Using floristic characteristics of contemporary vegetation for identifying archaeological sites: Tel ‘Eton archaeological site as a test case

Yair Sapir\textsuperscript{a}, Yuval Sapir\textsuperscript{b} and Avraham Faust\textsuperscript{a}

\textsuperscript{a}The Institute of Archaeology, The Martin (Szusz) Department of Land of Israel Studies and Archaeology, Bar Ilan University, Ramat-Gan, 5290002 Israel; \textsuperscript{b}The Botanical Garden, School of Plant Sciences and Food Security, Tel Aviv University, Tel Aviv, 69978 Israel

\textbf{ABSTRACT}

Over the last century, crosstalk between archaeologists and botanists had focused on the identification of plants remnants, such as charcoal or seeds found in archaeological inventory. Here we demonstrate how botany can play a fundamental role in identifying ancient landscape by using current vegetation. Identifying the loci of ancient human activity is the initial step of any archaeological study, enabling analyses such as settlement patterns, economic structures and land use, as well as devising excavations strategy. While mounds (tells) are standing out of their surroundings and are easily detected, other sites are hidden underground, and require various methods for detection. The cost and intensity of these methods vary, but most are time-consuming, require a team of specialists, and show somewhat limited success, leading archaeologists to seek new methods of site detection. Here, we describe a study of vegetational parameters at Tel ‘Eton (Israel), located in a semi-arid climatic region, where vegetation is mostly herbaceous, mainly comprised of annual plants. We compared above ground biomass, species richness and species composition among four plots in Tel ‘Eton and its surrounding. Two plots were located where ancient settlement found in a previous study, one on top of the mound and one below, where a “lower city” was previously identified. The other two plots were located in similar topographies, namely one on a hill and the other below, but in never-settled areas. While above ground biomass was similar between settled and not-settled plots, species richness was significantly higher in settled plots (40 and 32 species in settled plots, versus 28 and 9 species in non-settled) and species composition was significantly different between them. Our results demonstrate that loci of buried remains of human activity significantly differ from non-settled remains. We propose that floristic sampling of ground-level vegetation may allow archaeologists to identify buried sites, and hence increase the validity of various types of archaeological analyses, such as creating maps of settlements, which rely on the identification of sites without excavating them.

\textbf{ARTICLE HISTORY}

Received 8 March 2018
Accepted 31 August 2018

\textbf{KEYWORDS}

Archaeological survey; herbaceous plants; semi-arid climate; species diversity; species richness

\section*{Introduction}

Over the last century, crosstalk between archaeologists and botanists had focused on the identification of plants remnants, such as charcoal or seeds found in archaeological inventory. While growing number of studies deal with charred seeds and charcoals (Théry-Parisot et al. 2010; Weiss and Kislev 2007) and microscopic finds such as phytoliths and pollen (Cabanes et al. 2012; Langgut et al. 2013; Langgut et al. 2015), rarely do scholars try to deal with botanic patterns in wider extent (Danin 1988). Here we demonstrate how botany can play a fundamental role in identifying ancient landscape by using current vegetation.

