidence, cannot be used as unequivocal proof. Coins have also been uncovered near Abu Shusha and Megiddo, bearing the name "Gaba," naming Phillip as the city founder, and listing dates aligning with the era beginning in 61 B.C.E. (Barag 1988). This time period and name could suggest Lucius Marcius Philippus, procurator of Syria, as the city founder. The existence of these coins attests to the prominence of the city of origin, as few settlements minted their own coins during this time. This could be interpreted as support for the theory of Gaba Philippi as a city identification, rather than Gaba Hippaeon. While these coins certainly suggest that Gaba Philippi interacted with Abu Shusha and Megiddo socio-economically, it does not verify Abu Shusha as their origin.

While these theories based on textual accounts and unprovenanced artifacts may have merit, surface ceramic assemblages collected during survey currently represent our only method of dating this site. These collections indicate settlements during Hellenistic, Roman, Byzantine, various Islamic time periods, and the Ottoman era. These ceramics uncovered by the JVRP (11,444 sherds from primarily these time periods or the modern era) during survey serve as tentative evidence for settlement periods at Abu Shusha, as this quantity of sherds are unlikely to have traveled far from their origin. Documented surface features likely date to late Islamic and Ottoman eras, but it is also possible that some of these features may date to earlier times. Some of the visible features could also represent settlements inhabited more recently, previous to the Battle of Mishmar Haemek of 1948, in which Jewish and Islamic forces clashed and the area was deserted.

Theoretical Background

It is necessary to define terms that will be used to discuss spatial and societal organization and make explicit how these patterns will be inferred, as this research relies upon a number of assumptions regarding how analytical results may reflect societal organization in past cultures. “Neighborhood” as used in this study is a spatial and social unit of organization, in which actors are regularly interacting. Individualistic or household-based settlement patterning suggests a neighborhood in which these interactions are infrequent and disorganized. In such a community, activities such as crop cultivation and processing would occur within separate households, each reliatively self-sustaining. If a social group instead has internally organized activities, this suggests more communal behavior. This organizational strategy may be seen through shared installations, agriculture, storage, or burials, but only when there is no sign of outside intervention beyond the community. If this intervention does exist, the community may be more externally organized or centralized. This may be indicated by larger-scale activities or production that is not restricted to a neighborhood. These activities occurring beyond what could be consumed by a community may suggest export or trade. While Bronze Age centralization in the Near East is typically seen through powerful, centralized city-states (tel sites) with surrounding connected hinterlands, it should be considered that we see this pattern change during middle and late Islamic periods. Many settlements spread out and became less focused on the tel, yet were still heavily organized and centrally administrated (Edde 2010).

A central purpose of this research is to outline and test certain expectations regarding how behaviors of past social groups can be inferred through spatial analytical methods. A core idea being operated under is that clustering versus dispersion of archaeological remains can be used to interpret some of these social organizational strategies. At its most basic, heavy clustering of features in large spatial areas could represent condensed, organized communities, with dispersion respresenting more individualistic patterns of settlement. If multiple smaller, dense clusters exist on the landscape, this could suggest more internally communal behavior. Beyond this, separation of activitiy areas can provide deeper insight. In an individualistic society, we would expect to see heavily mixed feature types, with production activities occurring on a household level. If large production hubs exist, separate from residential areas, we are likely seeing a more communal, collective strategy. This may be true for other activity types as well, such as storage or burial of the dead. The scope of these activity hubs may be tentatively used to infer internal versus external organization. A processing center significantly larger than what might be expected for the surrounding community, even considering surplus and storage, might suggest some form of external administration and export of goods. This is particularly true if we are seeing production specialization, with feature types indicating that a neighborhood focused heavily on certain production activities and would have required additional goods beyond those produced locally. Spatial location may provide additional insight. For instance, production centers placed between smaller residential neighborhoods are more likely to indicate communally shared installations. The geospatial analytical methods in this study allow the user to identify and interpret many of these patterns in the landscape, and do so in a way that supplements visual interpretation and provides additional insight into settlement and organizational patterning.

Environmental Settlement Patterns

Human beings often act in predictable ways, due to social, economic, political, environmental, or ideological concerns. Choices made when placing settlements on the landscape may relate to any of these underlying influences, and it is often possible to isolate some of the driving forces. People may be likely to settle near a confluence of rivers for resources, agriculture, or access to trade routes, and flat landscapes may be preferred for agriculture. The resulting archaeological imprints left in the environment can be analyzed to gain insight into the relationship between landscape and social actor. There will always be exceptions to these common patterns, but they can still be used as templates from which to draw comparisons. Additionally, humans will often actively manipulate their activities or the landscape to expand or alter the environmental niche in which they inhabit. The decision to settle near water sources can be altered by canal construction, and flat areas for farming may not be as vital following the invention of terrace agriculture. Even with these manipulations, humans will often occupy a relatively narrow niche within the environment, with unsuitable landscapes avoided for settlement purposes. Interpretation of these patterns becomes increasingly difficult when attempting to separate out intentional human decision-making from random behavior. There is also an issue of proxy variables, as what seems to be an obvious relationship between two variables may simply be acting as a stand-in for other related factors.

Due to these issues, an intimate knowledge of the study area is invaluable. Human behavior and landscape are intrinsically related, so environmental patterning can only be understood when also considering agency and local history (see Thompson 2014). Additionally, differences in local topography may affect the patterns seen and the underlying causal processes. For example, Near Eastern Tel sites may be subject to an unusual degree of erosion and environmental alteration from repeated settlement (Wilkinson 2003). The Abu Shusha region is hilly with a high level of relief and evidence of terrace agriculture, so settlement patterns will likely reflect this behavior. At the scale of household organization, differing trends between residential and processing features may suggest specialization and purposeful placement of labor areas, as opposed to simply building these features near households for convenience. External variables may also cause this environmental patterning, as human societies do not exist in socio-political vacuums. Particularly in the Jezreel Valley, city fortifications were common and military strategy was a concern in city placement. A settlement that would otherwise logically be spread out to take advantage of the environment, may instead be constrained by the need for defense. Settlements may also be purposefully located to take advantage of trade routes.

Household and Neighborhood Organization

Scarcity of contextual and historical data for Abu Shusha makes the inference of small-scale organization difficult, but even without this background information it is possible to tease out spatial patterning of smaller social units within the landscape. Survey data may be used to identify potential households in this case, from remains of architectural elements or standing architecture. For identification of organizational units beyond the household, Smith's (2010:137) definition of a neighborhood as, "a small area of frequent face-to-face interaction," will be beneficial. As a multiple-component site without known stratigraphy it will be difficult to recognize smaller units of organization at Abu Shusha, but neighborhoods may be identified through clustering of surface features in the landscape.

Archaeological research looking at societal organization and neighborhood units is not uncommon, and has been used with a variety of data types. For example, Robertson (2001) uses quantitative and GIS methods for assessing the intra-site variability in social organization. While Robertson (2001) looks at wealth distribution as evidenced by surface ceramic assemblages, this study will instead consider distributions of surface features and how social neighborhood units are organized at Abu Shusha. In a similar vein, but using primarily textual and cultural data, Keith (2003) examines neighborhood units in,k Mesopotamian Old Babylonian cities. These studies suggest an integrated approach as potentially effective for organizational analyses, using archaeological, textual, and quantitative data.

CHAPTER II: LARGE-SCALE PATTERNING

This chapter investigates large-scale settlement patterns and environmental trends in placement of archaeological feature at Tel Abu Shusha and the surrounding landscape. The region analyzed was confined to only areas covered by the JVRP during archaeological survey, and this area was further clipped to remove atypical environments containing few archaeological features, primarily agricultural fields and modern settlements (Figure 5). Ripley's K function was used to determine the degree of clustering, dispersion, or randomness of archaeological features, Kolmogorov-Smirnov nonparametric tests were run to look at environmental trends in settlement choices, and cluster analyses were computed to locate potential activity areas and interpret social organization.

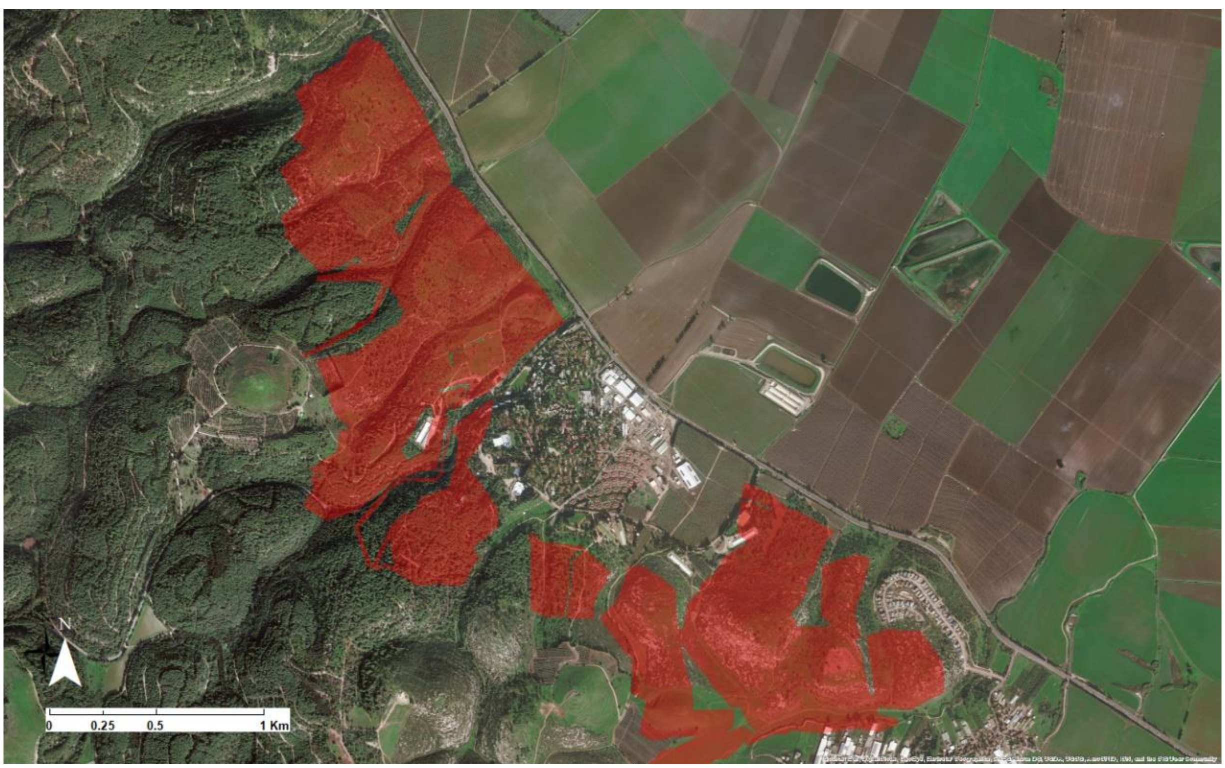


Figure 5. Tel Abu Shusha and surrounding landscape, areas included in analyses are highlighted in red.

Environmental Variables

Elevation

While surrounded by alluvial plains, Abu Shusha is in a hilly region with a high level of relief, and within this topography settlements and features may have been preferentially located at certain elevations for strategic, cultural, or practical purposes. One-meter Digital Elevation Models (DEMs) were obtained of the Jezreel Valley through LiDAR (Figure 6a), and additional environmental variables were derived from these data. Elevation values of the study area range from 69 to 328 m above sea level, with a mean of 137.6 m and standard deviation of 23.822 m.

Aspect

Past humans may locate settlements with purposeful directionality, seeking to obtain cultural or environmental advantage. The initially computed 360-degree aspect image was problematic for statistical analysis, so for the purposes of this study, aspect was split into two images (Figure 6b, 6c). “Aspect East/West,” is displayed on a scale from -1 (West) to 1 (East), and “Aspect North/South,” is on a scale from -1 (South) to 1 (North). The background area of Abu Shusha tends toward the East with a mean of 0.256 and standard deviation of 0.675, and slightly toward the North with a mean of 0.129 and standard deviation of 0.68. Certain aspects may be chosen to take advantage of sunlight or winds, or for other localized motivations.

Slope

In the slope image, the value of each pixel is calculated based on the elevation in that and neighboring cells. The pixel values in the final surface are depicted as a gradient in percentages,

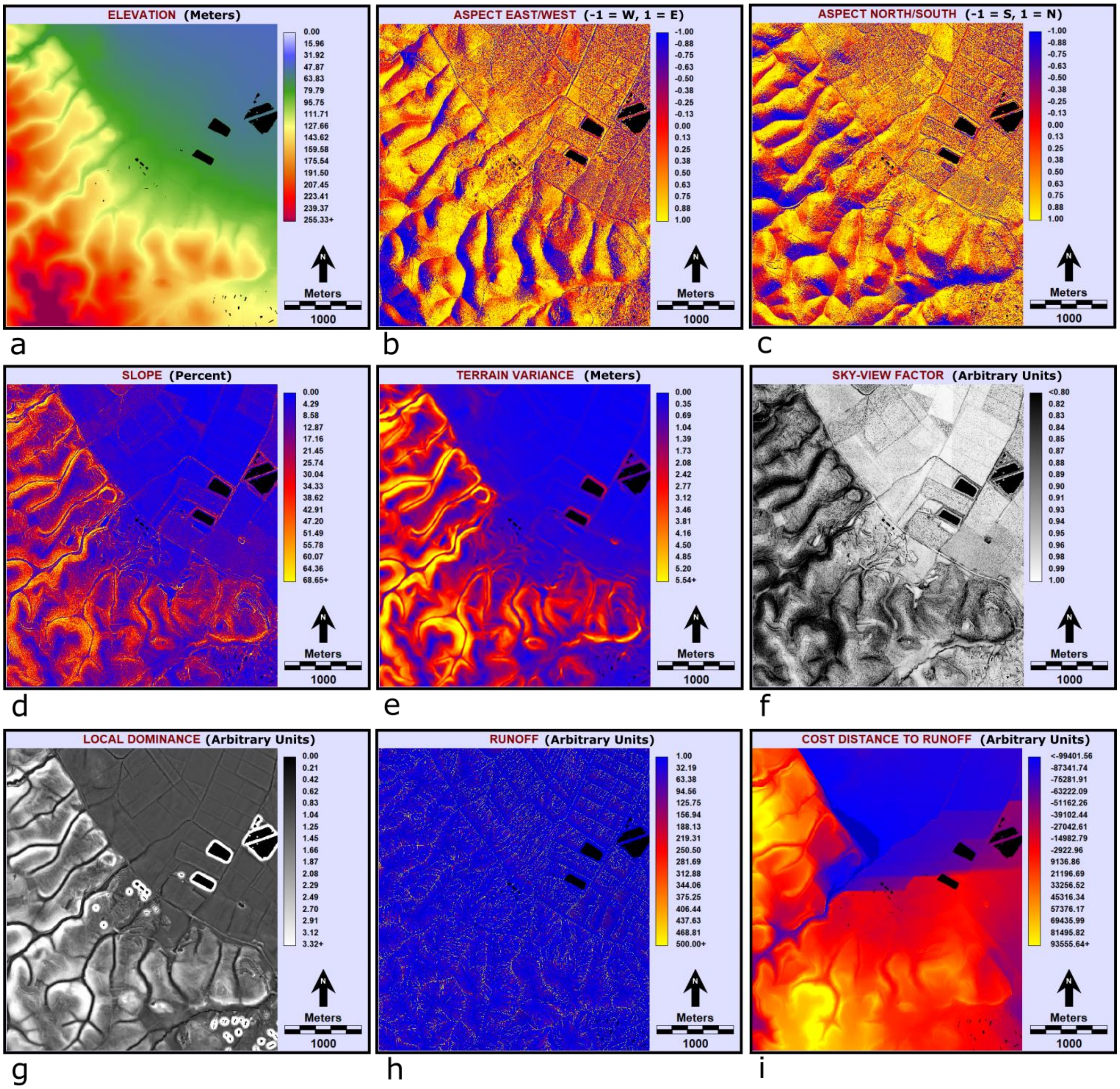


Figure 6. DEM-derived raster images of environmental variables used for analyses: a) Elevation (in meters), b) Aspect East/West (-1 = W, 1 = E), c) Aspect North/South (-1 = S, 1 = N), d) Slope (in percent), e) Terrain Variance (in meters), f) Sky-View Factor (in arbitrary units), g) Local Dominance (in arbitrary units), h) Runoff (in arbitrary units), and i) Cost Distance to Runoff (in arbitrary units). Areas in black are no-data cells from errors in LiDAR acquisition, which were excluded from analyses.

represented by the tangent of the angle multiplied by 100 (Figure 6d). A 0% value is a perfectly flat slope, 100% is a 45-degree angle, and infinitely high percentages will approach a 90-degree angle. Slope values in the study area range from 0.5 to 562.39 %, with a mean of 22.76 % and a standard deviation of 18.53 %. This suggests the presence of high outliers that may skew test results. We would generally expect settlements to be located on flat slopes for practical and travel purposes.

Terrain Variance

Terrain variance represents larger-scale variation. A 45 x 45 m standard deviation filter was used in this case to reduce correlation with slope, with the result depicting change in elevation within a circle defined by this filter (Figure 6e). Terrain variance values range from 0.1 to 9.82, with a standard deviation of 1.22. This surface is a large-scale representation of variability and accessibility of terrain. People may settle in areas of low terrain variance for travel and subsistence, or less obvious motivations may move people to settle in less accessible areas.

Sky-View Factor

Sky-view factor measures the proportion of sky visible from a location, and may be a proxy for illumination and openness of landscape (Zakšek et al. 2011). Flat terrain as well as peaks or ridges will likely have high sky-view values, while depressions will have low values (Figure 6f). Sky-view values in the study area range from 0.00005 to 1, with a mean of 0.89 and standard deviation of 0.06. Humans might settle in open areas with fertile soils and access to trade routes, high view distance may be preferred, or populations may require a large, open area for settlement. With high populations a high sky-view might also be more defensible, as there would be sufficient room for fortifications and invaders could be seen coming from further distances. It is also possible with smaller groups that lower sky-view areas would be chosen, to avoid detection by larger forces or to take advantage of natural fortifications. This variable may correlate with slope and terrain variance at some locations, but is measuring a distinct phenomenon.

Local Dominance

Local dominance visualizes how "dominant" an observer standing at a certain location would be over the surrounding landscape (Figure 6g). This is calculated as the average angle steepness at which an observer would look down on the nearby terrain within a certain radius (in this case 10 to 50 m), also accounting for observer height. Local dominance values in this area range from 0 to 72.49, with a mean of 1.7 and standard deviation of 1.01. Similar to slope, these data suggest high outliers. Higher local dominance areas may be preferred for better views, accessibility to surrounding regions, and defensibility.

Runoff

Runoff visualizes the accumulation of water in a landscape, as if one unit of precipitation were dropped on each pixel. Flow direction is computed for each cell within a 3 x 3 m area, and the process calculates to where this water would drain. The final image is a depiction of which areas accumulate the most water, with pits (depressions with higher elevations on all sides) removed (Figure 6h). Runoff values in this study range from 1 to 663,735.31, with a mean of 705.3 and standard deviation of 11,022.87. The amount of desired runoff for a settlement area may change based on cultural and subsistence practices, but it is expected that an excessive amount of runoff would be destructive to a society.

Cost Distance to Runoff

A threshold was then applied to the runoff image to create a binary map depicting drainage systems, as modern streams data were not available. By isolating areas with the highest accumulation of water, it is possible to determine the probable location of current and past water systems. A basic cost distance algorithm was then applied to this image to simulate distance to water sources (Figure 6i). “(Slope + 1)^2” was used as a friction surface, making steeper, difficult slopes costlier to traverse. Cost distance to runoff values range from -118,881.55 to 226,303.12, with a mean of 3,225.46 and standard deviation of 35,304.55. We would expect past settlements to be located near sources of water, but Euclidean distance is usually not a realistic portrayal of travel paths. The cost distance algorithm provides a more likely model of proximity to ancient water sources, given environmental constraints on travel.

Feature Categories

All Archaeological Features

The study area contains a total of 2,625 surface features, which are included in the “all features” category. In the field, these features were categorized as “wall”, “architectural element”, “built structure”, “built installation”, “unclassified built”, “cut structure”, “cut installation”, “unclassified cut”, “quarry”, “press”, “burial”, “cave”, or “unclassified”. For spatial analyses, categories were combined to investigate patterning in certain settlement behaviors. In the following larger-scale analysis, features representing habitation versus work spaces were of special interest, and unclassified features were excluded due to unclear identification.

Structures/Built Features

The "structures/built" category includes architectural elements, built structures, built (unclassified) features, and cut structures, with a total of 372 features. Feature types were chosen to isolate areas of habitation and living spaces.

Installation/Processing Features

Containing 343 features, the "processing" category includes built installations, cut installations, and presses. These features mostly relate to resource processing, such as oil and wine presses, grain mills, vats, basins, and channels. Additionally, potential installations for the processing of flax were discovered near Tel Abu Shusha (Safrai 1994,114).

Walls

The "walls" category includes only those features classified as walls, with a total of 505 data points. These are primarily sections of terrace agriculture walls. Some smaller structure walls are also in this category, as it was not always possible to determine the purpose of each wall in the field.

Galton's Problem

A problem inherent to studies of this nature is that of dependence, commonly known as "Galton's problem" (Naroll 1965). Essentially, it is difficult to argue that archaeological features are located based on separate decision-making processes, rather than due to proximity to other features or cultural diffusion. For many tests of statistical significance to be entirely correct, each cultural feature should represent an independent event caused by underlying processes. However, when it comes to regional patterning, cultural features are nearly always dependent on external factors, and it is generally more productive to analyze data while assuming independence. For this research, if multiple features were associated with a single event (e.g. a building), this was recorded as only one feature in the field.

Ripley's K Function

Ripley's K function (Ripley 1976, 1981) assesses clustering of spatial point features, by investigating these patterns at a variety of distances. This helps to avoid skewed results from focusing on a single resolution and neglecting to consider multiscalar variation, a common issue with archaeological statistics (Bevan and Conolly 2006). Spatial events are often autocorrelated, particularly in archaeological contexts, and this function helps to identify the distance thresholds at which certain spatial point patterns occur. The K function is defined as:

$$K(t) = \lambda^{-1}E$$

where λ is the "intensity", or points per area, at a certain location and E is the number of extra events within distance *t* of a randomly chosen event (Dixon 2002:1796). The distance between expected (using a Poisson process) and observed values are measured at all possible scales, to assess clustering, randomness, and dispersion.

For this research, the K distribution was transformed to $L(t) = \sqrt{K(t)/\pi}$, which displays expected values as a straight line for simpler interpretation (Bevan and Conolly 2006), a "border" edge correction was used (a weight function which is scaled lower when the radius extends out of the study area), and a confidence envelope was created marking significance at $\alpha = 0.01$ using Monte Carlo methods. When analyzing the "all features" category, the observed distribution is well above expected values, indicating a significant level of clustering at all distances from 1 to 800 m (Figure 7). This process was also run for "structures/built features", "installations/processing features", and "walls", with similar results suggesting significant

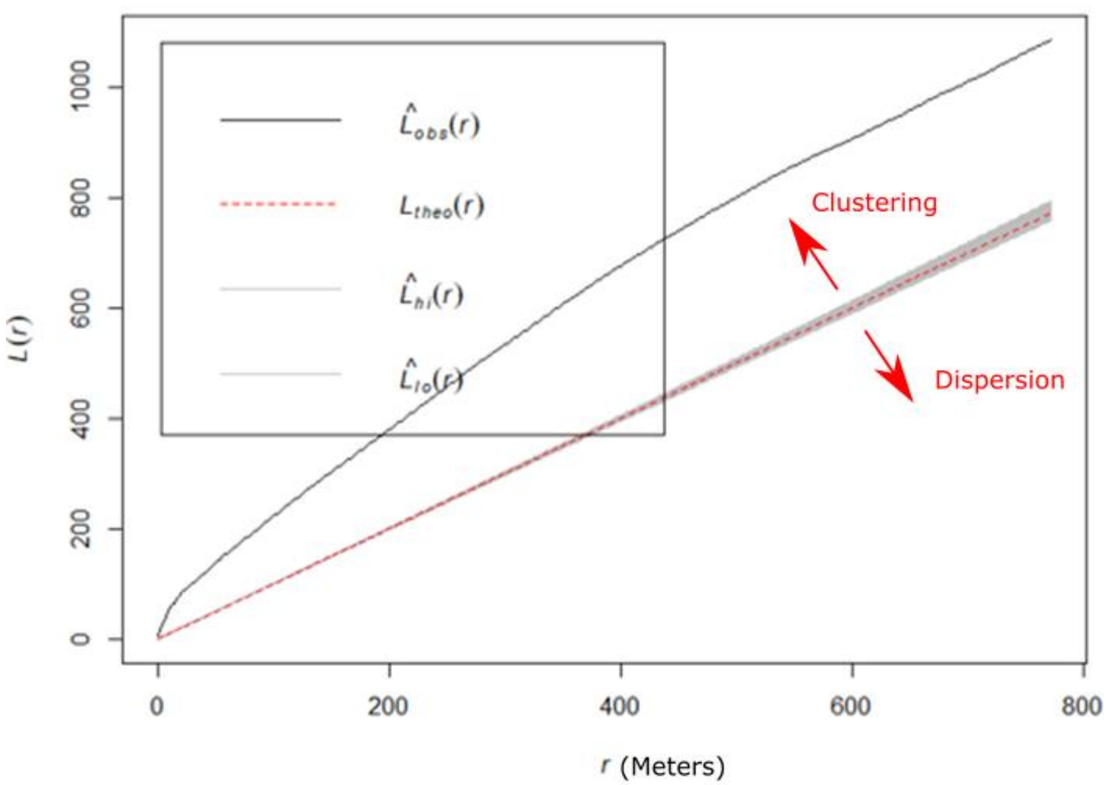


Figure 7. L function of "all features" category in study area. With radius (in meters) on the x-axis, red is expected values, black is observed values, and the gray envelope indicates significance levels.

clustering of features at all possible scales. These results indicate dependence of archaeological features in the study area, organized into neighborhoods on a local and likely a regional scale as well. Analyses in this study attempt to isolate cultural and environmental motivations for this clustering, as the heterogeneity of this landscape suggests complex processes driving feature location and settlement decision-making.

Environmental Trends

Clustering of archaeological events can be further investigated through analysis of environmental trends. In addition to visual examination, statistical tests allow us to identify patterns not apparent to the naked eye. The One-Sample Kolmogorov-Smirnov test compares the observed distribution function of a variable with a background distribution, with the resulting test statistic representing the maximum distance between observed and theoretical functions (Conover 1999:428). In addition to identifying differences in central tendency, this test allows us to identify differences in variance and to see where these differences are occurring. In this case, tests were run for each of the nine environmental variables previously listed, using four feature categories as samples. For these large-scale analyses, the distribution of each sample was compared to background population values, including only surveyed landscape immediately surrounding surface features (Figure 5). Pixel values were extracted in GIS from the full study area polygon for each of the nine environmental variables, then values were separately extracted only at feature locations. The resulting tests statistics, computed in R statistical software (The R Foundation 2016), were compared against quantiles to obtain significance levels (Table 3). The samples and background populations were also plotted as cumulative distribution functions, to better

Table 3. Kolmogorov-Smirnov p-values, with results significant at the level of α ≤ 0.05 in red.

	All Features	***Structures/ Built***	***Processing***	***Walls***
Elevation	*<0.02*	*<0.01*	*<0.01*	*<0.01*
Aspect E/W	*<0.01*	*>0.2*	*<0.01*	*>0.2*
Aspect N/S	*<0.1*	*>0.2*	*<0.01*	*>0.2*
Slope	*<0.01*	*<0.05*	*>0.2*	*<0.01*
Terrain Variance	*<0.01*	*<0.02*	*<0.01*	*<0.01*
Sky-View	*<0.01*	*<0.05*	*<0.2*	*<0.01*
Local Dominance	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Runoff	*<0.01*	*<0.01*	*>0.2*	*<0.01*
Cost Distance to Runoff	*<0.01*	*<0.01*	*<0.01*	*<0.01*

visualize where and in which direction samples deviate from the background environment (Figure 8).

The null hypothesis tested in these samples is as follows:

H_0: Archaeological feature locations are randomly distributed in the study area.

For the “all features” category, this null hypothesis can be rejected for all environmental variables excluding aspect north/south. This suggests significant trends in placement of all archaeological features compared to the surrounding landscape at east-facing aspect, higher

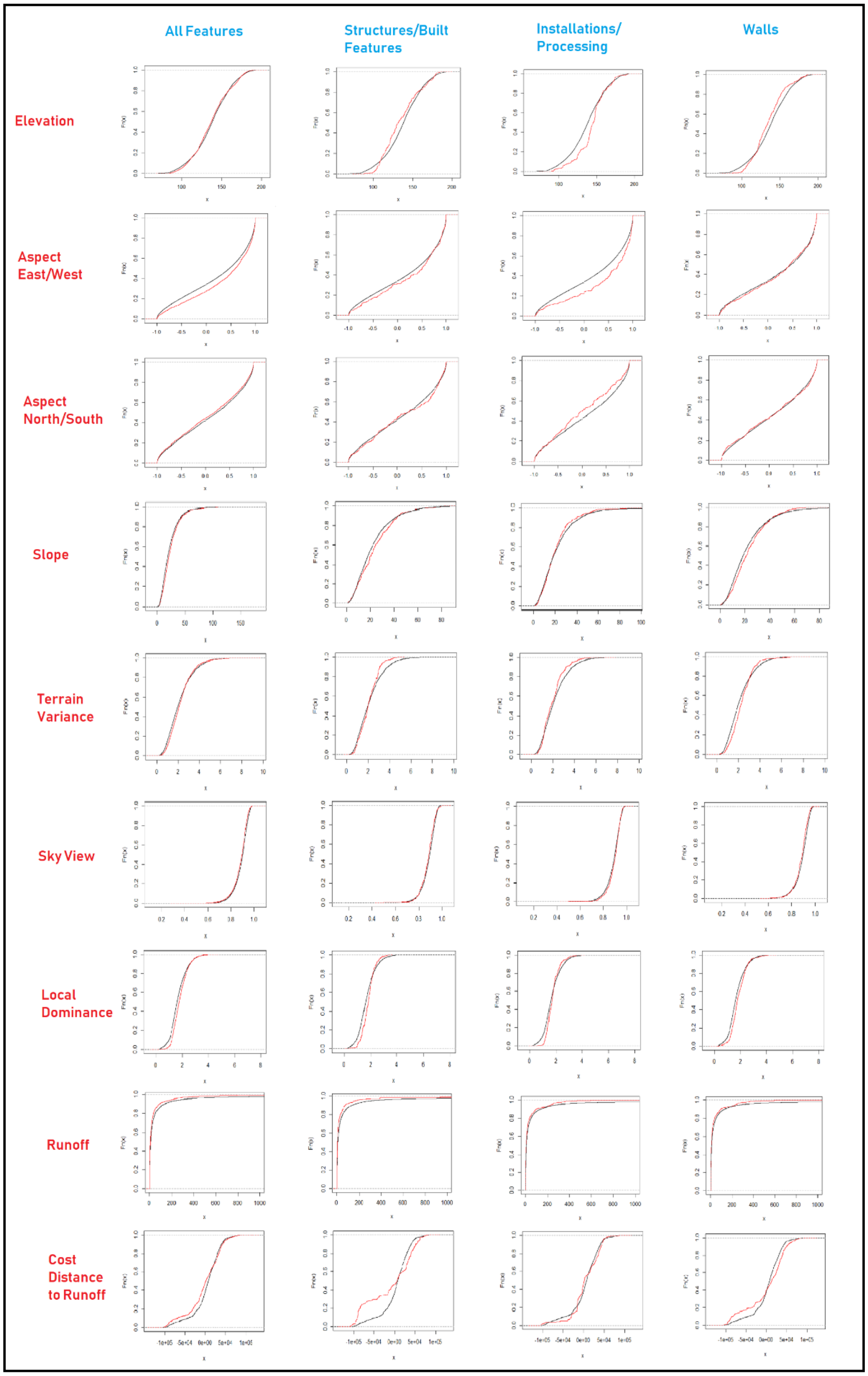


Figure 8. One-Sample Kolmogorov-Smirnov cumulative distribution functions, with background population in black and sample distribution in red.

slope, higher terrain variance, lower sky-view, higher local dominance, lower runoff, and lower cost distance to runoff. While elevation results are significant, the source of this is unclear, as mean and standard deviation values are nearly identical for sample and population. There is also a moderately significant pattern of feature placement at south-facing aspect. These results may partially be caused by natural variables, as the “all features” category includes features such as quarries and modified caves which may exhibit environmental trends in placement simply due to where exposed bedrock was available. For this reason, tests were also run on three specific feature categories of interest, mostly anthropogenic in origin. Structure/built features showed trends in placement at a narrower range of elevations, higher slope, lower terrain variance, lower sky-view, higher local dominance, lower runoff, and lower cost distance to runoff; processing features are at higher elevation, east and south-facing aspect, lower terrain variance, smaller variance of local dominance, and slightly higher cost distance to runoff; walls are located at a narrower range of elevation and slope, higher terrain variance, lower sky-view, higher local dominance, lower runoff, and lower cost distance to runoff.

As these results suggest differential placement of residential versus production-based areas in the landscape, two-sample Kolmogorov-Smirnov tests were used to further investigate the specifics of this relationship (Table 4). While similar to the preceding one-sample tests, this computation instead looks at variation between two sample distributions. When testing differences between structure/built and installation categories, results indicate that structure/built features tend to be located at lower elevation, west and north-facing aspect, lower sky-view, higher local dominance, and lower cost distance to runoff. There are also moderately strong patterns of built features at higher slope, a wider range of terrain variance, and lower runoff. When comparing structure/built to wall features, the only significant trends are placement of

Table 4. Kolmogorov-Smirnov two-sample p-values, with results significant at the level of α ≤ 0.05 in red. "Direction" indicates trends in placement of the specified feature category.

	Structure/ Built Vs Installation	Direction (Structure /Built)	Structure /Built Vs Wall	Direction (Structure /Built)	Installation Vs Wall	Direction (Wall)
Elevation	$2.69*10^{-11}$	Lower	0.376	-	$<2.2*10^{-16}$	Lower
Aspect E/W	0.031	West	0.317	-	0.0003	West
Aspect N/S	0.008	North	0.799	-	0.038	North
Slope	0.068	Higher	0.629	-	0.024	Higher
Terrain Variance	0.069	Lower Variance	0.026	Lower	$7.92*10^{-6}$	Higher
Sky-View	0.018	Lower	0.92	-	0.0003	Lower
Local Dominance	0.014	Higher	0.275	-	0.0003	Higher
Runoff	0.095	Lower	0.363	-	0.287	-
Cost Distance to Runoff	$9.01*10^{-9}$	Lower	0.009	Lower	0.001	Lower

structure/built features at lower terrain variance and lower cost distance to runoff. When compared against installation features, structure/built and wall features exhibit very similar environmental trends. The primary divergence is that tests comparing wall versus installation features resulted in more significant test statistics for all environmental variables except aspect north/south, runoff, and cost distance to runoff, which displayed less significant results. Overall, the most noticeable differences between environmental placement of feature types exist when comparing structure/built/wall features against installation/processing features.

These patterns suggest that past inhabitants of the Abu Shusha area commonly settled in medium to high elevations, and in relatively flat areas compared to the broader landscape. This is a tentative interpretation, due to the fact that we see structure/built features placed at lower terrain variance, yet higher slope and local dominance. The vital difference in these variables is that they are representing different scales of landscape variation, with terrain variance measuring larger-scale relief change and the other two variables measuring more immediate relief at a location. It is argued here that while higher slope and local dominance may provide some benefits for individual households, such as good views of the immediate area and defensive advantages, the lower terrain variance is instead reflecting settlement decision-making on a larger, societal scale, with lower overall relief to accommodate larger populations. As these analyses include the entire study area, it is also possible that these somewhat contradictory results may be reflecting variation in settlement strategies between sub-regions. The exception was placement of terrace walls, which were located at steeper, more topographically varied locations. Many of these settlements were placed at more east and south-facing aspect, likely to take advantage of more sunlight during mornings and winter months. Housing was located in drier areas to avoid accumulation of rainfall, yet easy travel to a source of water would also be necessary. This may reflect compromise between subsistence needs, defensibility, and accommodation of larger populations, a balancing act necessary due to the particularly bloody history of the Jezreel Valley from the Persian era to the modern day.

However, the inhabitants of Abu Shusha appear to have considered defense a secondary concern. For a large, nucleated city we might expect settlements and fortifications at large, flat, low expanses of land with high view distance in all direction for defensive purposes. While the large tel site suggests potential settlements of this nature further in the past, the fact that this is not seen on the surface at Abu Shusha indicates that the society living here during more recent eras may have prioritized production, agriculture, and trade. For a more moderately sized group, the general highland area would provide natural fortifications, and settlement on smaller ridges and protrusions would improve vision of approaching invaders in the immediate area. This culture would be more hidden in the landscape, and present less of a target. Those living at Abu Shusha would need to accommodate these defensive concerns, while also choosing areas with access to water, resources, sunlight, and nearby arable land for agriculture. It is also possible that this society was pursuing practical advantages by settling in higher areas, as valley bottoms would contain the most fertile soils in this hilly region. These lower, flatter regions are relatively sparse near Abu Shusha, so past humans may have chosen to reserve these areas for agriculture, instead settling in nearby higher locations.

These past humans also seem to have distinctly separated activity areas in the Abu Shusha landscape, when looking at living spaces versus processing/labor. Easy access to water was vital for residential areas, as well as lower rainfall accumulation on the ground. These spaces tended to be located at middle elevations, on local prominences in overall flatter areas, and in less open areas that would make these communities less visible. Interestingly, processing activity areas significantly diverged from this. The inhabitants of this area placed production centers higher up in the landscape, in flatter, more accessible lands. This would ease labor and travel, which appears to have taken priority over defensive concerns here. It is also likely that these locations were chosen for proximity to raw materials we suspect were being processed at this site, such as olive trees and flax. Access to water was not as vital for these processing, but plentiful sunlight was. The placement of these production centers at east and south-facing aspects would provide increased sunlight during morning and winter months, enabling longer work days and increased productivity.

Cluster Analysis

Pure locational (k-means) and unconstrained cluster analyses are complementary methods of heuristic spatial analysis that can provide information based on spatial location, density, and class composition of archaeological features (Kintigh and Ammerman 1982; Kintigh 1990). These approaches can be used to identify potential activity areas or settlements types, and are based on three broad feature categories in this study area: structure/built, installation/processing, and walls. In k-means clustering (Lloyd 1982), the user defines a desired number of clusters and the algorithm partitions space to create these classes. It is an iterative process that creates cluster centers and assigns point data to a cluster based on the sum of squared error (SSE), the sum of all squared distances to the mean. These center points are then moved and the process is repeated until SEE is minimized as much as possible for each cluster. Inflection points (marking changes in clustering) in a SSE plot can suggest useful clustering levels for investigation. For this study area, analyses based on 3, 5, and 8 cluster groupings were found to be productive, allowing multi-scalar examination of clustering. Clusters not conforming to circular shapes may not be well identified using this method.

Unconstrained clustering uses feature composition to identify data clusters (Whallon 1984; Kintigh 1990), an approach that may recognize cluster shapes missed by k-means methods. In this study, GIS was used to create raster images containing proportions of each feature type, with a histogram peak technique used. This resulted in a cluster image based on frequency and proportion of feature types in an area, rather than focusing on spatial location and point density. A common problem with this computation is low point feature counts, as a large cell with only one processing feature will still be labelled as containing 100% processing features in the final image. Methods commonly used to remedy this include increasing cell size, using a mask that excludes low feature count cells, and using a filter on each proportion image that "smooths" and spreads out feature counts. Ultimately most effective in this research was a combination of the three, using 40 x 40 m cell size, excluding cells with low feature counts, and using a 3 x 3 m mean filter on each feature count layer.

Based on the k-means results (Figure 9), there are three primary clusters at the largest scale: the central area including Abu Shusha, a relatively densely clustered northern area, and a more dispersed southern area. These clusters could represent discrete settlements, organizational neighborhoods within a single settlement, or separation of activity areas. It could be argued that these settlement differences are partially due to differing topography, but landscape within the full study area is uniform enough for this explanation to be unsatisfactory. In the 5 and 8 cluster images we see further partitioning of feature groupings, the smaller scale of which is likely to represent activity areas within single settlements. When looking at unconstrained clustering results (Figure 10), the red cluster consists primarily of architectural features and walls, white is mostly processing features, and green is almost exclusively wall features. This suggests that red areas are heavily residential, white is more commonly evidence of food processing and labor activities, and green is mostly terrace walls. The fact that structure/built and wall features are heavily mixed and often present in the same clusters supports the argument made in the preceding environmental analyses, that settlement motivations driving placement of structure/built and wall features were often similar. Overall, these data support the idea of a nucleated city center at Abu Shusha, with agricultural activities and resource processing in the surrounding hinterlands. Built/structure versus processing features are noticeably separated at the tel, with processing activities occurring outside of the living spaces. Social behavior was likely highly integrated and communal at Abu Shusha, with large-scale organized labor occurring beyond the household level.

Further north at Abu Shusha, these clusters become similarly condensed but in less regular shapes. In this area, structure/built and processing features mostly occupy the same spaces and there is little evidence of large processing centers (Figure 10b). This mixing of feature types suggests increasingly individualistic and isolated cultural behavior, particularly if processing and subsistence activities occurred on a household level. Additionally, areas consisting of only wall features are more evident in this northern area. As households are relatively dispersed in this region and thus fortification walls would be unlikely, this pattern indicates the presence of terrace walls and predominant agricultural activity. Terracing would have been essential for agriculture in the hilly landscape around Abu Shusha, and the extensive scope of terrace wall construction at Abu Shusha suggests some form of organized labor. K-means results agree with these interpretations, as northern clusters at all scales exhibit the highest proportions of walls compared to other feature types. The people of this northern area appear to have lived in semi-condensed residential areas with resource processing occurring on a more household level.