Identifying loci of ancient human activity is typically the first step of most archaeological studies, enabling scholars to reconstruct ancient settlement patterns and past land use. While some sites, especially mounds (tells), are well known from the beginning of modern research and literally stick-out from their surroundings, others lie below the ground, and various detection methods were employed to identify them. Pedestrian survey is a simple and common method for aboveground non-destructive exploration of archaeological remains. While such surveys do identify many sites on the basis of sherds concentration or other visible remains on the surface, they have many limitations and often fail to identify other sites,
especially sites of non-intensive human activity (e.g. Faust and Safrai 2005, 2015; Sapir and Faust 2016, and references therein). In order to avoid this shortcoming, alternative methods were designed, such as shovel testing, which is practically a large number of tiny, yet time-consuming, excavations (Krackert et al. 1983; Shott 1985; Faust and Katz 2012; Leibner 2014). Geo-archaeological studies, using methods such as soil analyses (e.g. Sedov et al. 2017; Smejda et al. 2017; Paz et al. 2017; Itkin et al. 2018) or archaeobotanical studies (e.g. Orendi et al. 2017) are promising. Yet, despite the growing amount of such studies, they require a great deal of laboratory and field work and sometimes special and expensive equipment. Another approach is the use of advanced remote sensing methods such as geophysical survey or satellite imaging (Kvamme 2003; Parcak 2009). These methods, however, require special equipment and are not fully conclusive. Moreover, remote sensing is prone to failure, as identification of small sites in heterogeneous environments is challenging (e.g. Campana and Francovich 2005; Pincus Ben-Avraham 2011). Although modern remote-sensing techniques had advanced rapidly in the last decade, there is still lack of studies connecting vegetation patterns and archaeology. Taken together, despite major advances made over the last decades, archaeologists are in a constant search of new methods for identifying sites of human habitation as well as other loci of human activity.

Plants can serve as indicators of buried features or anthropogenic soils through their visible characteristics, which can be detected by remote systems. In most cases, vegetation studies by remote sensing are spatially large-scale and require good preliminary knowledge of the vegetation characteristics. They also require long and tedious fine-tuning of the method in order to understand the patterns and their discrepancies (Galiatsatos 2004; Parcak 2009; Menze and Ur 2012; Campana 2016; Kirk, Thompson and Lip-pitt 2016). Some studies in Europe and North America examined the relations between current vegetation cover and the past land use (Brook and Johannes 1990; Dupouey et al. 2002; Dambrine et al. 2007; Celka 2011). Yet, in our heterogeneous region, the issue was almost not studied nor referenced at all. Very few studies used detailed observations of current vegetation cover in order to detect buried elements (Braun and Gophna 2004; Ackermann 2007; Gorzalczyzny 2007; Oshri 2007). Yet, these studies are based on sporadic and qualitative observations, rather than detailed quantitative analysis of the landscape. Ackermann et al. (2004) referred to a single species, Sarcopoterium spinosum, as an indicator for a specific feature in the landscape. Wieler et al. (2017) used geo-botanical field survey and inspected the relationship between the vegetation coverage and surface properties in dry environment. They demonstrated how the vegetation patterns are affected by runoff units, and this pattern enables detection of agricultural installations. However, both methods are insufficient when heterogenous areas are examined.

We propose that studying the association of vegetation characteristics and ancient settlement sites may provide a reliable tool to predict the location of underground anthropological remains, thereby complementing other methods and improving the existing archaeological protocol of site detection. In addition to improving studies of settlement patterns and land use, this may also assist in decision making regarding whether and where to excavate. In order to examine this hypothesis, we used the well-studied archaeological site of Tel ‘Eton as a test-case.

Tel ‘Eton is a large mound of about 6.6 ha, located in the southeastern Judean foothills (Shephelah), Israel (Fig. 1A). The climate is semi-arid with mean annual precipitation of about 350 mm (Urman and Stern 1988; Goldreich 1998). The soils are dark brown grumusol and brown rendzina (Dan and Raz 1970), and the bedrock is chalky Maresha formation from the Middle Eocene, covered by Calcrete, known locally as Nari (Hirsch 1983; Sneh and Avni 2008; Itkin et al. 2012). The vegetation comprises mainly of dwarf shrubs and herbaceous annuals. Trees or shrubs are relatively rare and mostly grow in crevices of large rock outcrops or in relatively humid places such as shallow caves (see also Ackermann 2007). No intense human activity took place on the mound over the past few decades, but despite the recovery tendency of perennial vegetation (Shoshany 2002), no trees or large shrubs grow there. Although the region is under high grazing pressure, as well as fires caused by military practices in the area (Danin 1988), these are probably not the reasons for the lack of trees on the mound as grazing and military activity are expected to have similar effects on both the mound and its surroundings.