In the southern region, features become increasingly dispersed. Structure/built and wall features are heavily mixed together, but the spatial division between structure/built/wall and processing features is more pronounced, with large processing centers that are distinct from these residential areas. The inhabitants of this area likely participated in some level of group-based, communal production, as these processing centers are more extensive than in any other region. These patterns become increasingly clear as we move further south, perhaps extending

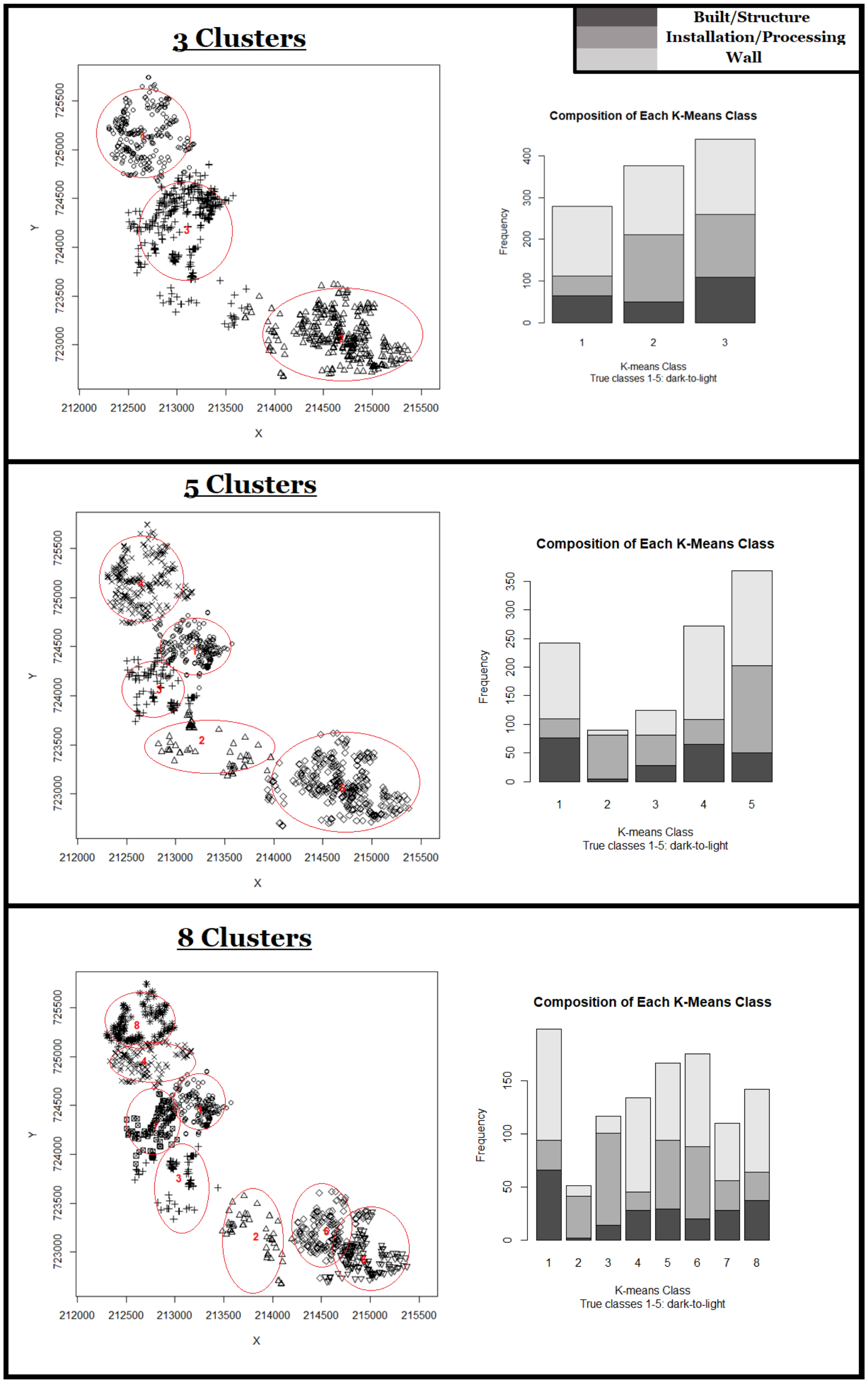


Figure 9. K-means clustering result, with axes indicating Israeli Transverse Mercator (ITM) coordinates. Point symbols indicate to which k-means cluster a feature belongs.

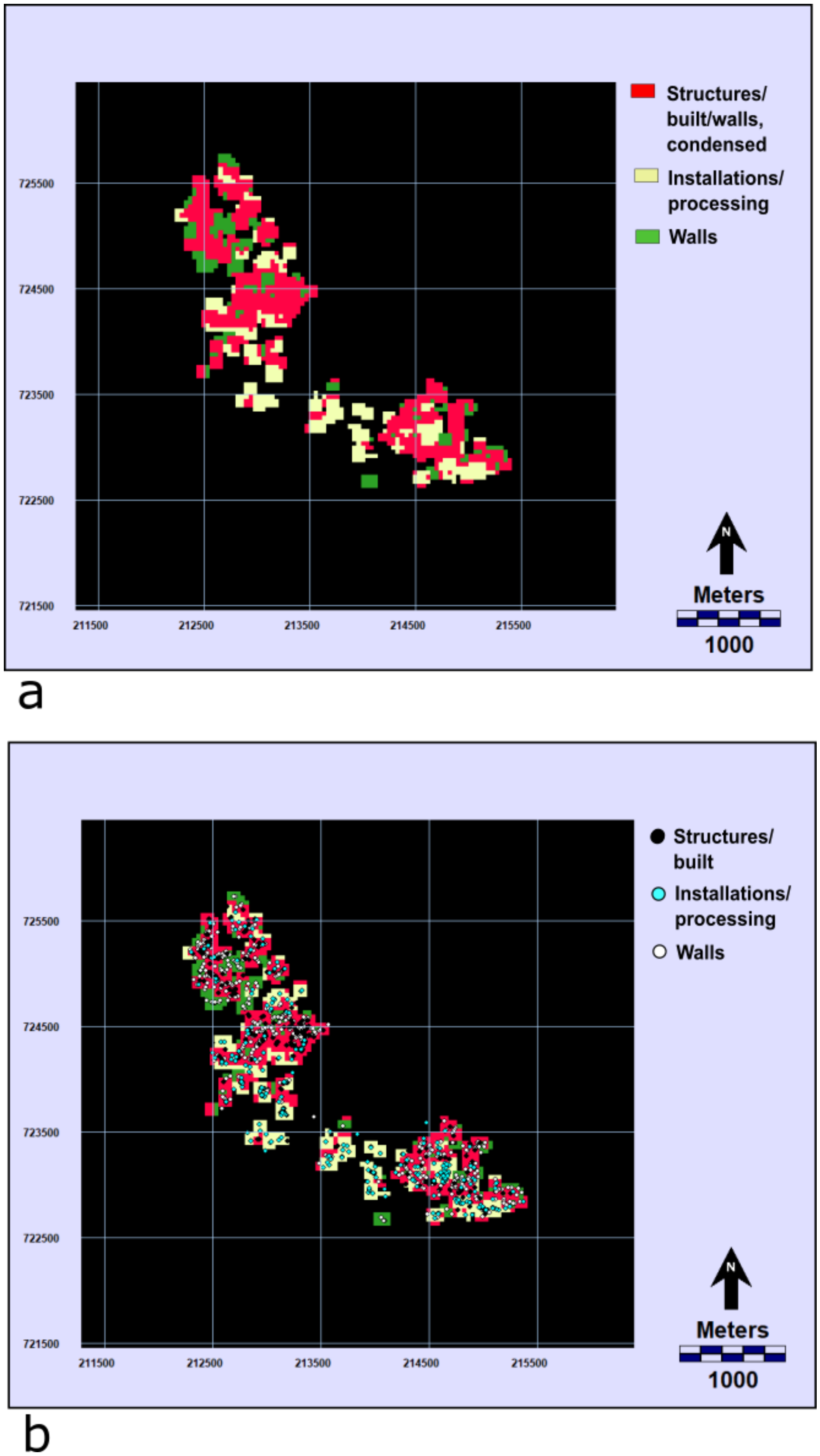


Figure 10. Unconstrained clustering results, axes in ITM coordinates: a) image with a cluster size of 3, b) cluster image overlaid with archaeological features.

continuously from Abu Shusha but interrupted by the modern settlement of Mishmar HaEmek. These settlement patterns differ noticeably from the central Abu Shusha area, as people in the south are living in relatively disparate, isolated households but participating in group-driven production behavior. There is no clear residential hub in this settlement area, and k-means results indicate that the southern clusters contain some of the lowest proportions of structure/built features (Figure 9). Because of this, it is likely that the organized labor of this area was administered by a nearby region, the obvious choice being Abu Shusha with its noticeable scarcity of production centers. Resource processing may have been administered by the city center of Abu Shusha yet carried out primarily in this southern region, with smaller neighborhoods consisting of multiple households with shared processing facilities. At the very least, it is probable that extensive trade was occurring between this southern region and neighboring communities.

CHAPTER III: NEIGHBORHOOD ORGANIZATION

In this chapter, integrated methods are applied to assess smaller-scale social and spatial organization, with emphasis on identification and interpretation of “neighborhoods”, organizational settlement units in which agents are regularly interacting. Four study blocks are used as case studies, each measuring 300 x 300 m (Figure 11). They are spaced broadly across the study area, centered on clusters of surface features, and are located to explore areas of potentially differing settlement styles. One and two-sample Kolmogorov-Smirnov tests are used to investigate environmental trends in feature placement within these smaller landscapes, k-means clustering assigns features to cluster groups based on spatial location and point density, and unconstrained clustering creates feature groupings based on proportions of feature types in an area. Additionally, color composite approaches are explored, a simple method of visualizing densities of each feature type and looking at where these clusters overlap. Feature densities may be represented by red, green, or blue colors (RGB). The color becomes yellow where red and green overlap, magenta where blue and red overlap, cyan where blue and green overlap, white where all three colors overlap, and black where no RGB colors are present.
We begin by focusing on Tel Abu Shusha itself (Area 1), then expand outward.

While large-scale investigations into archaeological patterning may provide useful information, this scale of inquiry enables mostly generalized interpretations. In the previous chapter, feature groups were simplified into three broader categories, but the following smaller geographic case studies allow for examination of more specific feature classes. “Unclassified” includes mostly built features of less clear purpose that are primarily structure/architectural remains, “unclassified cut” indicates a range of features cut into bedrock such as potential processing installations, cut marks, and quarries, “quarry” includes only clear evidence of

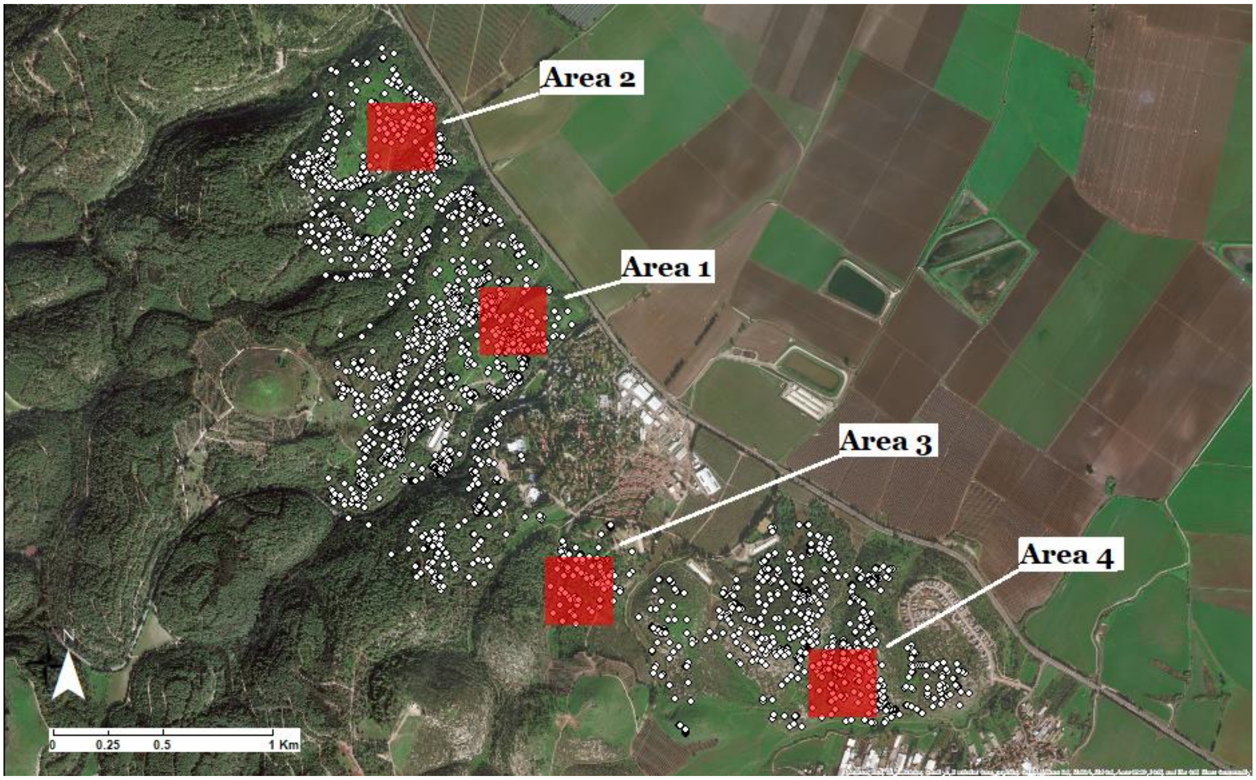


Figure 11. Case study areas, ordered beginning with Tel Abu Shusha (Area 1) and expanding outward.

bedrock quarrying installations, and “burial” includes human graves. Smaller sample sizes within these case studies allow for examination of each individual feature photo for clarity.

Area 1: Tel Abu Shusha

Area 1 covers Tel Abu Shusha (Figure 12), including the southern, western, and northern slopes of the tel, the summit, and a portion of the surrounding area. Nearby terrain is topographically similar to the tel, and as such should not overly bias statistical results.

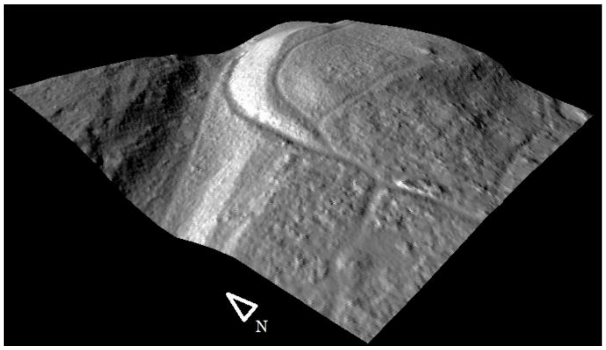


Figure 12. Area 1, measures 9 ha.

This study block encompasses 154 archaeological features (Figure 13), of which the most heavily represented categories are structure/built, wall, and unclassified. Based on examination of photographs, the majority of unclassified features in this area represent architectural debris or

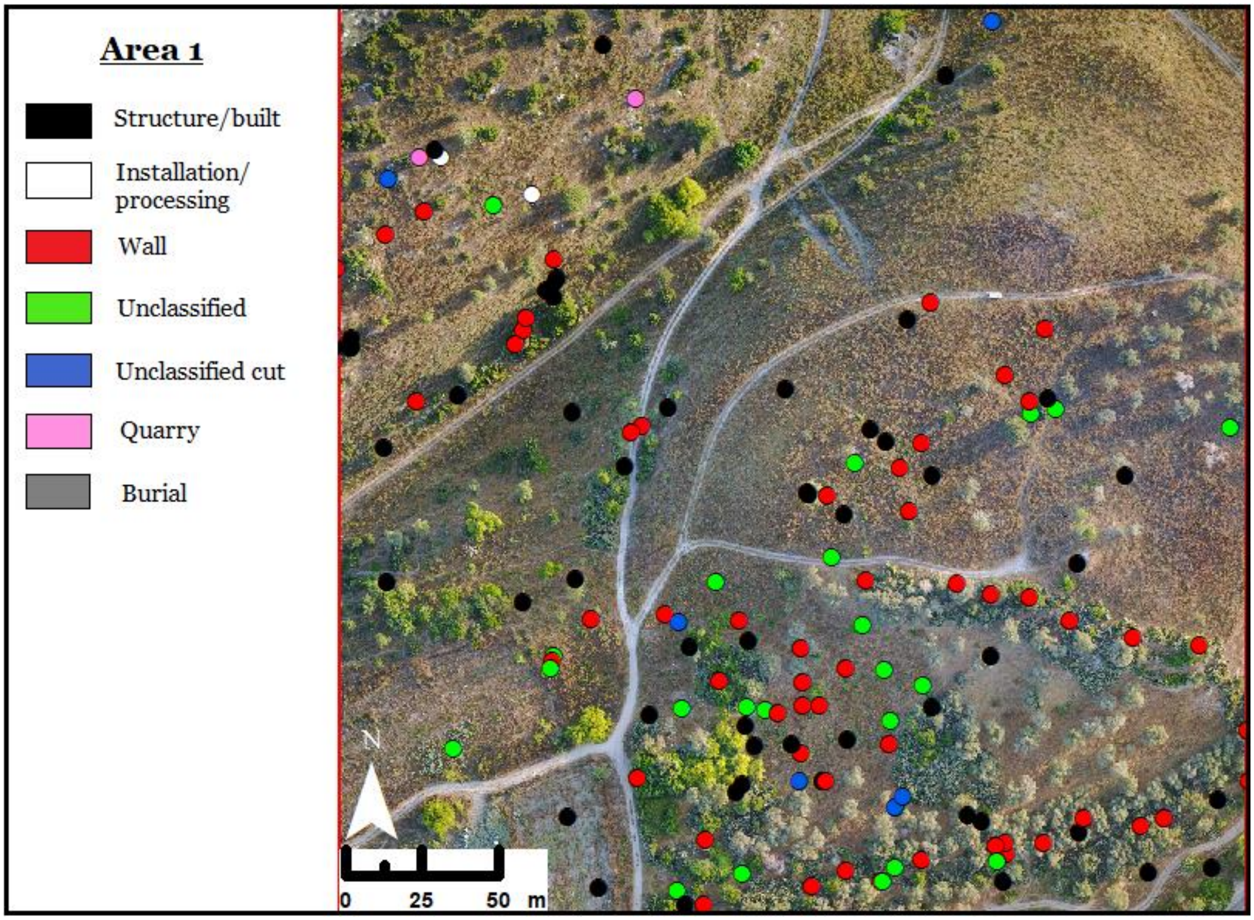


Figure 13. Area 1 overlaid with surface features. Orthophoto courtesy of Adam Prins and the JVRP.

dump sites. At first look, archaeological features appear to be amassed on the southern slope of the tel. However, features in flatter areas may simply be more deeply buried due to decreased erosion. The landscape has a high level of relief, with dense weeds and sabra cacti. Surface soils are primarily sandy silt, light to medium brownish-gray in color, unplowed, dry, and soft, with 1-15% stone abundance of medium-sized pebbles (0.6-2 cm). High densities of surface ceramics were collected at the tel as well.

It should also be discussed here the relationship between these surface features and the eroded southern slope of the tel. While there appears to be a dense distribution of residential features on this slope, this may be partially due to natural factors. Oftentimes erosion will wash archaeological remains downslope from their origin, but this is relatively unlikely in this case, as these features are primarily large-scale or cut into the bedrock itself. However, it is certainly possible that large quantities of shallow features were uncovered on this slope due to erosion. If so, this density of features may simply be the most visible area of settlement, rather than the most densely settled. Regardless, we will be operating under the assumption that a nucleated settlement existed, if not on the southern slope, at least in the immediate area of Tel Abu Shusha.

Environmental Trends

Statistical tests looking at significance of environmental variables may be effective when applied to these smaller case studies, particularly for gaining a perspective on local settlement decisions. If similar trends are seen in multiple case studies, this may also support interpretations of larger-scale environmental decision-making. For the 9 ha Area 1, Kolmogorov-Smirnov one-sample tests were run within this smaller subset of data, looking at placement of archaeological features on the landscape based on nine environmental variables (Table 5), with the “all features” category including all documented survey features except natural phenomena such as unmodified caves. This was computed using 150 sample data points compared against 90,000 background data points, extracted from pixels in the 300 x 300 m study block. Results suggest possible preferential placement of features compared to the environment at higher elevation, south-facing aspect, lower terrain variance, lower local dominance, and lower cost distance to runoff. There is also a moderately significant pattern of feature placement at lower runoff values.

Those living near tel sites will often settle at higher elevations, as societies built atop one another and reuse materials and resources. Particularly in the Jezreel Valley, these sites may have been chosen for better views or defensive purposes, as well as to reserve lower areas with more fertile soil for agriculture. Despite this, accessible and less topographically varying locations were also sought after. People were not necessarily living in prominent locations that were "dominant" over the local landscape, such as local protrusions or steeper slopes, perhaps prioritizing more regional strategic concerns at this central hub. Additionally, the inhabitants of Abu Shusha had to balance this with practical motivations. South-facing aspect may have been chosen for increased sunlight, particularly in winter months, though this pattern may also

Table 5. Area 1 Kolmogorov-Smirnov p-values with results significant at the level of α ≤ 0.05 in red, and direction of this variation.

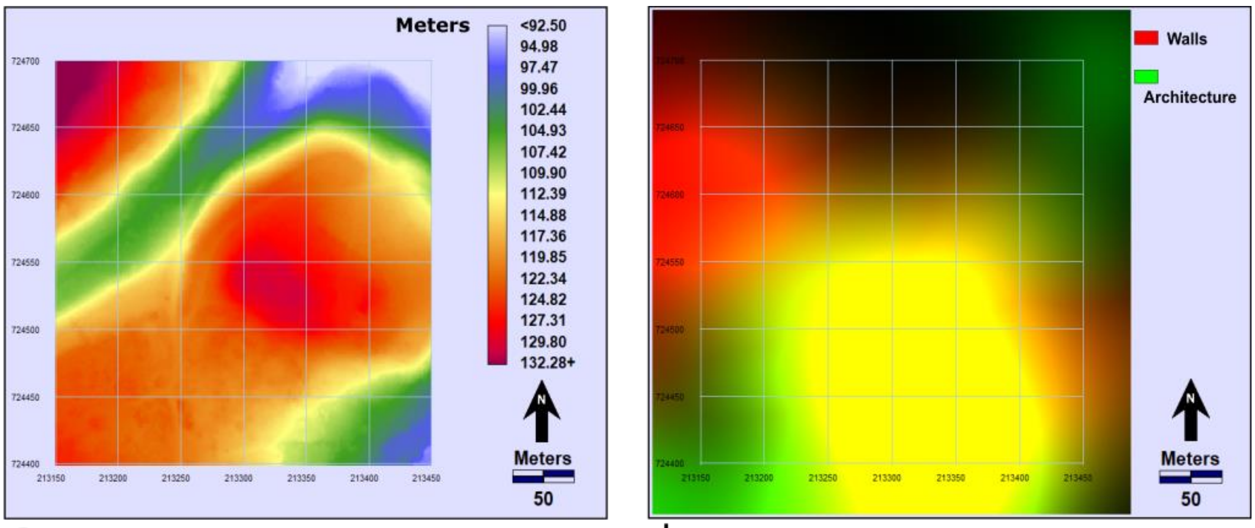
	All Features	***Direction (Features)***
Elevation	*<0.05*	*Higher*
Aspect E/W	*>0.2*	*-*
Aspect N/S	*<0.01*	*South*
Slope	*>0.2*	*-*
Terrain Variance	*<0.1*	*Lower*
Sky-View	*>0.2*	*-*
Local Dominance	*<0.02*	*Lower*
Runoff	*<0.1*	*Lower*
Cost Distance to Runoff	*<0.01*	*Lower*

simply be a result of the tel having a gentler slope, more suitable for settlement, on the south-west side. However, if this were true, we might also expect a settlement trend on west-facing aspects, which is not seen. Areas retaining large quantities of rainfall would not be ideal for settlement, but ease of travel to nearby water resources was needed. Those living at Abu Shusha seem to have participated in a somewhat larger, organized community. Flatter areas were likely preferred to accommodate a larger population, as well as relatively accessible locations close to natural resources. This may reflect a compromise between concerns of resource availability, population accommodation, and defensibility, not unusual for a medium to large-scale settlement in the Jezreel Valley.