The earliest cultural remains found in the mound are dated to the Early Bronze age (third millennium BCE). It was settled intermittently until the Late Persian or Early Hellenistic period (fourth and early third
centuries BCE). The site was then abandoned and never re-settled, although some agricultural terraces were constructed on its slopes during the Roman/Byzantine period (first half of the first millennium CE; Faust 2011, 2014, 2016; Faust and Katz 2012, 2015; Faust et al. 2015). In the last decades, the area functions as a military training zone, therefore there is relatively low human disturbance.

We have previously found that the soil on the mound’s top (hereafter referred as “topsoil”) is homogeneous, with lower clay content and higher phosphate concentrations, compared to the surrounding environment (Sapir et al. unpublished; see also Holliday and Gartner 2007; Sedov et al. 2017; Smejda et al. 2017; Paz et al. 2017). We therefore hypothesized that contemporary vegetation on the mound will be different from its surroundings. Specifically, we hypothesized that ancient land use, rather than topography, will affect above ground vegetation. High nutrients concentrations (namely, the above-mentioned phosphorous and others, such as nitrogen) may support higher biomass and such a significant soil difference will thus be associated with different richness and composition of plant species. We predict that these vegetation characteristics will be sufficient to result in differences between habitats affected by ancient settlements, compared to never-settled habitats. We expected that plots that contain underground archaeological remains will be similar in their vegetation characteristics, even in case of topographical differences. Overall, our sampling

Figure 1. Location of Tel ‘Eton and sampling plots. A. Location of Tel ‘Eton, as well as other archaeological sites of similar age, on the background of a precipitation map of Israel. B. View of the northern part of the mound and its surrounding from the South. Letters denote the study sampling units (plots).
was designed to depict a distinction between archaeological and non-archaeological environments, while controlling for topographical differences.

**Materials and methods**

**Sampling design**

To test our hypotheses regarding the vegetation characteristics, we defined four sampling units (plots) near the Tel `Eton site (Fig. 1B), representing four combinations of topography and archaeological remains. These plots were chosen based on mapping of findings concentrations in molehills (Sapir and Faust 2016).

On the top of the mound we sampled a large terrace (plot T). In the settlement below the mound we sampled the area near the previously excavated lower city (area F in Faust 2016; see Postscript in Sapir and Faust 2016), where buried architecture was found, and the visible remains exposed in the wadi section (plot F).

Northwest of the lower city, where hardly any artifacts were found, we sampled an area consisting of deep soil (plot G). The fourth plot, chosen as a control area, was a flat abandoned field on the hillslope located north to the wadi (plot C). Plots T and F both represent areas with an ancient settlement, while plots G and C represent areas with no archaeological findings. On the other hand, plots T and C represent the same topography, on a flat shoulder of a slope, while plots F and G are spatially near located in the same plane, and topographically similar.

Sampling was performed on March 22nd, 2016, at the peak of vegetation growth season. In order to sample the plot systematically, we chose a random point inside the putative range of each plot and sampled in constant distances of approximately 3 m between points. To sample the vegetation we used a square wooden frame of 28 × 28 cm and sampled the inner 25 × 25 cm, in order to avoid edge effects. In plots G and C, we verified that there were no (or almost no) artifacts or sherds on the surface after the collection of the plants in each sample. We repeated this sampling in each plot as follows: plot T: n = 15; plot F: n = 14; plot G: n = 16; plot C: n = 15.

**Vegetation sampling**

In each sampling point, total above ground plant biomass was collected, stored in a paper bag and brought to the laboratory. On the next day, samples were oven-dried at 60° C for 72 h. Samples were weighted and biomass was estimated as the total dry weight of the plant material. Next, plants were separated and identified to the species level and species richness was estimated as the number of species identified in each sample. The very few un-identified species were also considered for this parameter.
Statistical analyses

All statistical analyses were executed using R (Development Core Team 2014). Because biomass data were highly left-skewed, $x^1$ transformation was used for the significance testing to improve normality. Species richness was ln-transformed for the significance testing due to Poisson-like distribution. One-way analysis of variance was performed on both biomass and species richness, followed by a Tukey post-hoc test.