Spatial Organization

A variety of visual, spatial, and statistical methods were used to address questions relating to social organization in these case study areas, including k-means clustering, unconstrained clustering, and color composite images based on kernel density estimate (KDE) computations (Figure 14). KDE bandwidth is a complex statistical function of distance, and determines the level of smoothing. A bandwidth of 50 was used for Area 1, and density surfaces were computed based on spatial location of feature point data. For each study block, differing feature categories were created, depending on feature composition in the area and settlement patterns of interest. The organization of structures, habitations, and walls is of primary interest in Area 1, and to explore this, two categories were created: structure/built/unclassified, and wall. The former group will be referred to as "architecture."

Various scales were investigated for k-means clustering, but the use of 4 clusters was the only size with a noticeable inflection point that provided helpful results (Figure 14c). None of the clusters are dominated by a certain feature type in this case, each is split relatively evenly between architectural and wall features. Clusters 1 to 4 show increasing dispersion in this order, with similar levels of dispersion in clusters 1 and 2. Lastly, unconstrained clustering was used with these two feature categories, resulting in two clusters (Figure 14d). The red cluster represents



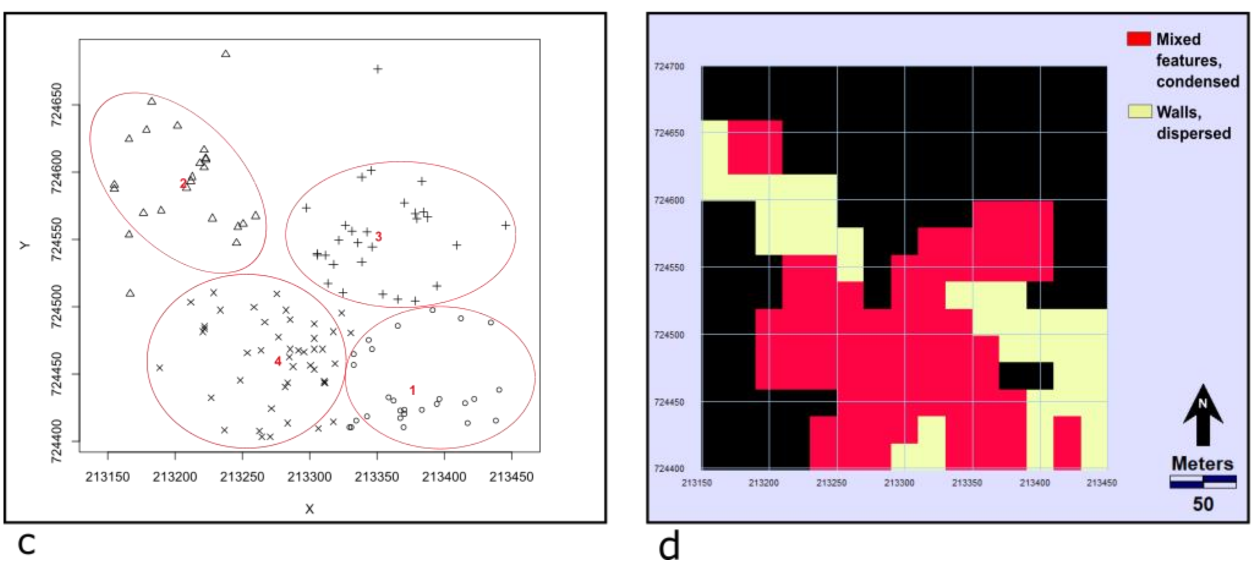


Figure 14. Area 1 analyses and images, with axes in ITM coordinates: a) DEM (in meters), b) color composite c) k-means clustering, d) unconstrained clustering.

the higher density area of mixed architectural and wall features, while the white cluster is composed primarily of dispersed wall features. The relative uniformity of these features suggests highly communal behavior, with a central residential neighborhood on the southern slope of the tel.

Discussion

This neighborhood sits between two large-scale walls running east-west on the southern slope of the tel. This residential zone is almost entirely composed of architectural remains, and wall features here are smaller-scale and appear to be related to structures. This was likely a densely populated, medium to large city-center, and the lack of processing or agricultural activity nearby suggests that this neighborhood was residential, perhaps heavily administrative or consisting of specialized activities. This group would need to be highly integrated with the surrounding hinterland, as there would not be sufficient food production here to support this population. Laborers would likely live in smaller settlements below the tel, closer to natural resources and labor activity areas. This suggests some degree of regionally organized labor. North of here, the summit of the tel contains large-scale walls and some residential features, but they are dispersed and their purpose is less clear. This could represent another residential neighborhood, but if so it would be less condensed and centrally organized. The features north-west of the tel are somewhat spread out and represent a much wider range of feature types, signifying either a shift to more individualized settlement behavior, or a change to a production-based activity area.

Area 2: Northern Hills

This northern case study covers a hilly area with a relatively high level of relief (Figure 15). A modern path cuts through in a north-east to south-west direction, and the terrain slopes upward sharply from both sides before leveling out again at higher elevations in the north-west and south-east. This area contains 105 archaeological features (Figure 16), primarily unclassified, unclassified cut, and wall features. Unclassified features in this area are primarily architectural remains, and unclassified cut features are a mixture of processing and

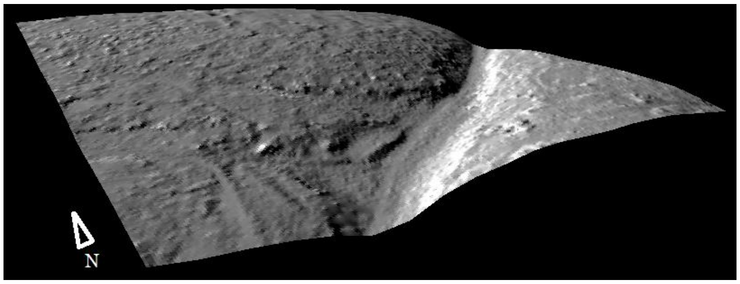


Figure 15. Area 2, measures 9 ha.

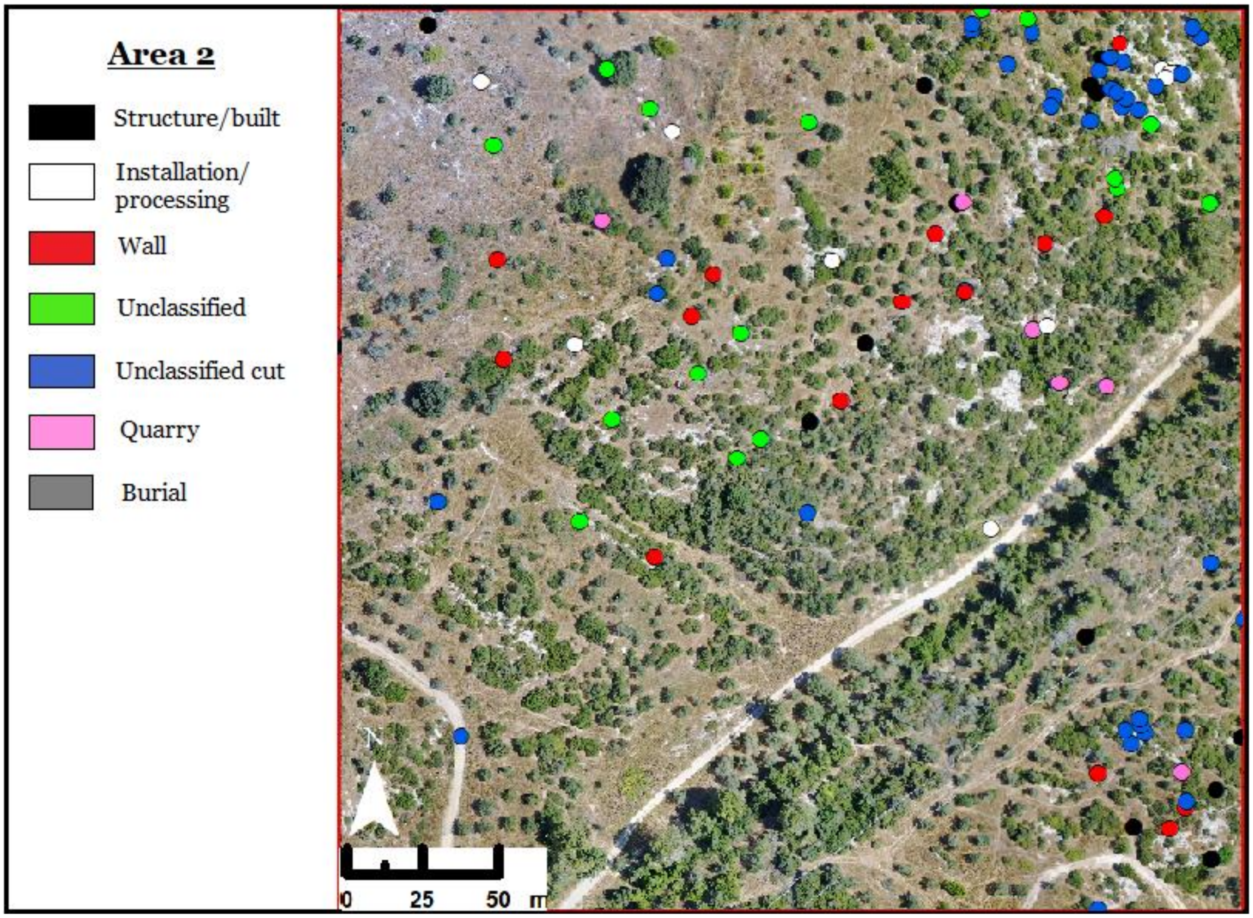


Figure 16. Area 2 overlaid with surface features. Orthophoto courtesy of Adam Prins and the JVRP.

quarry features. The landscape is densely covered with tall trees, scrub, weeds, and grass. Surface soils are mostly sand and silty sand, medium grayish-brown, unplowed, dry, and soft, with 16-35% stone abundance of medium sized pebbles (0.6-2 cm).

Environmental Trends

Located in the less condensed northern region, Area 2 exhibits more gradual topographic change compared to Abu Shusha. Steeper slopes are seen in certain portions of the study block, but there are fewer abrupt shifts in landscape. For Kolmogorov-Smirnov tests, 100 sample features were compared against 90,000 background data points in Area 2. Results suggest significant patterns of archaeological feature placement within the surrounding landscape at lower elevation and slope, south and east-facing aspect, higher local dominance and sky-view factor, and lower runoff and cost distance to runoff (Table 6).

Table 6. Area 2 Kolmogorov-Smirnov p-values with results significant at the level of $\alpha \leq 0.05$ in red, and direction of this variation.

	All Features	***Direction (Features)***
Elevation	*<0.01*	*Lower*
Aspect E/W	*<0.01*	*East*
Aspect N/S	*<0.01*	*South*
Slope	*<0.01*	*Lower*
Terrain Variance	*<0.01*	*Lower Variance*
Sky-View	*<0.01*	*Higher*
Local Dominance	*<0.01*	*Higher*
Runoff	*<0.05*	*Lower*
Cost Distance to Runoff	*<0.01*	*Lower*

Settlement at lower elevations in this study block contrasts with patterns seen at Abu Shusha, perhaps due to a more mixed composition of features reflecting habitation, processing, and possible agriculture. This may be an agricultural area, with lower elevations containing more fertile soils in this area. Feature placement in flat, open areas support the idea that processing activities relating to agriculture may have occurred. Increased sunlight during mornings and winter months would prolong work days, and access to water would be necessary. The pattern of high local dominance is difficult to interpret in this case, but likely reflects a tendency to place features on protrusions overlooking the local landscape. This landscape could give better views, and terrace walls would commonly be placed in areas of high slope to prevent erosion and assist with the rainfed agriculture common to highland regions. These issues of resource acquisition, access to water, and accumulation of rainfall would be especially vital if we are looking at a more agricultural or production-based region.

Spatial Organization

Area 2 contains a mixture of architectural, processing, and wall features, and as such presents an opportunity to investigate the relationship between these feature types in a less nucleated area. Three categories were created to best represent these archaeological feature types for analyses: structure/built/unclassified (architecture), installation/processing/unclassified cut (which will be referred to as "processing"), and wall (Figure 17). With k-means analysis, a cluster size of 6 was found to be most effective for isolating smaller spatial units within the landscape. Processing features are the most spread out among all k-means clusters compared to other feature types, but only by a small margin. Clusters 2, 3, and 6 are composed primarily of processing features (70-77%), and cluster 5 is heavily wall features (71%). Clusters 1 and 4 are small with mixed feature composition, but both contain high proportions of architectural remains (> 45%). Point dispersion within clusters 2, 3, 5, 6, 1, and 4 increases in this order, with cluster 4

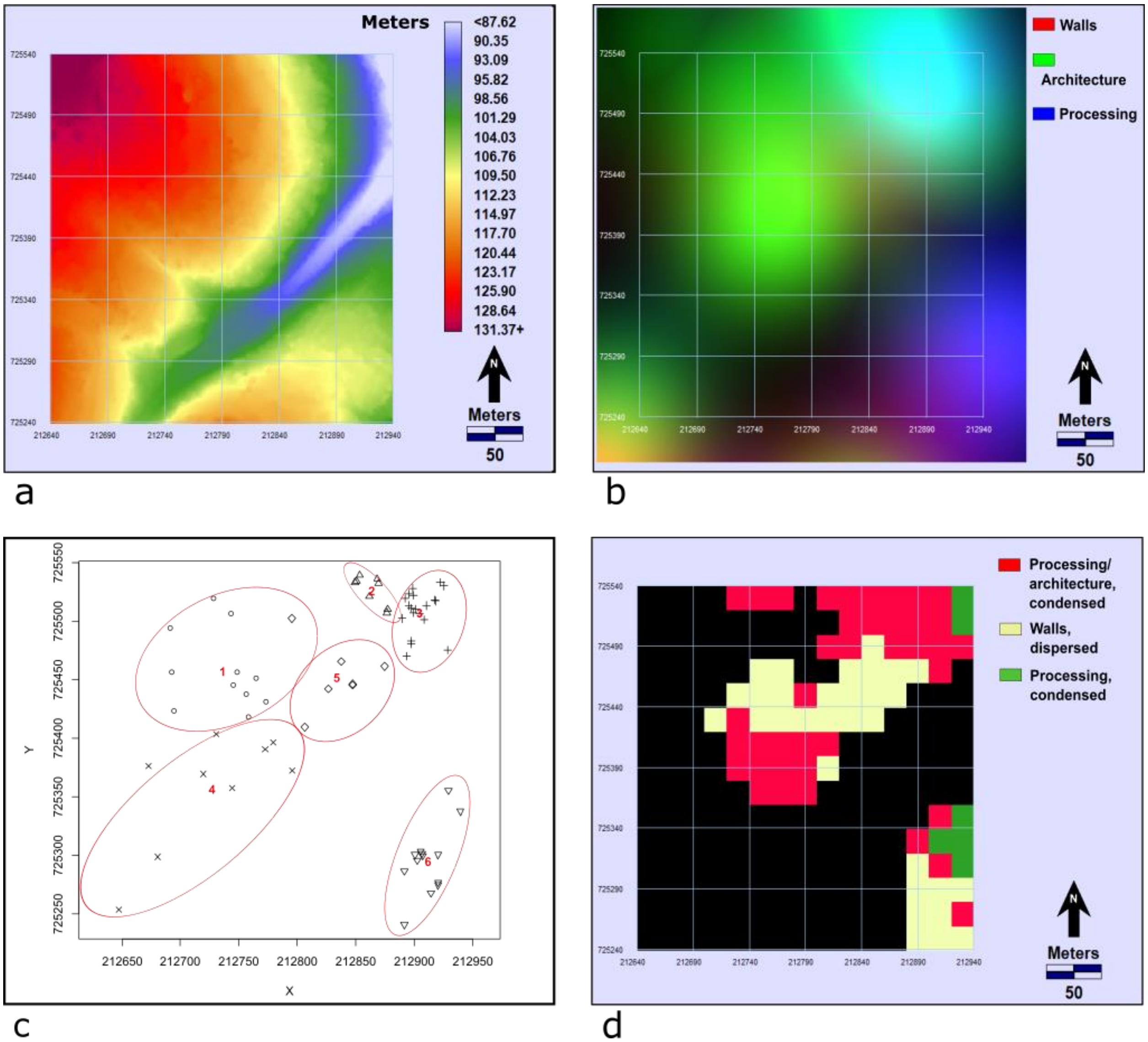


Figure 17: Area 2 analyses and images, with axes in ITM coordinates: a) DEM (in meters), b) color composite c) k-means clustering, d) unconstrained. clustering.

twice as dispersed as any other k-means class (Figure 17c). There are no apparent larger neighborhoods in Area 2 aside from the large processing center in the north-east, but there is still evidence of large-scale organization. The unconstrained clustering results suggest that past humans were living in dispersed households mixed with processing and larger wall features (red cluster), with certain activity areas devoted to processing and labor activities (white cluster).

Composition of the green cluster is less clear, but it seems to be located at the highest densities of processing features (Figure 17d).

Discussion

Based on examination of feature photographs, walls in the north-east and central areas appear to be larger-scale, perhaps for terracing purposes, while walls in the south-east are smaller and likely related to habitation areas. Additionally, the more gradual slope here would be conducive to terrace agriculture. Unclassified cut features in this south-east cluster are mostly evidence of quarrying, while in the north-east cluster they are primarily presses, vats, channels, and other processing features. The central area with dispersed features is less clear, with mixed architecture, processing, and walls. Overall, this is a settlement seemingly devoted to intensified agricultural activities. The inhabitants of Area 2 were not living in a condensed, organized manner, but processing activities seem to be organized to some degree. This irregular settlement pattern could simply represent a more household-based organization absent of agriculture, but if so the processing center to the north-east would be unusual. This is one of the largest, most nucleated collections of food processing features in the northern region, much larger than would be necessary for food processing on a household scale. These patterns do not suggest a small, cohesive, internally organized group. Instead, it is more probable that this area displays organized labor because it is connected to a nearby settlement hub, with Abu Shusha being the most likely candidate.

Area 3: Central Hills

While Area 3 has a moderate to high amount of relief in terms of the broader region, it is relatively flat compared to the other three case studies (Figure 18). Ninety-three features were documented within this study block, the majority being quarries or unclassified cut features (Figure 19).

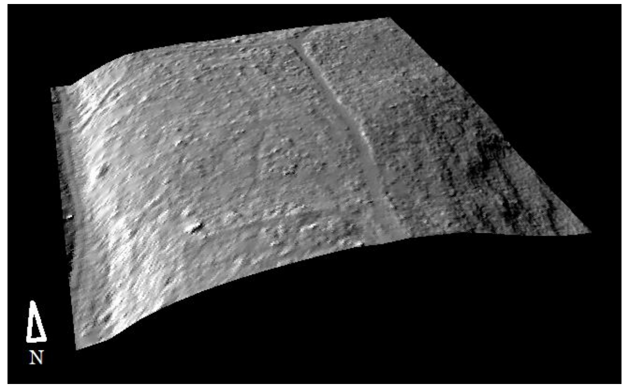


Figure 19. Area 3, measures 9 ha.

Unclassified cut features here appear to be primarily processing installations, with some evidence of quarrying. The area is covered in tall trees, scrub, weeds, and grass. Surface soils are

Figure 18. Area 3 overlaid with surface features. Orthophoto courtesy of Adam Prins and the JVRP.

mostly sand, light to medium brownish-gray, unplowed, dry, and soft, with 16-35% stone abundance of medium-sized pebbles (0.6-2 cm).

Environmental Trends

Kolmogorov-Smirnov tests in Area 3 compared 90 feature sample points against 90,000 background data points from the full study block. Results indicate significant patterns of feature placement at east-facing aspect, flatter slope, lower terrain variance, higher sky-view factor, and lower cost distance to runoff (Table 7). Interestingly, elevation and local dominance tests for this area resulted in significant distributional differences, but in terms of variance rather than central tendency. Measures of central tendency were similar for populations and samples, but sample distributions were located within a narrower range of values for these two variables. This could be a case in which moderate levels of elevation and local dominance were preferred, as this restricted variance still suggests some type of locational patterning.

Table 7. Area 3 Kolmogorov-Smirnov p-values with results significant at the level of α ≤ 0.05 in red, and direction of this variation.

	All Features	***Direction (Features)***
Elevation	*<0.02*	*Lower Variance*
Aspect E/W	*<0.05*	*East*
Aspect N/S	*<0.2*	*-*
Slope	*<0.02*	*Lower*
Terrain Variance	*<0.01*	*Lower*
Sky-View	*<0.01*	*Higher*
Local Dominance	*<0.02*	*Lower Variance*
Runoff	*<0.2*	*-*
Cost Distance to Runoff	*<0.01*	*Lower*

While some of these environmental trends may simply be a product of where bedrock was exposed, a tendency for features to be located at east-facing aspects still suggests an attempt to take advantage of morning sunlight, and lower cost distance to runoff likely reflects concerns of resource availability. Unclassified cut features in the study block vary widely, including quarries, presses, tie points, and other mixed processing installations. The inhabitants of this area likely chose flat, open environments to facilitate habitation, work, and travel. Though decidedly speculative, there is another possibility: olive trees grow best on limestone slopes, and olive oil was a major component of Palestinian economy and cuisine, particularly during Hellenistic and Roman times (Safrai 1994,104)). A number of oil presses, cut into bedrock, were clearly identified during this survey, and it is probable the inhabitants Area 3 were cultivating olives at least as a portion of their crop. While placements of processing centers on steep slopes would not be practical, laborers would likely build these centers at relatively flat areas near limestone slopes, to ease harvest and transport of olive crops. Additionally, olive trees thrive in temperate climates without shade (Safrai 1994,118), and the openness of this landscape would provide a good environment for cultivation.

Spatial Organization

Visually, Area 3 appears to contain more dispersed data points than previous study blocks, primarily food processing and quarrying features. To better investigate these patterns, archaeological features were divided into three categories for analyses (Figure 20): unclassified cut, quarry, and installation/processing. For k-means analysis, a cluster size of 8 was found to provide useful results. Unclassified cut features are spread throughout all eight clusters and dominate clusters 1 through 6 with compositions of 70% or higher, likely due to the overall high quantity of these features in the area. Installation/processing features are spread throughout six of the clusters, but quarries are present only in two. All k-means groups exhibit similar levels of dispersion except for cluster 1, which is significantly more dispersed (Figure 20c). Additionally, unconstrained clustering was used to create three groups, representing a dense quarrying area, a more dispersed area of unclassified cut features, and multiple areas of mixed unclassified cut and processing features. Though unclassified cut features in this study block are mostly evidence of

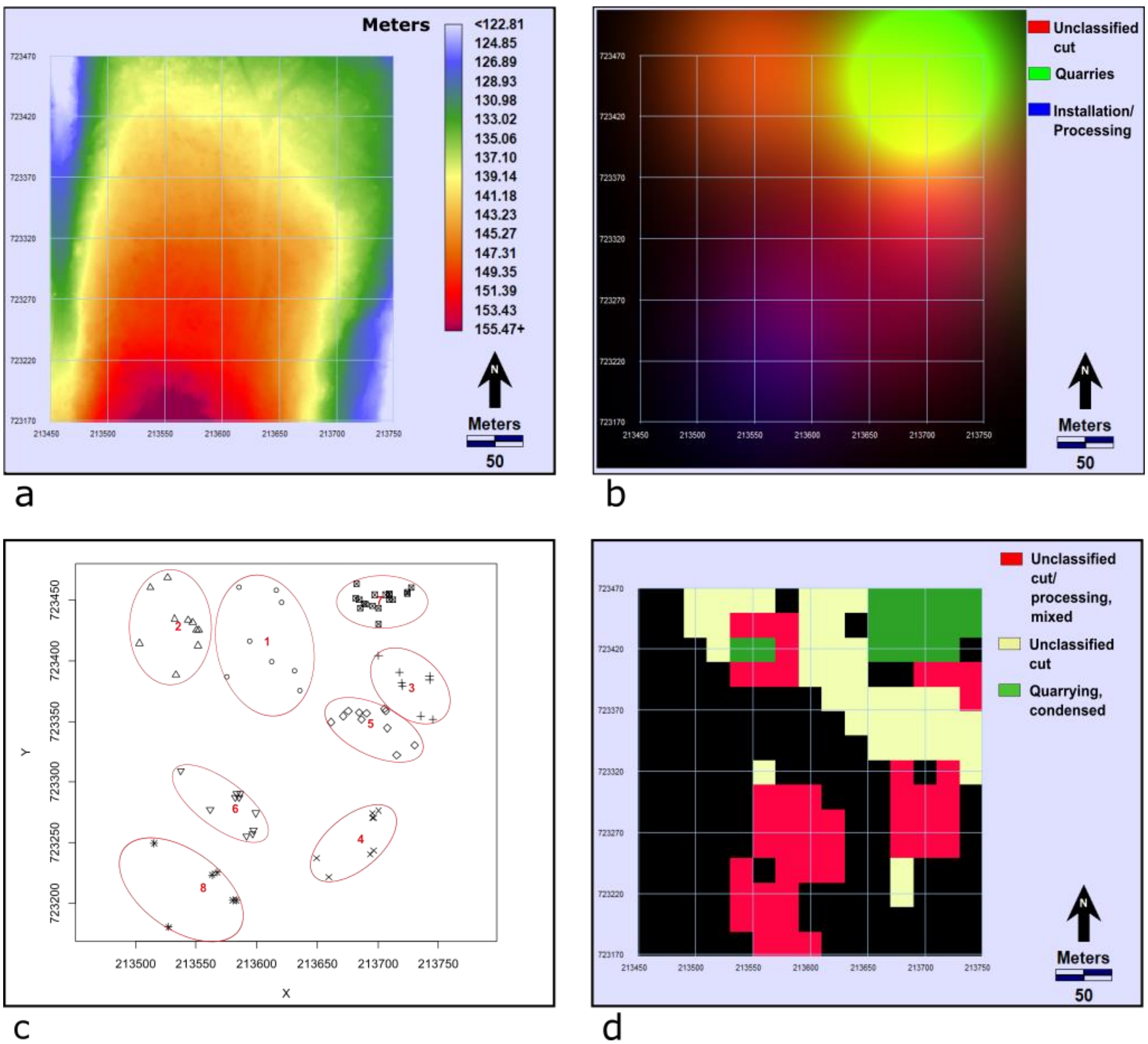


Figure 20. Area 3 analyses and images, with axes in ITM coordinates: a) DEM (in meters), b) color composite c) k-means clustering, d) unconstrained clustering.

processing, it is partially mixed with other feature types, and as such should be interpreted with caution.

Discussion

Despite some lack of clarity in feature purpose, Area 3 appears to be an area primarily devoted to labor and resource processing. Though very few structures are visible on the surface, it is reasonable to assume that some did exist in this landscape or nearby, as it would be impractical to quarry limestone blocks distant from their destination. The north-east cluster of features represents the most condensed evidence of quarrying, the central area contains mixed large-scale features cut into bedrock, and in the south-west region we begin to see more features clearly relating to resource processing, as well as occasional structure remains. This high occurrence of cut features suggests an area of intensified production, possibly related to olive oil growth and processing. Settlement patterns are increasingly dispersed in this region, with smaller groupings of spatially and compositionally related features. While the inhabitants of Area 3 may have practiced a more household-based settlement approach, the existence of production areas composed almost entirely of processing features suggests more formally-organized labor practices. Processing features are grouped into smaller units and in many cases mixed with some architectural remains, but many of these clusters contain large-scale evidence of processing, seemingly more than would be used by a single household. Processing installations, particularly oil presses, were often communal installations in ancient Palestine to serve multiple growers (Safrai 1994,124), but the particularly high frequency of specialized labor activity areas support the idea of a structured cultural group connected to a larger nearby population center, with organization beyond that of an internally communal group with surplus.

Area 4: Tel Bar/Tell el Aghbariyeh

This final case study covers a site known locally as Tel Bar (Tell el Aghbariyeh), located at the southern end of the study area (Figure 21). The terrain slopes sharply upward from all directions, with the summit of the tel measuring approximately 150 m across in the center of the 9 ha study block. The area contains 170 surface features, consisting of wall, unclassified, unclassified cut, structure/built, installation/processing, and burial features (Figure 22). These

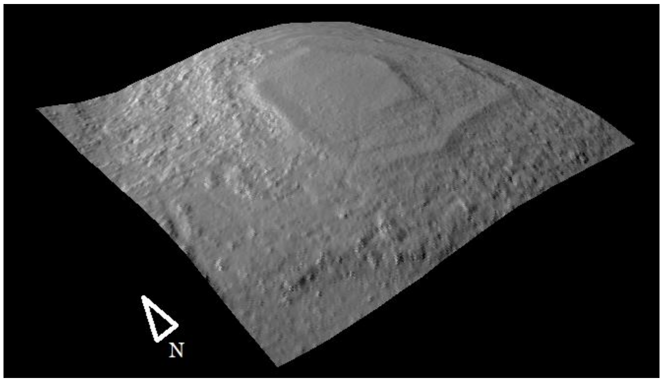


Figure 22. Area 4, measures 9 ha.

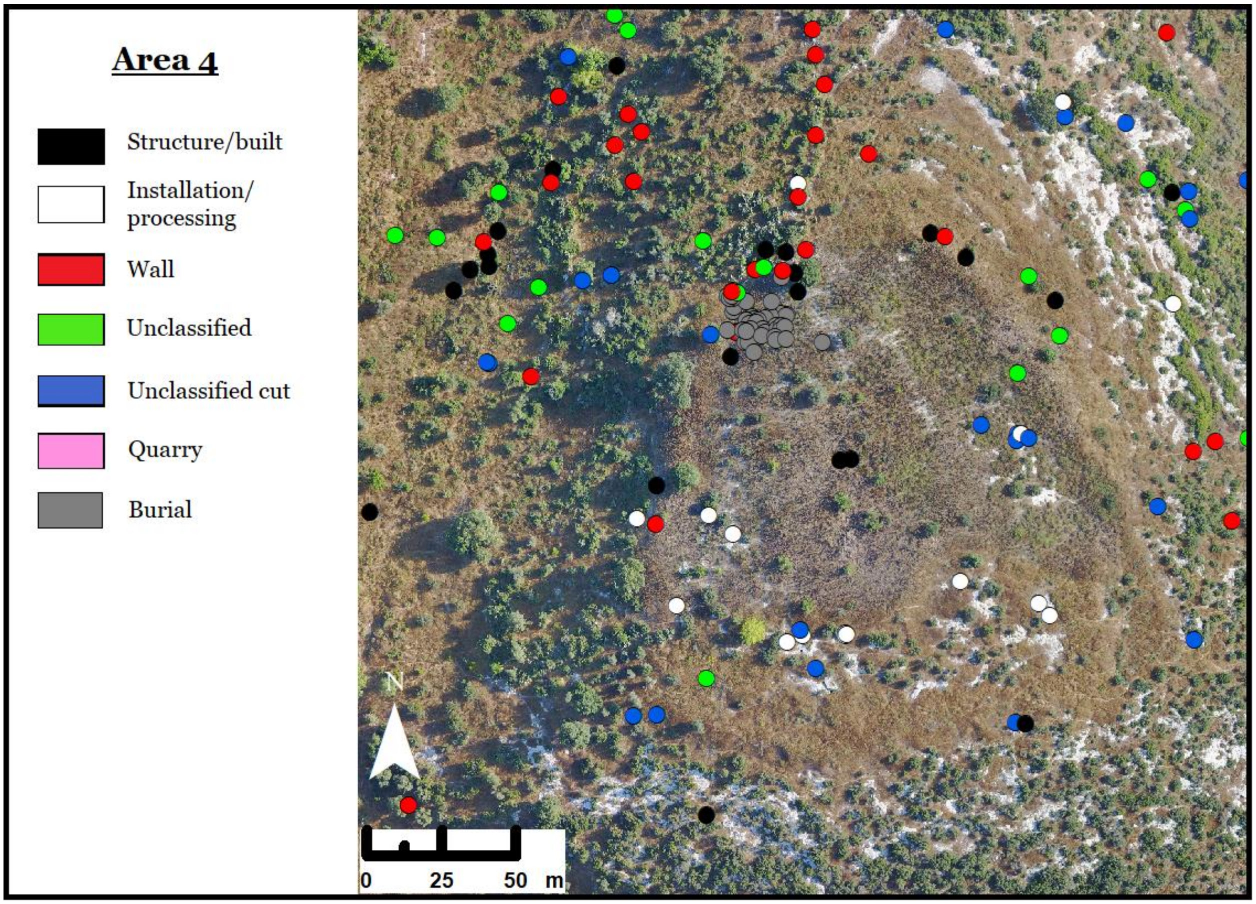


Figure 21. Area 4 overlaid with surface features. Orthophoto courtesy of Adam Prins and the JVRP.

burials are located in what is thought to be an Ottoman cemetery. Photographs suggest that most unclassified features here represent architectural debris, while unclassified cut features are primarily evidence of food processing with some tie points (cuts in bedrock used to tie down animals) and quarries mixed in. The landscape is densely covered in short trees, scrub, sabra cacti, weeds, and grass. Surface soils are mostly sand or sandy silt, medium grayish-brown, unplowed, dry, and soft, with 1-15% stone abundance of small stones (6-20 cm). A high density of ceramics was collected in this area.

Environmental Trends

In Area 4, Kolmogorov-Smirnov tests compared 163 feature sample points against 90,000 background data points in the study block. Results indicate significant trends in placement of features at higher elevation, north and west-facing aspect, and higher local dominance, and lower cost distance to runoff (Table 8). Some of these outcomes are counterintuitive to practical concerns, and suggest divergence in settlement decision-making compared to the three preceding case studies. Feature placement at higher elevations may

Table 8. Area 4 Kolmogorov-Smirnov p-values with results significant at the level of α ≤ 0.05 in red, and direction of this variation.

	All Features	***Direction (Features)***
Elevation	*<0.01*	*Higher*
Aspect E/W	*<0.05*	*West*
Aspect N/S	*<0.05*	*North*
Slope	*>0.2*	-
Terrain Variance	*<0.2*	-
Sky-View	*>0.2*	-
Local Dominance	*<0.01*	*Higher*
Runoff	*<0.1*	-
Cost Distance to Runoff	*<0.01*	*Lower*

reflect typical tel settlement patterns, but do not align with many of settlements in the study area. Preferences for north and west-facing aspects are more difficult to interpret. Those living in Area 4 could be seeking to gain evening sunlight, but these motivations are somewhat difficult to argue as they run counter to what is seen in previous case studies. It is more likely that practical, subsistence-based advantages were sacrificed in favor of cultural or ritual motivations, particularly considering the settlement here at high, prominent areas. As patterns of this sort may be expected for a cemetery, this brings up a new question: are non-burial features in the study block placed purely in relation to these burials, or are these tests primarily reflecting patterns in burial placement, as they comprise one-third of the sample features?

Kolmogorov-Smirnov two-sample tests, comparing environmental tendencies of burials versus non-burial features in the study block, suggest that non-burial features are placed at more east and south-facing aspect, lower elevation, higher slope, higher terrain variance, lower sky-view factor, lower local dominance, higher runoff, and lower cost distance to runoff. The inhabitants of this area were settling in locations with greater practical environmental benefits compared to the cemetery. To further investigate this, one-sample tests were completed

Table 9. Area 4 Kolmogorov-Smirnov p-values with results significant at the level of $\alpha \leq 0.05$ in red, and direction of this variation.

	Non-burial Features	***Direction (Features)***
Elevation	*<0.1*	*Lower Variance*
Aspect E/W	*>0.2*	-
Aspect N/S	*<0.01*	*North*
Slope	*>0.2*	-
Terrain Variance	*<0.2*	-
Sky-View	*>0.2*	-
Local Dominance	*>0.05*	*Lower Variance*
Runoff	*>0.2*	-
Cost Distance to Runoff	*<0.1*	-

for all features excluding burials (Table 9). These results suggest that non-burial features are preferentially located at north-facing aspect and at a narrower range of local dominance values. There is also a moderately significant trend for feature placement at a narrower range of moderate elevations. This does not clearly support ideas of preferential placement of non-burial archaeological features for this study block, an outcome somewhat unexpected for a tel site. While there are clear trends in placement of burials, the residents of this area do not appear to have chosen household locations to take advantage of the environment. If these settlements are contemporaneous to the Ottoman burials, they may have been purposefully placed in relation to the cemetery. Otherwise, settlement motivations are unclear.

Spatial Organization

Area 4 contains a diverse array of feature types, and presents an opportunity to examine relationships between habitation, processing, and ritual activity areas. For this reason, four feature categories were created for k-means and unconstrained clustering (Figure 23): structure/built/unclassified (architecture), installation/processing/unclassified cut (processing), wall, and burial. For the color composite image, in which only three categories can be used, burials were excluded. It should also be considered that this Ottoman cemetery may vary temporally from archaeological features in the immediate area, as burials often post date settlement history.

In k-means analysis, a cluster size of 9 was used to take advantage of the variation in settlement patterns within this study block (Figure 23c). All 9 clusters contain processing features, and architectural and wall features are both present in 8 clusters, while burials are only in 2 clusters. Cluster 1 is composed of 83% walls, cluster 2 is 88% burials, cluster 5 is 71%

processing features, and cluster 8 is 83% processing features. All other k-means classes are split somewhat more evenly between feature categories. Clusters 1, 9, 3, 8, 2, 4, 7, 6, and 5 exhibit increasing dispersion in this order, with clusters 6 and 5 showing noticeably higher levels of dispersion. Aside from the cemetery, the people living at Tel Bar appear to have had a much more individualized, household-based approach. There is no clear evidence of specialized activity areas, and resource processing was likely occurring on a household level. In

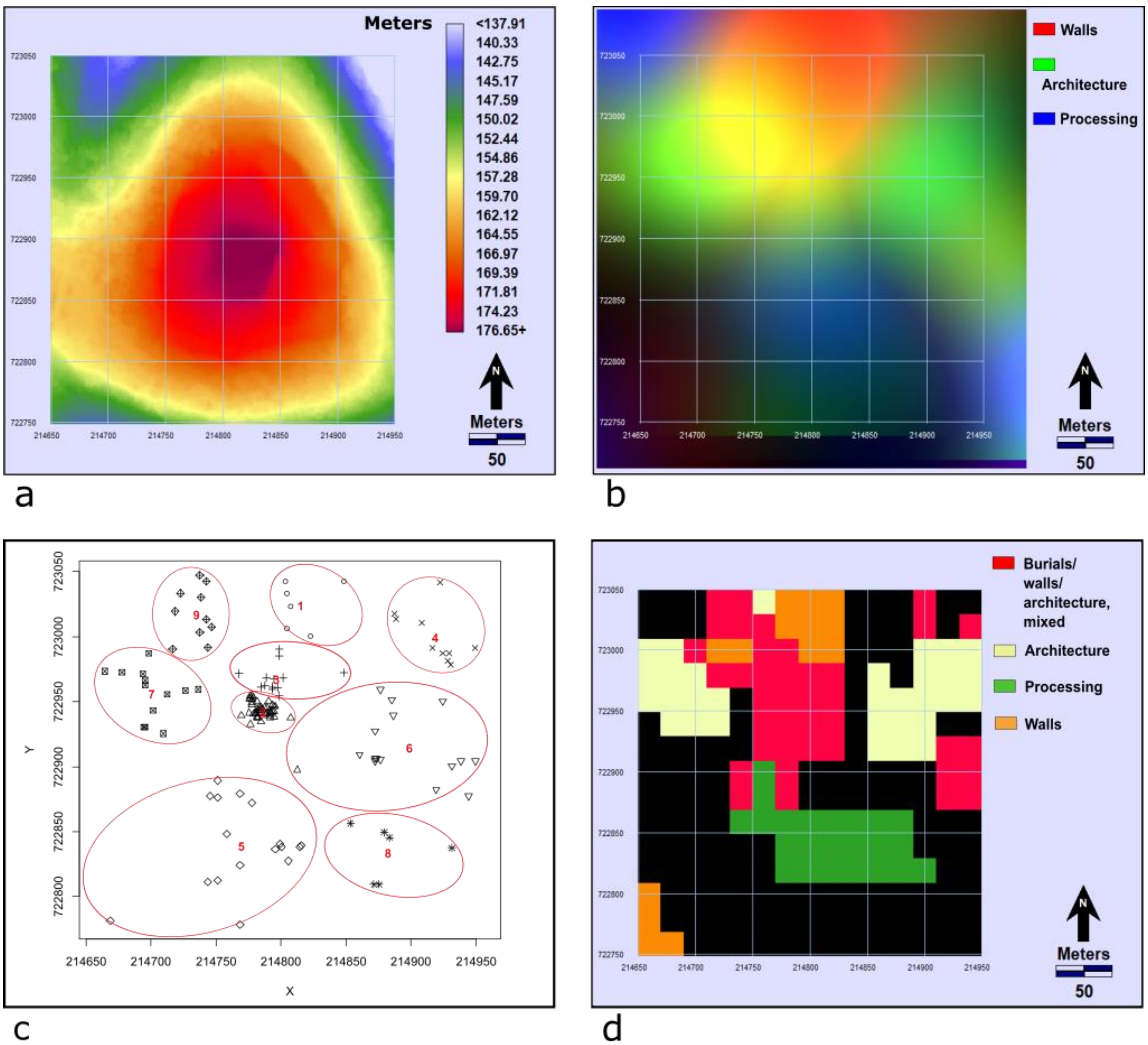


Figure 23. Area 4 analyses and images, with axes in ITM coordinates: a) DEM (in meters), b) color composite c) k-means clustering, d) unconstrained clustering.

unconstrained clustering, the red cluster represents a high density of burial features with some inclusion of walls and architecture, the white cluster is heavily architectural features, the green cluster is composed almost entirely of processing features, and the orange cluster represents high densities of walls (Figure 23d). While the southern area is mostly evidence of processing, these features are too dispersed to represent a specialized activity area. The northern area includes what appears to be smaller residential neighborhoods, possibly with some communal processing installations, but these spheres of interaction are particularly small with no evidence of formal organization.