Species composition was analyzed using the presence or absence of each species in each sample. We used multi-dimensional scaling to describe the clustering of plots based on species composition in the samples. To compare species composition between plots, we used the presence and absence of species in a sample as a Bernoulli experiment, where presence is considered as 1 and absence as 0. Generalized linear model (GLM) for binomial data was used to test the differences between plots in “success” (presence) or “failure” (absence) of each species in each plot, followed by a pre-designed contrast to compare plots C and G to plots F and T, followed by comparisons between plots C and G and between plots F and T.

Results

Biomass

Mean biomass was significantly different between the four areas of sampling (ANOVA: $F_{3,61} = 5.92, P < 0.001$; Fig. 2). The highest biomass was found in plot F (mean biomass 63.0 g ± 6.72 S.E.), significantly higher than plot C (32.3 g ± 3.86) and plot T (40.1 g ± 3.40), but not significantly higher than plot G (47.6 g ± 5.29). Biomass in plot T was higher but not significantly different from plot C.

Species richness

The number of species recorded in the four plots differed considerably, with a total of 67 species recorded, of these 40 species were recorded on the tell (plot T), 32 in plot F, 28 in plot G, and as low as nine species recorded in the control plot (C; see Supplementary Information for full list of species in plots). The most common plant species found in the sampling was *Avena sterilis*, found in 51 samples in all four plots, followed by *Stipa capensis*, found in 34 samples in all four plots. 28 species were uniquely found in one sample only. Three species were identified only to the genus level.

The species were categorized by their synanthropy (association with disturbed habitats) based on Danin and Fragman-Sapir (2016+). Most of the species were obligate natural (36 species) or were mostly natural, but also synanthropic (22), while 5 species were equally either natural or synanthropic, and one species (*Sonchus oleraceus*) was mostly synanthropic. The latter was found only once, in plot G. We found no association of plot and synanthropic category of species ($X^2_{6} = 5.06; P = 0.536$).

The mean number of species was significantly different among the four plots of sampling (ANOVA: $F_{3,61} = 17.91, P < 0.001$; Fig. 3). The highest mean richness was found in plot T (8.1 ± 0.62 species), significantly higher than plot C (2.1 ± 0.13 species) and plot G (4.7 ± 0.67 species). Plot F (5.9 ± 0.79 species) was higher than

Figure 2. Dry biomass of above ground herbaceous vegetation in 25 × 25 cm quadrates. Bars are means ± standard errors. Bars with different letters denote significantly different values (P < 0.05; Tukey post-hoc test).

Figure 3. Mean number of plant species in 25 × 25 cm quadrates. Bars are means ± standard errors. Bars with different letters denote significantly different values (P < 0.05; Tukey post-hoc test on ln-transformed data).
plot G, but this difference was not significant. Species richness in plot C was significantly less than all the other plots.

**Species composition**

Multidimensional scaling revealed a separation of samples from plot C on the first axis, and a partial separation of plot F on the second axis (Fig. 4). To compare species composition between the four areas, we used GLM with binomial data distribution and compared this model to a null model, without the plot as factor. This analysis showed that the plot significantly affected species composition ($\chi^2 = 36.3; P < 0.001$). Contrast analysis revealed that plot F and plot T were not significantly different from each other ($P = 0.164$), but both were significantly different from plot G and plot C ($P < 0.001$). Plot C was significantly different from plot G ($P < 0.001$).