Discussion

In the Near Eastern Bronze and Iron Ages, smaller tel sites are often interpreted as nucleated satellite settlements, related to larger nearby urban hubs (Wilkinson 2003). Based on surface assemblages, this does not appear to be the case at Tel Bar. While a large north-south wall on the northern slope of the tel may reflect some organized behavior, its directionality suggests that it was not related to agricultural activities. There are no clear processing centers, and non-burial surface features are relatively dispersed, with heavily mixed feature types. This evidence of noncommunal behavior is more pronounced than in any other case study, and may even suggest that we are beginning to see communities less connected to northern city centers. These patterns are evident in various parts of the southern region, with increasingly household-based organization.

Summary

If there is one clear inference to be made from these case studies, it is that the area surrounding Abu Shusha consisted of a diverse array of past lifeways and cultural behaviors. However, we are also beginning to see threads connecting these otherwise dissimilar communities. It is highly probable that Abu Shusha was a cultural and population hub, with concentrated residential neighborhoods evident in the archaeological record. Additionally, as there is no clear indication of resource processing or labor activities at the tel itself, this society would have been integrated to some degree with the surrounding hinterlands. Moving away from the tel, there appears to be an increasing amount of labor specialization. In the north, terracing as well as large processing centers suggest extensive agricultural activity. While past humans were likely living and working in this area, there is no evidence that the population here was large enough to require processing facilities on this scale. It is more probable that labor activities were administrated to some degree by the city-center of Abu Shusha, or at the very least a significant amount of trade occurred between the northern laborers and neighboring communities. To the south, we see an even greater increase in production activities, though the processed materials are less clear. Residential patterns are relatively individualized otherwise, but the size and extent of these processing facilities suggests export of goods, at least to Abu Shusha or neighboring areas, but perhaps even on a regional scale. In the furthest southern reaches of the study area, this pattern becomes less pronounced as organization becomes increasingly dispersed and household-based, perhaps as the influence of Abu Shusha lessens. We know that the Jezreel Valley was a large supplier of grain in ancient times (Safrai 1994:114), there is evidence of surface flax processing installations near Abu Shusha, and the environment is appropriate for olive cultivation. These materials may have been cultivated and processed at Abu Shusha, and perhaps also exported to nearby regions. While these interpretations are speculative, the inhabitants of this site may have practiced larger-scale productions of trade goods during some of the later Islamic periods. Abu Shusha is argued to have been a regional power in Bronze, Iron, and Roman periods, and the evidence here suggests that it may have also been the site of economically influential social groups in more recent eras.

CHAPTER IV: MAGNETIC SUSCEPTIBILITY

The final component of this project is an exploratory use of magnetic susceptibility (MS) geophysical measurements to supplement archaeological survey and spatial analyses. MS can be particularly effective for locating large anomalies, and can often detect diffuse feature boundaries (Dalan 2008:3). While the 10 cm depth penetration of the MS2D sensor is shallow for this terrain, the high concentrations of surface features suggest that midden and other anthropogenic remains may be detected at this depth, particularly with the activities of insects and rodents bringing deeper sediment upward. The effectiveness of this approach for identification of settlement soils is examined, as well as to what degree these results align with archaeological surface feature distribution. Emphasis is placed on correlating MS and feature data, with global and local Pearson's *r* methods used to integrate and compare these datasets.

Four MS grid blocks were surveyed within the study area, each located within a case study from Chapter III. Ideal grid block size was 100 x 100 m with 10 x 10 m data density, but these parameters varied for each grid block. Images were clipped to the edges of the data points, and MS values were expressed in volume susceptibility units (κ). While magnetic contrast within a grid block is of primary interest, comparison of absolute MS values between areas can also provide useful information (Figure 24).

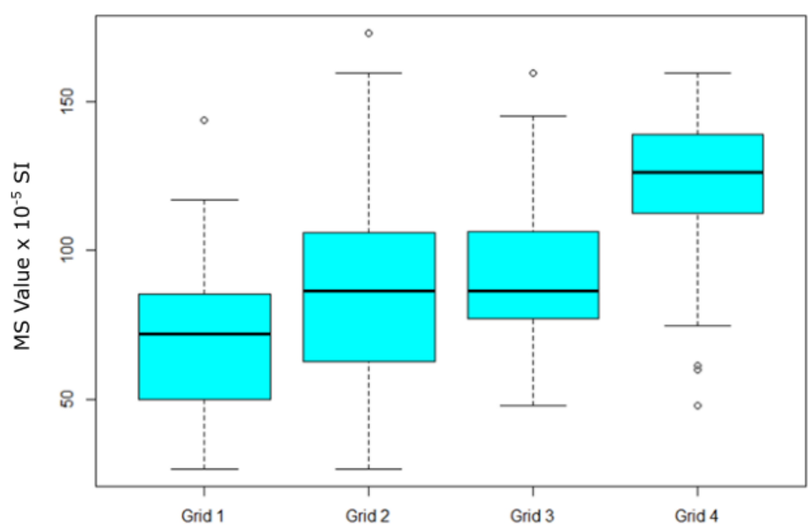


Figure 24. Range of MS values collected for each grid, measured in volume susceptibility units (y-axis).

Theory and Formation Processes

Magnetic Susceptibility (MS) is an underused geophysical technique in North American archaeology, but has begun to gain popularity in recent years. New developments allow the use of both field and laboratory soil magnetic techniques in concert, and down-hole susceptibility can produce three-dimensional results (Dalan 2006b). While intensive data collection is time consuming, MS can produce unique data regarding near surface archaeological features as well as both natural and cultural site formation processes. Various methods can tell us that a magnetic anomaly exists, but MS is rare in that it can investigate the nature and origin of these anomalies. This method may be used as a primary technique, or as a large-scale explorative approach for choosing smaller areas for deployment of other geophysical instruments.

Magnetic geophysical methods are ideally suited for the study of past humans. Natural and cultural behaviors alter sediments and materials, allowing modern surveyors to detect the resulting magnetic contrast. This magnetism can be partitioned into *remanent* and *induced*. *Remanent* magnetism is permanent, existing even after the process that caused it. When material is heated beyond the Curie point (approximately 600 degrees Celsius), magnetic domains previously pointed in random directions become aligned (Kvamme 2006:207). The *induced* component, on the other hand, exists only in the presence of a magnetizing field. Inclusions of parent materials in soil alter this value with iron oxides such as magnetite and maghaemite greatly increasing magnetism (Clark 1996:100). Passive techniques such as magnetometry record net magnetic values in the Earth's magnetic field, but the active MS method is unique in that it isolates the *induced* component, quantifying the ability of materials to be magnetized in the presence of an artificial field (Dalan 2008).

Evans and Heller (2003:9) define the ways in which MS induced magnetism values in sediments and materials can be measured. This is expressed either as volume susceptibility (κ) or mass normalized susceptibility (χ). If a material is placed in a uniform magnetic field (*H*) and gains a magnetization per unit volume of *M*, the volume susceptibility is defined as:

$$\kappa = M / H$$

As the ratio of acquired magnetization per unit volume to the induced magnetic field, κ is dimensionless in SI units (i.e. International System of Units). To obtain the mass normalized susceptibility, we divide the volume susceptibility by density (ρ):

$$\chi = \kappa / \rho$$

As κ is dimensionless, χ is measured in units of m3 / kg.

Magnetic contrast between cultural and natural soils forms the basis of MS studies, and certain cultural processes can be isolated that contribute to the formation of magnetic anomalies (Clark 1996; Evans and Heller 2003; Kvamme 2006; Tite 1972; Tite and Linington 1975):

1. *Firing events*: As mentioned previously, heating materials beyond the Curie point aligns the magnetic domains, greatly enhancing magnetic susceptibility. This is a spectrum rather than an absolute level, so materials heated at lower temperatures may still exhibit moderately increased magnetism. Humans create fires for warmth, cooking, and crafting, and accidental or destructive fires may occur. Repeated use will increase this magnetism, so a hearth will generally be more strongly magnetic than a transitory campfire.

2. *Topsoil processes*: Dispersal of fired materials in the topsoil, resulting from activities such as hearth cleanings, may produce magnetic enrichment. Additionally, organic matter can cause a subtler enhancement of topsoil due to a ‘fermentation effect’, in which the presence of magnetotactic bacteria causes a reduction of haematite to magnetite. This effect most commonly enables the detection of middens. As an extension of this process, accumulation or removal of topsoil may cause significantly altered magnetism.
3. *Stone and Iron*: Imported construction materials may result in increased magnetic contrast. Limestone quarried from another area and used to build a structure may cause magnetic contrast due to the stone’s naturally low susceptibility, while igneous materials usually exhibit high remanent magnetism. Additionally, iron artifacts often show up as strong magnetic anomalies in survey, which can be a mixed blessing as modern debris may also introduce noise into the data.

While these cultural activities can often be detected through survey, natural causes of magnetic variability must also be considered (Dalan 2006; Dalan and Banerjee 1998; Evans and Heller 2003; Kvamme 2006):

1. Variation in natural magnetic susceptibility exists between soil and material types. A high degree of contrast may be detected in a survey, yet this could be representative of natural changes in the environment.
2. Naturally occurring fires can result in magnetic enrichment of soils.
3. Various natural pedogenic processes may alter the susceptibility of soils. Weathering can greatly affect the magnetism of topsoil layers, as well as biogenic enhancement involving magnetotactic bacteria. Alluvium (deposits left by flowing water) often causes high MS,

as particles will align to magnetic north in water and remain so once the water source dries up. Additionally, overburden (varying depth of soil overlying archaeological features) is a common problem in susceptibility studies, as similar features with varying levels of topsoil above them will have differing magnetic signatures. Many of these natural processes are not fully understood, yet still must be considered during geophysical survey.

Global and Local Correlation

Pearson's *r* is a quantitative measure of linear correlation, and reflects the strength of a negative or positive relationship between two variables. This global statistic is used to spatially compare MS values against kernel density estimate (KDE) images, density maps computed based on surface feature distribution. Additionally, global correlations were processed comparing MS data in each grid block to three environmental variables: elevation, slope, and runoff. Each pixel in an image is considered a separate measurement, and the resulting Pearson's *r* value represents overall correlation between two images. For this study, a Pearson's *r* value of 1 will be considered a perfect positive correlation; 0.7 - 1 a strong correlation; 0.5 - 0.7 a moderate correlation; 0.3 - 0.5 a weak correlation; and 0 - 0.3 little to no correlation, with respective negative values indicating strength of negative relationships.

Though global correlation often provides useful results, when applied in a spatial context it may demonstrate weaker relationships than expected. This is a consequence of employing a statistic that produces generalized, average correlations with images containing hundreds to thousands of pixel values. Local statistics may provide improved results, looking at how correlation varies within smaller spatial neighborhoods. Specifically, Local Pearson's *r* is an innovative technique only recently applied to archaeological geophysics, and has been used to effectively demonstrate local areas of correlation between datasets exhibiting insignificant global correlation (Kvamme 2018). Correlation between images is calculated within a specified radius, with the resulting image containing a Pearson's *r* value in each pixel, representing the strength of correlation in this area between the two original datasets. For this study, radii of 10, 20, and 30 m were experimented with for each grid block, to capture multi-scalar variation. R statistical software was used for computations (The R Foundation 2016).

Grid Block 1

The first MS grid block is within the Area 1 case study. It contains 45 archaeological features, mostly architecture and walls, and is located on the southern slope of Tel Abu Shusha (Figure 24). Distance between data points was somewhat inconsistent due to obstructions of sabra cacti and bedrock, and ranged from 10 to 20 m. The grid block measures approximately 160 x 100 m with a total of 60 measurements taken, and MS values range from 34.7 x 10^{-5} to 136.5 x 10^{-5} SI with a mean of 69.9 x 10^{-5} SI. Visually, surface features do not appear to be located at areas of high MS; in fact, they seem to consistently correspond with low MS areas or the edges of magnetic anomalies (Figure 25a). Most of these features are architectural and constructed from limestone, so decreased overburden in these residential areas along with the naturally low MS of limestone may cause these patterns. A relatively high degree of erosion has also occurred on this slope, a natural movement of topsoil which may exacerbate this decrease in overburden.

While the occurrence of widespread, exposed bedrock may reduce MS at the location of individual features, correlations suggest that overall feature density increases and decreases

Figure 24. Grid 1: Red lines show grid borders; white marks indicate MS measurement locations. Orthophoto courtesy of Adam Prins and the JVRP.

in concert with MS values to some degree. Global correlation, with 13,791 pixels considered in each image, resulted in $r = 0.65$ for all features, $r = 0.6$ for built features, and $r = 0.62$ for walls, positive correlations that are unusually high in a spatial context. MS also exhibited moderate correlation with elevation, with $r = 0.4$, with no other environmental variables producing significant results. Generally, this supports arguments of densely populated residential neighborhoods within Area 1, not specialized for a certain activity type. Anthropogenic activity often produces highly magnetic soils, and when past humans in this area discarded organic materials, create fires, and dispersed fired materials, the soil would be magnetically enhanced. This social organization was likely relatively integrated and densely populated, with repeated activities affecting soil properties. Communal activity areas, firing events, and group disposal of

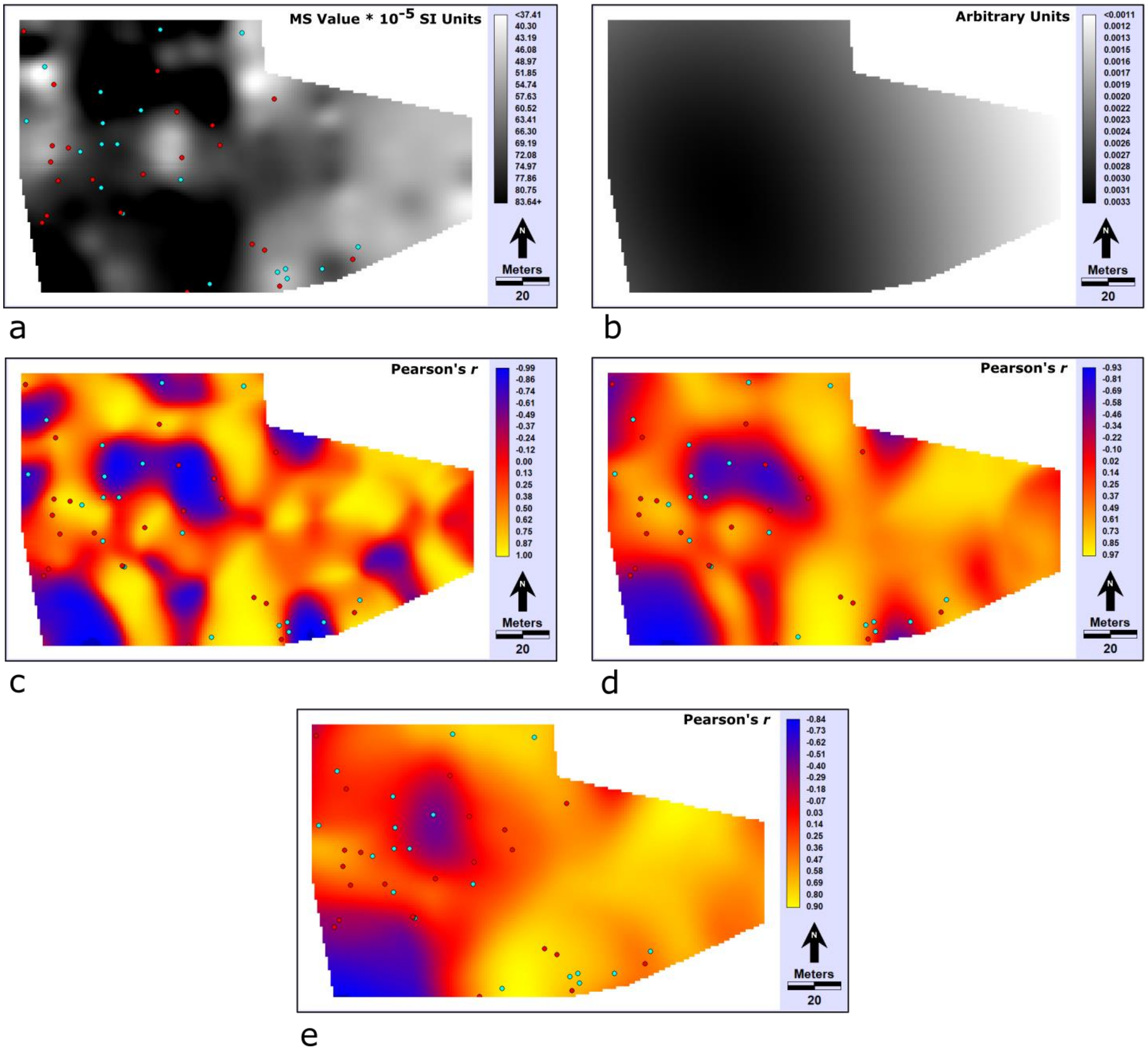


Figure 25. Grid 1 images overlaid with architectural (red) and wall (cyan) features: a) MS (in SI units), b) "all features" KDE image with a bandwidth of 50 (in arbitrary units), c) 10 m radius local correlation, d) 20 m radius, and e) 30 m radius (latter three in Pearson's Correlation Coefficient units).

waste would intensify these affects, causing some instances of increased soil MS despite areas of exposed bedrock.

Local correlation images with neighborhood radii of 10, 20, and 30 m display areas of both strongly positive and negative correlation (Figure 25b, 25c, 25d). Most surface features are located in areas of moderate to high correlation, with a small number located in areas of negative correlation or borders between the two extremes. This runs somewhat counter to what is seen visually in the area, as we would expect negative correlation at architectural features if MS decreased at these locations. Interestingly, the central area of strong negative correlation corresponds with the largest expanse of exposed bedrock visible in Figure 24, suggesting that the visual pattern of MS compared to feature location is misleading. Measurements at specific locations of shallow limestone bedrock may be creating low values, but more broadly the magnetism of settlement soils appears to be changing in concert with feature density. The densely populated inhabitants of this tel likely had organized systems of refuse disposal, and creation of large middens separated from limestone architecture would greatly increase MS, perhaps explaining the anomalies to the north and south. While it needs to be considered that natural formation processes could be causing patterns in this and subsequent examples, consistently high correlations are unlikely if no relation exists between MS and architectural feature density. Varying slope and the resulting erosion can also modify MS values, but in this case slope does not change alongside MS.

Grid Block 2

Located in the north-east corner of Area 2, Grid Block 2 contains 27 total features, primarily evidence of processing but with a small number of architectural features (Figure 26). The grid block is approximately 70 by 70 m in size, and includes 43 MS data points. The landscape slopes steeply towards the south-west, and distance between MS data points range from 7 to 15 m due to terrain and vegetation obstructions. MS values range from 34.5 x 10^{-5} to 169.1 x 10^{-5} SI with a mean of 91.1 x 10^{-5} SI. In this grid block, surface features appear to presses, and other processing features in the north-east (Figure 27a). This area contains heavily exposed limestone bedrock, and these patterns make a strong case for significant midden near

Figure 25. Grid 2: Red lines show grid borders; white marks indicate MS measurement locations. Orthophoto courtesy of Adam Prins and the JVRP.

correspond to areas of higher MS, particularly when considering clusters of vats, channels, this processing center. While areas of exposed limestone might be expected to exhibit low MS, the inverse effect seen here suggests that certain anthropogenic processes may be affecting soil magnetism near processing features, but not necessarily near other cut bedrock features. Similarly, slope is steeper in the area of this high MS anomaly, which would normally be expected to cause lowered MS values.

Global correlation, using 8,212 pixel values in each image, resulted in $r = 0.51$ for all features, $r = 0.69$ for processing features, and $r = 0.27$ for architecture. No correlations above $r = 0.11$ were reported for environmental variables. This positive correlation is particularly strong for processing features, and suggests that past intensified human activity may have altered soil magnetism within this area. This grid block includes a large processing center, and its location in the northern region of the study area suggests that it was related to agriculture or horticulture.

This was likely a location of large-scale specialized production, and these high correlations support the idea of food processing activities in this area. Workers who were processing food here might consistently dispose of large amounts of organic waste, and would likely do so in an organized manner. The resulting extensive middens could significantly impact the landscape and cause enhanced soil MS.

For local correlations, a KDE bandwidth of 22 was used, as this level of smoothing better represents local surface feature density in this area (Figure 26b, 26c, 26d). This grid block suggests a potential problem with local correlation when used to analyze larger-scale trends. Many of the strongest correlation values are seen in areas distant from any surface features, where MS and KDE values are both decreasing at similar rates. While this may provide some

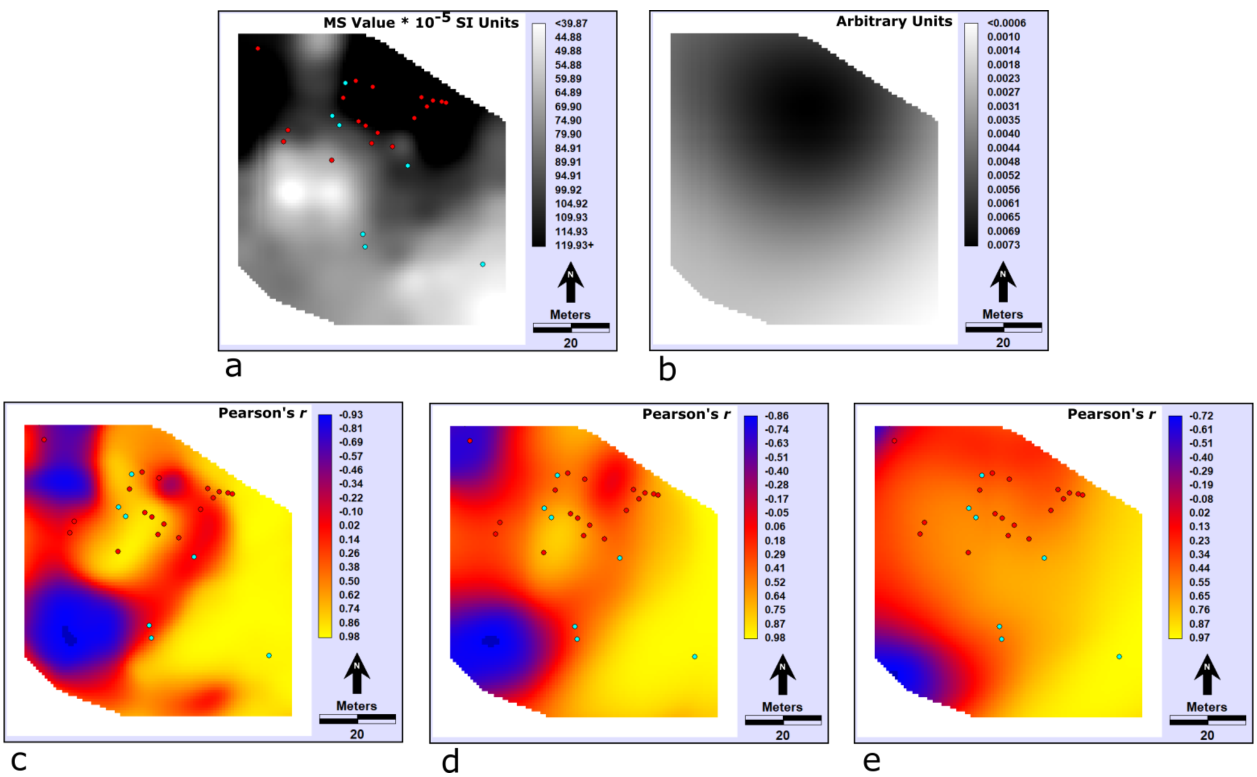


Figure 26. Grid 2 images overlaid with processing (red) and architectural (cyan) features: a) MS (in SI units), b) "all features" KDE image with a bandwidth of 50 (in arbitrary units), c) 10 m radius local correlation, d) 20 m radius, and e) 30 m radius (latter three in Pearson's Correlation Coefficient units).

insight, and supports the argument of absence of settlement soils in the area, it also causes difficulty for interpreting correlations in areas with smaller magnetic anomalies. Regardless, near the processing center in the north-east, there seems to be a pattern similar to that discussed by Kvamme (2018:4). Around the edges of the anomaly, local correlations are high as both MS and feature density increase, but at the peak there is an area of decreasing correlation where both values are consistently high. This effect becomes less pronounced as we increase the neighborhood radius, and suggests a condensed area of high correlation in this north-east corner, focused on the processing center. As the central areas of exposed bedrock exhibit low MS, it is apparent that an additional process is affecting soil magnetism. The north-western area of strong negative correlation aligns with particularly high MS values also, but in the absence of surface features. This location is a viable candidate for overflow refuse, as laborers would likely have been creating organic waste at the processing center, then dumping excess waste at a discrete nearby midden area.

Grid Block 3

Grid Block 3 contains 26 total surface features, mostly evidence of processing and quarrying, and is located in the north-east corner of Area 3 (Figure 28). This landscape slopes gently downward towards the north-east, and includes 70 MS data measurements, with data points at 9 to 13 m intervals. MS values range from 55.8 x 10^{-5} to 152.7 x 10^{-5} SI with a mean of 92.9 x 10^{-5} SI, a distribution similar to that of Grid Block 2. As this and the previous area are topographically dissimilar, yet possess similarly high overall MS values compared to Grid Block 1, it is possible that the increase of processing features could cause this pattern. However, the magnetic trends here are visually unclear, as archaeological features do not appear to

Figure 27. Grid 3: Red lines show grid borders; white marks indicate MS measurement locations. Orthophoto courtesy of Adam Prins and the JVRP.

consistently correspond to high or low MS, or to borders between the two (Figure 29a). It is possible that this lack of pattern may be due to a more mixed composition of quarrying and food processing features compared to grid block 2, as these activities may affect soil magnetism differently. Natural topographic variation between the two distant areas may also be a cause, but slope variation within Grid Block 1 does not appear to be affecting MS measurements.

Considering 8,200 total pixels in each image, global correlation computations resulted in $r = 0.17$ for all features, $r = -0.01$ for processing features, and $r = 0.07$ for quarries. When comparing MS values to elevation, a correlation of $r = -0.54$ was found, suggesting that to some degree, high MS values occur at lower elevations as well as the inverse. Other environmental variables did not significantly correlate with MS data. These results do not indicate a significant

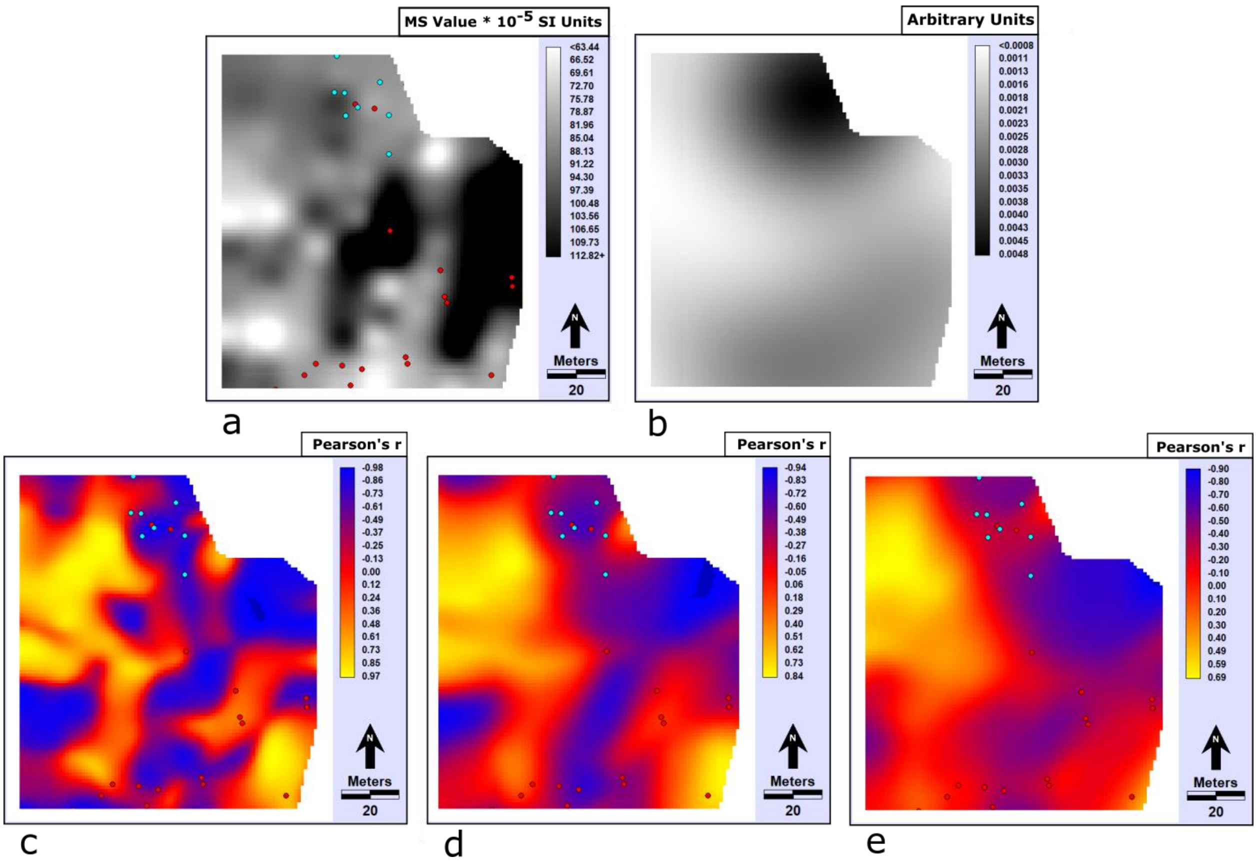


Figure 28. Grid 3 images overlaid with unclassified cut/processing (red) and quarry (cyan) features: a) MS (in SI units), b) "all features" KDE image with a bandwidth of 50 (in arbitrary units), c) 10 m radius local correlation, d) 20 m radius, and e) 30 m radius (latter three in Pearson's Correlation Coefficient units).

relationship between MS and feature density. This suggests that inhabitants of this area may have been part of a less integrated community, with mixed processing types rather than larger centers dedicated to specialized activities. As these features are more dispersed, it is likely that these groups had scattered, infrequent waste disposal practices that would impact the environment less.

With local correlation computations, a KDE bandwidth of 22 was used (Figure 29b, 29c, 29d). In these images, particularly with smaller neighborhood radii, the cluster of northern quarries seem to be located in an area of strong negative correlation. This supports the assertion of lower MS near non-processing cut bedrock features, as quarries are generally located at large expanses of exposed limestone, and it is unlikely that organic refuse would be disposed of here.

Those living in this region were cutting processing features into bedrock, areas which may have naturally lower MS, and labor activities occurring here were of insufficient intensity to counteract this pattern. Denser clusters of food processing features would likely have a greater effect on the environment, but the pattern evident in this grid block may be too dispersed to significantly affect larger-scale soil MS trends.

Grid 4

Located in the center of Area 4 and on the summit of Tel Bar, Grid Block 4 contains 42 total archaeological features, mostly burials. Based on local knowledge and visual examination, the north-western feature cluster appears to be an Ottoman-period cemetery. The topography is flat compared to previously studied areas, and includes 80 MS measurements, spaced at 8 to 10 m intervals (Figure 30). MS data values range from 52×10^{-5} to 158×10^{-5} SI, with a mean of 123×10^{-5} SI. This distribution is noticeably higher than in other grid blocks, perhaps due to the flatter terrain and resulting increased overburden. However, this explanation is not fully satisfactory, as the tel summit would likely exhibit a moderate degree of erosion as well, which may be accelerated due to goats and other browsing mammals altering vegetation cover. Patterns in the MS data are somewhat unclear, as there is a large western section of high MS soil that is adjacent to the cemetery (Figure 31a). While this could be caused by natural factors, it may also be evidence of a larger area of settlement soils, with archaeological features buried more deeply. Uncharacteristically, MS values noticeably decrease in the cemetery from multiple directions. While soil magnetism varies greatly on a site-by-site basis, this pattern runs contrary to the more common trend of raised MS over human burials, due to fermentation of organic materials (e.g. Evans and Heller 2003:235). However, many of the studies documenting this effect occurred in

Figure 29. Grid 4: Red lines show grid borders; white marks indicate MS measurement locations. Orthophoto courtesy of Adam Prins and the JVRP.

wetter regions, and this pattern of lower MS at burials could be due to the more arid Palestinian climate and resulting drier soils.

Global correlation, considering 10,099 pixels in each image, resulted in $r = 0.41$ for all features, which represents primarily burials. This is likely a result of decreasing MS and feature density to the east. Environmental analyses resulted in no significant correlations. Global correlations are somewhat misleading in this case, potentially due to all features in this grid block being clustered in one area. While these data increase and decrease in concert to some degree in various locations, this does not appear to be representative of past human activity.

Local correlation, using a KDE bandwidth of 50, is more useful here as an interpretive aid (Figure 31b, 31c, 31d). Condensed areas of negative correlation, centered on the

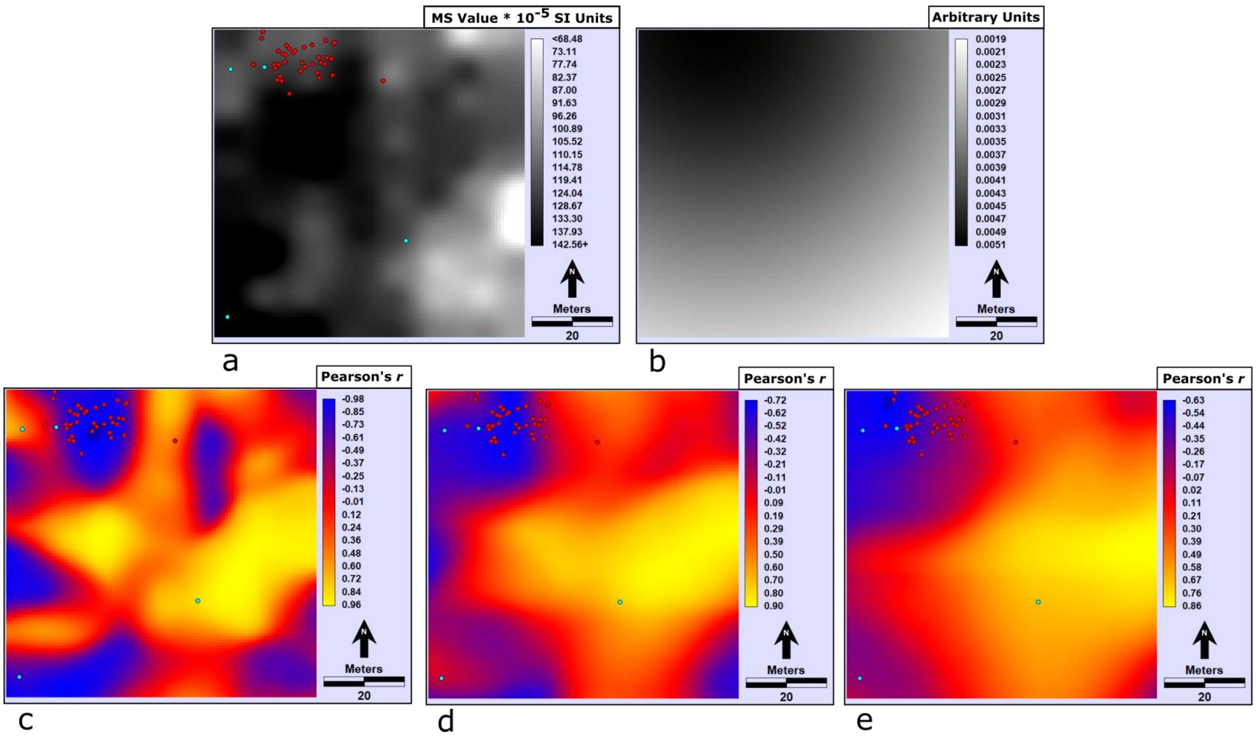


Figure 30. Grid 4 images overlaid with burial (red) and architectural (cyan) features: a) MS (in SI units), b) "all features" KDE image with a bandwidth of 50 (in arbitrary units), c) 10 m radius local correlation, d) 20 m radius, and e) 30 m radius (latter three in Pearson's Correlation Coefficient units).

cluster of burial features, are evident at all neighborhood radii. Particularly in the 10 m radius image (Figure 31b), the cemetery area is characterized by correlations of $r > 0.9$. While absolute MS values are not particularly low here compared to the overall image, there is a marked MS decrease in the immediate area as burial feature density increases. This supports the pattern seen visually, but the underlying process is unclear. Graves are constructed of cut bedrock, and buried stones, as well as limestone inclusions in the soil from deteriorating graves, may cause decreasing MS. Less topsoil from erosion as we move closer to the tel slopes in the north-west could also be a factor. Though a more unlikely cause, past inhabitants of this Tel may have kept the cemetery as a "cleaner" space. Particularly if higher MS south of this cluster represents a more deeply buried settlement, this Ottoman burial ground would be space with little human activity occurring. The community living at the tel would likely not dispose of organic refuse here, and firing events may not occur in the vicinity.

Limitations

The difficult terrain of the study area poses problems for many geophysical instruments, and is a primary reason why this low-density MS approach may be a more effective option. Steep slopes and dense vegetation make techniques such as magnetometry and ground-penetrating radar less ideal, though survey with these methods during winter months when vegetation is less dominant could be productive. Additionally, without further study of soil composition, it is unclear to what extent natural formation processes are affecting soil magnetism. Particularly on steeper slopes, increased weathering and erosion is likely, which may result in lowered MS. In terms of local correlation, this method's effectiveness when used on this larger scale is uncertain. While its application was clearly productive in some of the preceding examples, areas devoid of archaeological features provided consistently problematic results. Overly smoothed KDE images may have also contributed these problems, as there was difficultly creating lower bandwidth KDE results that accurately depicted feature density. Lastly, with the MS technique used in this research, a primary issue was depth of study. As the Bartington MS2D sensor is limited to the top 10 cm of sediment, measurements may be unusually affected by natural formation processes. For future geophysical survey, methods with deeper depth penetration (ideally a minimum of 40 to 50 cm) may provide improved results.

Summary

Past social groups were clearly active in these landscapes; the true question is how well human activity and organization can be interpreted through magnetic susceptibility methods. These communities consistently exploited their environment, particularly through quarrying of limestone and creation of installations cut into bedrock. The remnants of these activities are evident on the landscape, and appear to be significantly affecting soil magnetism in certain conditions. Areas of widespread exposed limestone bedrock consistently exhibit decreasing MS from the surrounding landscape. Burials display a similar trend of low MS, possibly due to limestone deterioration. The exception to this pattern is seen when these societies were organizing resource processing facilities, particularly when these activities were extensive, specialized for certain production types, and isolated from living spaces. Especially when considering food processing, these centers were likely creating organic refuse on a relatively large scale. These specialized activities tend to exhibit high MS despite exposed bedrock in the area. This suggests that while the presence of limestone affects soil magnetism, it is not necessarily a dominating factor. However, this conclusion is currently based on only a single case study, and requires more evidence to substantiate. Other soil formation processes may still produce higher MS values in these areas, including firing and fermentation of organic materials.

While large processing centers do exist in the southern region, there are consistent smaller areas of dispersed, household level organization. The inhabitants of these areas do not seem to have impacted the environment significantly enough to override the effects of limestone and other natural processes, due to dispersed activity and household patterns of production. Otherwise, magnetic patterns are relatively inconsistent, and do no enable easy interpretation. As this project represents initial research in the area of Abu Shusha, geophysical and survey data alike can only be treated as tentative evidence of human occupation. Ultimately, further study will be required to determine to what degree this MS data is capturing accurate evidence of past cultural activity.

CHAPTER V: DISCUSSION AND CONCLUSION

Archaeological research often focuses on the tel as a paramount unit of societal organization in the Near East, but this condition becomes less pronounced as we move forward in time from the Bronze Ages. Populations became increasingly dispersed throughout the Levant in the following millennia, and city-states were no longer sole dominating powers. This appears to be the case in the Abu Shusha study area, which at its broadest scale can be divided into three settlement areas: the central residential zone focused on the tel, the agricultural north, and the more diverse south. The inhabitants of the tel itself lived in densely packed residential neighborhoods on the southern slope, with living spaces distinctly separated from labor areas on the outskirts. It is possible that many of the people living here either held elite status or practiced specialized, administrative duties, and traded for necessary goods with neighboring societies. These residents chose an area that was relatively defensible and accommodated a medium to large population, but was also located near natural resources. There is a significant divide between habitation and production areas, with households located at areas with moderate elevations conducive to larger-scale settlement and defense, and production at higher, flatter areas near natural resources with high amounts of sunlight. Households may have been built at moderate rather than low elevation areas to avoid pooling of rainwater in living spaces, or to preserve the more fertile valley bottom soils for agriculture.

Those living in the northern region practiced intensified agriculture, and processing centers here were likely focusing on food and organic products. While there is evidence of large-scale, formalized organization in terms of production activities, households were dispersed. Laborers could have been living in these areas, but the scale of these agricultural practices suggests some level of collective behavior, and perhaps even external organization. In terms of terrain, production activity areas were located primarily to take advantage of natural resources and practical concerns. The final southern area is much more variable, exhibiting multiple settlement strategies, as households are noticeably dispersed and not organized into clear neighborhoods. Still, production activities occurred here on a larger scale than in any other region. Unlike the north, this does not seem to necessarily be focused on food, and may include a wider array of products. While this labor would have involved formal organization and oversight, it is likely that only the larger production centers were heavily administrated by external forces. With inconsistent settlement patterns and shifts between household and communal production approaches, there may have been a looser control system in the margins with increasing labor organization moving inward toward the most nucleated processing centers. Additionally, areas of ritualized behavior seem to have sometimes been distinct from residential neighborhoods, with communally organized construction of spaces such as burial grounds.

The archaeological features in this study likely date to primarily Fatimid- Ottoman (969-1918 C.E) periods. Despite varying political atmospheres and ruling strategies, there was relatively consistent conflict including raiding, revolt, and regional war during these times. Especially in the Fatimid period, there is record of a large proportion of land trade employing the coastal route of the Jezreel Valley (Edde 2010:172), and Tel Abu Shusha is placed at a bottleneck on this trade path. Additionally, there is a long history of widespread settlement in the hill country of Palestine, similar to the hinterlands of Abu Shusha, going back to the Canaanites. The existence of terrace walls in the study area is unsurprising, as terraced agriculture is essential to the rainfed agriculture of Palestinian highland landscape (Wilkinson 2003:135), but the size and scope of these constructions suggests internally organized labor at the very least. Medium to large-scale production is occurring as well at organized processing centers, with production and possible export of grains, flax, and olive oil at the very least. Overall, patterns seen at this site suggest compromise between defensive and subsistence-related motivations.

This research was limited in a number of ways, particularly due to the relatively sparse archaeological data, lack of chronology, and multiple-component nature of the site. Despite these shortcomings, the integration of historical, archaeological, environmental, and geospatial approaches made it possible to extract a great deal of useful information and draw some preliminary, generalized hypotheses regarding the area of Tel Abu Shusha:

1. In the Abu Shusha area, settlement decision-making of past humans varied based on activity type more than location. Residential areas were built with access to resources in mind and in expansive, low-relief areas to accommodate sizable populations. When these conditions were met, locations providing some defensive advantages were preferred. These defensive matters were not prioritized when choosing where to process goods. These groups often placed production centers in high, flat areas with sunlight, likely near raw materials. Valley bottoms were avoided for settlement, but terrace walls were likely placed in these areas for agricultural purposes.
2. There existed a great deal of variation in organization type and level of integration within the Abu Shusha area. Even in relatively recent Islamic periods, the tel appears to be the central administrative hub within the study area. Neighborhoods here were nucleated, heavily residential, and possibly specialized to non-labor tasks. While some of these residents did participate in production activities, this was relatively uncommon, with production installations rare and dispersed. While the agricultural activities of the northern region would be heavily organized, the lifeways of those living here were

particularly individualized and household-based, suggesting some external administration. Much of the southern region was similarly unintegrated, but production activities occurred here on an immense scale. This processing likely included multiple resources types, as opposed to the food focused activities of the north.

3. The highland landscape of Abu Shusha and surrounding hinterlands caused certain problems for magnetic susceptibility studies, but some trends were interpretable. It was evident that large expanses of exposed bedrock, including architectural, wall, quarry, and processing features, exhibited low susceptibility. However, certain larger-scale processing centers still displayed high susceptibility, possibly representing the specialized production of food and subsequent disposal of organic waste. Residential areas, though not displaying particularly high absolute susceptibility values due to limestone construction materials, still show strong correlation between architectural features and susceptibility. This may be a result of assorted anthropogenic behavior enhancing the soil in these areas, causing a more generalized magnetic trend.

This thesis has presented several GIS and spatial analytical procedures that aid in interpretation of both archaeological survey and magnetic susceptibility data. Kolmogorov-Smirnov nonparametric tests aided in locating distributional trends in placement of archaeological features on the landscape, Ripley's K analysis was used to examine multiscalar point patterning, pure locational (k-means) methods looked at clustering of features based on spatial location and density, and unconstrained clustering supplemented this with information on feature proportions. In addition to magnetic susceptibility surveys, local correlation methods were proven to be particularly effective at comparing and integrating data in a spatial context.

Despite severe limits to this research, it was shown that a great deal of insight on archaeological problems can be gained by taking an integrated approach to interpretation of the available datasets. These procedures demonstrated how a holistic view of past cultures is attainable when such methods are used to supplement other archaeological and textual sources of information. It is anticipated that future archaeological studies of Tel Abu Shusha and the Jezreel Valley will be enriched by the results and interpretations presented here.

BIBLIOGRAPHY

Avni, Gideon, Naomi Porat and Yoav Avni
2013 Byzantine-Early Islamic agricultural systems in the Negev Highlands: Stages of development as interpreted through OSL dating. *Journal of Field Archaeology* 38(4):332-346.

Barag, Dan
1988 Geva and Geva Parashim. In *Geva: Archaeological Discoveries at Tell Abu-Shusha, Mishmar Ha-'Emeq,* edited by Benjamin Mazar, pp. 4-12. Haqibbutz Hameuchad and The Israel Exploration Society, Jerusalem.

Bevan, Andrew, and James Conolly
2006 Multiscalar Approaches to Settlement Pattern Analysis. In *Confronting Scale in Archaeology: Issues of Theory and Practice*, edited by Gary Lock and Brian Molyneaux, pp. 217-34. Springer, New York.

Burks, Jarrod
2016 The Highland County Gist Settlement (33Hi417): Archaeological Investigations into the Results of Manumission at a Settlement of Freedmen in Southern Ohio. Manuscript on file, Ohio Valley Archaeology, Inc., Columbus, Ohio.

Clark, Anthony
1996 *Seeing Beneath the Soil: Prospecting Methods in Archaeology*. Routledge, New York.

Clark Labs
2017 TerrSet Geospatial Monitoring and Modeling Software, https://clarklabs.org/terrset, accessed March 15, 2018.

Conover, W. J.
1999 *Practical Nonparametric Statistics, Third Edition*. John Wiley & Sons, Inc., New York.

Cook, Robert A., and Jarrod Burks
2011 Determining Site Size and Structure: A Fort Ancient Example. *American Antiquity* 76(1): 145-162.

Dalan, Rinita A.
2006a Magnetic Susceptibility. In *Remote Sensing in Archaeology: An Explicitly North American Perspective*, edited by Jay K. Johnson, pp. 161-203. The University of Alabama Press, Tuscaloosa.
2006b A Geophysical Approach to Buried Site Detection using Down-hole Susceptibility and Soil Magnetic Techniques. *Archaeological Prospection* 13:182-206.
2008 A Review of the Role of Magnetic Susceptibility in Archaeogeophysical Studies in the USA: Recent Developments and Prospects. *Archaeological Prospection* 15:1-31.

Dixon, Philip M.
2002 Ripley's K Function. In *Encyclopedia of Environmetrics*, edited by Abdel El-Shaarawi and Walter Piegorsch, pp. 1796-1803. John Wiley & Sons, Ltd, Chichester.

Ebert, James I.
1992 *Distributional Archaeology*. University of New Mexico Press, Albuquerque.

Edde, Anne-Marie
2010 Bilad al-Sham, from the Fatimid Conquest to the Fall of the Ayyubids (359–658/970–1260). In *The New Cambridge History of Islam,* Vol. 2, Pt. 2, edited by Michael Cook, pp. 161-200. Cambridge University Press, Cambridge.

Environmental Systems Research Institute (ESRI)
2017 About ArcGIS, http://www.esri.com/arcgis/about-arcgis, accessed March 15, 2018.

Flavius, Josephus
2000 *Life of Josephus*. Translated by Steve Mason. Brill, Leiden.

Giveon, Raphael
1988 Geva in Egyptian Documents. In *Geva: Archaeological Discoveries at Tell Abu-Shusha, Mishmar Ha-'Emeq,* edited by Benjamin Mazar, pp. 1-3. Haqibbutz Hameuchad and The Israel Exploration Society, Jerusalem.

Homsher, Robert S., Matthew J. Adams, Adam B. Prins, Ryan Gardner-Cook, and Yotam Tepper
2017 New Directions with Digital Archaeology and Spatial Analysis in the Jezreel Valley. *Journal of Landscape Ecology* 10(3):154-164.

Keith, Kathryn
2003 The Spatial Patterns of Everyday Life in Old Babylonian Neighborhoods. In *The Social Construction of Ancient Cities,* edited by Monica Smith, pp. 56-80. Smithsonian Institution, Washington D.C.

Kintigh, Keith W.
1990 Intrasite Spatial Analysis: A Commentary of Major Methods. In *Mathematics and Information Science in Archaeology: A Flexible Framework,* edited by Albertus Voorrips, pp. 165-200. Holos, Bonn.

Kintigh, Keith W., and Albert J. Ammerman
1982 Heuristic Approaches to Spatial Analysis in Archaeology. In *American Antiquity* 47 (1): 31-63.

Kokalj, Žiga, Klemen Zakšek and Krištof Oštir
2011 Application of Sky-View Factor for the Visualization of Historic Landscape Features in Lidar-Derived Relief Models. *Antiquity* 85 (327): 263–273.

Kvamme, Kenneth L.
2006 Magnetometry: Nature's Gift to Archaeology. In *Remote Sensing in Archaeology: An Explicitly North American Perspective*, edited by Jay K. Johnson, pp. 205-233. The University of Alabama Press, Tuscaloosa.
2018 Geophysical Correlation: Global Versus Local Perspectives. *Archaeological Prospection:* 1-10.

Laland, Kevin N., and Michael J. O'Brien
2010 Niche Construction Theory and Archaeology. *Journal of Archaeological Method and Theory* 17(4):303-322.

Levanoni, Amalia
2010 The Mamluks in Egypt and Syria: the Turkish Mamluk sultanate (648–784/ 1250–1382) and the Circassian Mamluk sultanate (784–923/1382–1517). In *The New Cambridge History of Islam*, Vol. 2, Pt. 2, edited by Michael Cook, pp. 237-284. Cambridge University Press, Cambridge.

Lloyd, Stuart P.
1982 Least Squares Quantization in PCM. *IEEE Transactions on Information Theory* 28(2):129-137.

Masters, Bruce
2010 Egypt and Syria under the Ottomans. In *The New Cambridge History of Islam,* Vol. 2, Pt. 3, edited by Michael Cook, pp. 411-435. Cambridge University Press, Cambridge.

Mazar, Benjamin (editor)
1988 *Geva: Archaeological Discoveries at Tell Abu-Shusha, Mishmar Ha-'Emeq.* Haqibbutz Hameuchad and The Israel Exploration Society, Jerusalem.

Naroll, Raoul
1965 Galton's Problem: The Logic of Cross-Cultural Analysis. *Social Research* 32(4):428-451.

Orni, Efraim, and Elisha Efrat
1964 *Geography of Israel*. Jerusalem: Israel Program for Scientific Translations.

Ripley, Brian D.
1976 The Second-Order Analysis of Stationary Point Processes. *Journal of Applied Probability.* 13(2): 255-266.
1981 *Spatial Statistics*. John Wiley & Sons, Inc., New Jersey.

Robertson, Ian G.
2001 Mapping the Social Landscape of an Early Urban Center: Socio-Spatial Variation in Teotihuacan. PhD Dissertation, Department of Anthropology, Arizona State University, Phoenix.

Safra, Ze'ev
1994 *The Economy of Roman Palestine*. Routledge, London.

Schmidt, Armin
2007 Archeology, Magnetic Methods. In *Encyclopedia of Geomagnetism and Paleomagnetism*, edited by David Gubbins and Emilio Herrero-Bervera, pp. 23-31. Springer, New York.

Siegelmann, Asriel
1989 Two Lead Weights from Tẹ̄l Šōš (Tell Abū Šūše). *Zeitschrift des Deutschen Palästina-Vereins (1953-)* 105:123-24.

Smith, Michael E.
2010 The Archaeological Study of Neighborhoods and Districts in Ancient Cities. *Journal of Anthropological Archaeology* 29:137-154.

Stone, Elizabeth C.
1987 *Nippur Neighborhoods.* The University of Chicago, Chicago.

The R Foundation
2016 The R Project for Statistical Computing, https://www.r-project.org, accessed March 15, 2018.

Thompson, Victor D.
2014 What I Believe: Reflections on Historical and Political Ecology as Research Frameworks in Southeastern Archaeology. *Southeastern Archaeology* 33(2):246-254.

Tite, M.S.
1972 The Influence of Geology on the Magnetic Susceptibility of Soils on Archaeological Site. *Archaeometry* 14: 229-236.

Tite, M.S. and R.E. Linington
1975 Effect of Climate on the Magnetic Susceptibility of Soils. *Nature* 256: 565-566.

Whallon, R.
1984 Unconstrained Clustering for the Analysis of Spatial Distributions in Archaeology. In *Intrasite Spatial Analysis in Archaeology*, edited by H.J. Hietala, pp. 242-277. Cambridge University Press, Cambridge.

Wilkinson T. J.
2003 *Archaeological Landscapes of the Near East.* The University of Arizona Press, Tucson.

Zakšek, Klemen, Krištof Oštir and Žiga Kokalj
2011 Sky-View Factor as a Relief Visualization Technique. *Remote Sensing* 3: 398–415.

APPENDIX: SPATIAL ANALYTICS AND STATISTICS

Clark Labs' Terrset: Unconstrained Clustering

1. Create separate vector files for each category analyzed (here "built," "installation," and "wall"). Higher quantities of categories can be used if desired.
2. Run INITIAL to create raster files for each of the three categories. In "output reference information," choose x and y coordinates that include all data sets, "plane" reference system, and number of columns and rows that results in desired cell resolution (here 40 x 40 m). Run RASTERVECTOR with each vector file and corresponding raster files previously created, choosing "vector to raster," "point to raster," and "change cells to record the frequency of points."
3. Use IMAGE CALCULATOR to add the three resulting raster images, creating a total count layer. (Here: *TOTAL = [BUILT_COUNT] + [INSTALLATION_COUNT] + [WALL_COUNT]*).
4. Use IMAGE CALCULATOR to create a mask to restrict analyses to only areas containing features (*MASK = [TOTAL] > 0)*. This 0 value can be increased to eliminate cells with low feature counts.
5. Use IMAGE CALCULATOR to create a proportions layer for each category (for BUILT_COUNT the expression will be: BUILT_PROP = [BUILT_COUNT] / [TOTAL] * [MASK]). If desired, a mean filter can be applied to these resulting proportions layers in FILTER, to further eliminate bias caused by low feature counts.
6. Run CLUSTER, inputting layers BUILT_PROP, INSTALLATION_PROP, and WALL_PROP. Use MASK, set maximum number of clusters to "3" (or other desired number), and leave all other parameters as the defaults.

R Code: Kolmogorov-Smirnov Tests

One and Two-Sample Tests

Single-column lists of raster cell values should be extracted from GIS, then placed in text or raster files. Two files should be imported: 1) the background population area (here “pop.rst”), and 2) the sample being compared (here “samp.rst”). For two-sample tests, a second sample should be imported instead of a background population.

pop = read.table(“pop.rst”)

samp = read.table(“samp.rst”)

RUN KOLMOGOROV-SMIRNOV TEST

ks.test(samp,pop,alternative=“two.sided”)

PARAMETERS: SAMPLE 1 (samp); BACKGROUND POPULATION (pop; FOR TWO-SAMPLE TESTS, A SECOND SAMPLE CAN BE USED INSTEAD); alternative INDICATES THE ALTERNATIVE HYPOTHESIS.

FOR ONE-SAMPLE TESTS, THE P-VALUE IS INFLATED; INSTEAD, THE TEST STATISTIC (D) SHOULD BE COMPARED TO A ONE-SAMPLE KOLMOGOROV-SMIRNOV QUANTILE TABLE (e.g. Conover 1999).

FOR TWO-SAMPLE TESTS, THE P-VALUE GIVEN BY ks.test IS ACCURATE.

Kolmogorov-Smirnov Cumulative Distribution Function Plot

Data sets are imported using the same procedure as the previous Kolmogorov-Smirnov tests. The following procedure can be used for both one and two-sample tests.

PLOT BACKGROUND POPULATION IN BLACK, WITH VERTICAL LINES AT STEPS.

plot(ecdf(pop),col=‘black’,verticals=T)

ADD SAMPLE TO THE EXISTING PLOT IN RED, WITH VERTICAL LINES AT STEPS.

plot(ecdf(samp),col=‘red’,verticals=T,add=T)

R Code: Local Correlation (code adapted from Kvamme 2018)

Raster data sets (here “ms” and “kde”), are imported as vector variables in this order (column or row major) with length rows x columns. These datasets are then combined into one dataframe (here “*grid*”).

grid = data.frame(ms,kde)

The *x* and *y* spatial coordinates of each raster pixel are imported in the same order as the previous data sets, creating a data frame with two columns (*x* and *y*) and of the same length as *grid* (here named “*coord*”).

LOAD “sp” AND “GWmodel” PACKAGES

library("sp", lib.loc="~/R/win-library/3.3")

```
library("GWmodel", lib.loc="~/R/win-library/3.3")
# CREATE A SPATIAL DATAFRAME AS DEFINED IN PACKAGE “sp.”
grid.spdf = SpatialPointsDataFrame(coord,grid)
# grid.spdf COMBINES COORDINATES AND MEASUREMENTS: ms AND kde HELD
# WITHIN.
localstats = gwss(grid.spdf,vars=c(‘ms’,‘kde’),kernel=‘boxcar’,bw=10)
# gwss IS A “GEOGRAPHICALLY WEIGHTED SUMMARY STATISTICS MODULE” IN
# GWmodel.
# PARAMETERS: SPATIAL DATA FRAME (grid.spdf); vars (ms & kde; TWO OR MORE
# MAY BE LISTED); kernel (HERE boxcar OPTION IS USED WHERE CASE WEIGHT = 1
# IF DISTANCE < bw, 0 OTHERWISE); bw IS DISTANCE WITHIN WHICH OTHER
# MEASUREMENTS ARE CONSIDERED FOR COMPUTATION OF LOCAL STATISTICS.
cor.ms.kde = localstats$SDF@data[,‘Corr_ms.kde’]
# cor.ms.kde EXTRACTS LOCAL CORRELATION DATA TO A VECTOR VARIABLE.
write.table(cor.ms.kde,‘corMSKDE.dat’,row.names=F,col.names=F)
# PREVIOUS STATEMENT EXPORTS DATA AS AN ASCII FILE IN A SINGLE COLUMN
# OF LENGTH ROWS X COLUMNS FOR IMPORT TO GIS.
```

R Code: Pure Locational Clustering (code adapted from Kvamme 2012,2016)

SSE Plot

Each data set should be exported and combined into a single space delimited text file with a header line, here "abushusha.txt." This file should have "x," "y," "z" columns, where x and y contain coordinates and z contains category codes.

```
# READ "abushusha.txt" TO TABLE "dataset"; STORE SAMPLE SIZE IN VARIABLE "n";
# STORE SPATIAL COORDINATES IN VARIABLE "coord."
dataset = read.table(abushusha.txt,skip=1)
n = length(dataset[,1])
coord = cbind(dataset[,1],dataset[,2])
# SET MAXIMUM NUMBER OF CLUSTERS IN SSE PLOT.
maxclust = 16
ss = dim(maxclust)
clusters = 1:iclus
# COMPUTE K-MEAN FOR EACH CLUSTER SIZE FROM 1 TO 16.
set.seed(98765)
for (i in 2:iclus) {
        km=kmeans(coord,centers=i,iter.max=50,nstart=5)
        ss[i] = km$tot.withinss
}
ss[1] = km$totss
```

logss = log10(ss)

CREATE SSE PLOT

plot(clusters,ss,xlab='CLUSTERS',ylab='SSE',type='l',log='y',xaxp=c(1,iclus,iclus-1))

INFLECTION POINTS (UPWARD BENDS) IN SSE PLOT REPRESENT CHANGES IN

CLUSTERING, POTENTIALLY SIGNIFICANT CLUSTER NUMBERS TO INVESTIGATE

IN FURTHER ANALYSES.

Plotting Clusters and Cluster Statistics

dataset = read.table(abushusha.txt,skip=1)

n = length(dataset[,1])

coord = cbind(dataset[,1],dataset[,2])

symb = c('1','2','3','4','5','6','7','8','9','0','A','B')

CLUSTER = INPUT DESIRED NUMBER OF CLUSTERS.

cluster = 3

iclus = as.integer(cluster)

if (iclus < 2) {iclus=2}

if (iclus > 16) {iclus=16}

K-MEANS ANALYSIS.

set.seed(98765)

km = kmeans(coord,centers=iclus)

CLUSTER STATISTICS REPORT.

cat('CLUSTER STATISTICS :',iclus,'-cluster solution','\n')

```
cat('Total SS: ',km$totss,'\n')
cat('Total within-group SS: ',km$tot.withinss,'\n')
cat('\n')
for (i in 1:iclus) {
  cat('Cluster ',i,':','\n')
  cat('-Mean coordinates: ',km$centers[i,],'\n')
  cat('-Cluster size: ',km$size[i],' data points','\n')
  cat('-Relative dispersion (Within SS): ',km$withinss[i],'\n')
  cat('\n')
}
# TRUE CLASS BY K-MEANS CLASS TABULATED RESULTS.
tab=table(dat[,3],km$cluster)
# CHANGE ROW NAMES FOR NUMBER AND NAMES OF TRUE CLASSES.
rownames(tab)=c('Built','Installation','Wall')
cat('FREQUENCIES BY K-MEANS CLASS:','\n')
print.table(cbind(tab,margin.table(tab,1)))
cat('\n')
cat('PERCENTAGES, K-MEANS CLASS COMPOSITIONS:','\n')
print.table(round(100.0*prop.table(tab,2),1))
barplot(tab,xlab='K-means Class',ylab='Frequency',main='Composition of Each K-Means
Class',sub='True classes 1-5: dark-to-light')
# PLOT EACH CLUSTER AS UNIQUE SYMBOL.
plot(coord,pch=km$cluster,xlab='X',ylab='Y',asp=1)
```

ADD SPATIAL CLUSTER MEANS IN RED.

points(km$centers,col='red',pch=symb,font=2)

ADD 1 METER GRID**.**

abline(h=seq(3,12),v=seq(4,15))

R Code: Ripley's K

Spatial coordinates of point data should be exported to a text file (here "Features.txt") with two columns for "x" and "y" coordinates, then read into R software (here "feat").

feat = read.csv("Features.txt")

LOAD "maptools" AND "spatstat" PACKAGES.

library("maptools", lib.loc="~/R/win-library/3.3")

library("spatstat", lib.loc="~/R/win-library/3.3")

CONVERT TO A POINT PATTERN DATASET ("ppp") FOR USE IN spatstat PACKAGE.

featppp=as.ppp(feat,c(212290,215380,722660,725800))

PARAMETERS: DATASET TO BE CONVERTED (feat); SPATIAL RANGE (c(minimum x,

maximum x, minimum y, maximum y)).

lfunc = Lest(featppp, correction='border')

PROCESSES RIPLEY'S K FUNCTION. A L-FUNCTION TRANSFORMATION IS USED TO EASE INTERPRETATION HERE, FOR K-FUNCTION THE "Kest" COMMAND SHOULD INSTEAD BE USED.

PARAMETERS: POINT PATTERN DATASET (featppp); correction DEFINES THE TYPE OF EDGE CORRECTION TO BE APPLIED.

lfunc.env = envelope(featppp,Lest,correction='border')

plot(lfunc.env)

PREVIOUS STATEMENTS PROCESS/PLOT L-FUNCTION AND ENVELOPE ANALYSIS.

GRAY ENVELOPE INDICATES 99% CONFIDENCE INTERVAL.