**Discussion**

Given the importance of site detection for archeology, and the limitations of common survey methods, specifically the highly common pedestrian survey, archaeologists have recently focused on developing advanced methods, using mostly geophysical surveys or remote sensing (Kvamme 2003; Parcak 2009; Menze and U, 2012; Campana 2016; Kirk et al. 2016). A few studies used anecdotal observations of plant patterns (Braun and Gophna 2004; Ackermann 2007; Gorzalczy 2007; Oshri 2007) and others examined a single species (Ackermann et al. 2004) or limited features detection (Wieler et al. 2017). In order to avoid the limitations (including costs) of existing methods, we propose to use above ground vegetation as an indicator of buried archaeological remains. Here we utilized the extensively studied Tel ‘Eton as a test case. Despite being limited to one site and one season, our study suggests that after calibrating for regional differences, detailed vegetation sampling may be an efficient non-destructive method for identifying below ground archaeological remains.

In the present study, we employed three parameters to reveal differences in the current vegetation between the mound (plot T), the lower city (plot F), a never-settled area just outside the lower city (plot G), and an un-settled area located on a nearby slope (plot C), slightly farther away from the mound. The two settled locations (plots T and F) differed in topography, one on a topographical shoulder and the other residing in a flat area in the valley, as were the two non-settled locations (plots G and C), enabling us to control for topographical variable. We clearly show that the mound (plot T) and the lower city (plot F), both heavily occupied until the late Iron Age (2600-2700 years ago; Faust 2016), are similar in species richness and composition, while the not-settled area (plot C) was significantly different from both plots in these two parameters.

We found the highest number of species on the mound and in the lower city (plots T and F, respectively).
The non-archaeological locations (plots G and C) had lower species diversity, but only plot C was significantly lower than the archaeological plot F (Fig. 3). This implies that anthropogenic habitats are favorable for a larger spectrum of species, possibly due to a higher nutrients concentration (Sapir et al. unpublished). Plot G has an intermediate number of species, between the archaeological plots (T, F) and the never-settled area (C). This may be the result of the topographical situation of plot G, which is similar to this of plot F, and its location between two anthropogenic soils.

Similar to species richness, species composition was found to be an indicator of ancient anthropogenic habitats, as there is distinction between plots T and C in Coordinate 1, and distinction between plots F and G in Coordinate 2 (Fig. 4). In other words, natural and anthropogenic habitats, which are located in similar topography, can be distinguished by species composition. This suggests that some species are more tolerant or more sensitive to such habitats. However, in this study we could not identify generalities in the assembly of species that could serve as a rule for other sites.

Vegetation biomass was found to be less reliable as an indicator for archaeological remains. A previous study in the same location (Tel ‘Eton) showed that vegetation biomass was high on the mound, relative to the natural surroundings, probably resulting from a higher phosphate (and other nutrients) concentration on the mound’s top (Sapir et al. unpublished). Therefore, we expected biomass to be highest in the anthropogenic plots (T and F) and lower in the ‘natural’ control field (C) and the unsettled plateau near the lower city (G). Our results here, however, show that while biomass in the anthropogenic plots (F and T) was higher than the biomass in natural plots with a similar topography (G and C, respectively), the difference was not significant (Fig. 2). Instead, biomass values were better partitioned by the topography, as plots on hilltops (T and C) were more similar to each other in biomass than valley plots (F and G). While lack of nutrients can limit vegetation growth and species richness, much depends on the availability of water. Because plot F is adjacent to the wadi and below the mound, it is expected to have higher biomass comparing to mound (plot T) due to higher water availability (supply of runoff from the slopes), but further study is required for testing this hypothesis. We should note, however, that while the previous study showed that the biomass on the mound was higher than the surrounding, the difference was significant only in one of the two years of that study. Therefore, we conclude that the suitability of plant biomass to serve as a parameter to discriminate between anthropogenic and natural areas is relatively limited, because this parameter is influenced by fluctuating factors, other than nutrients concentration solely.

The patterns identified above indicate the possible use of above ground patterns to identify below ground ones. The method suggested here is relatively fast and inexpensive. Workload was roughly three days: one day of field sampling and two days of lab work. Moreover, if plants are identified in the field before harvesting, it may expedite the analysis. Thus, plant species richness and composition may be used for cheap and rapid identification of areas of archaeological interest. Our results suggest that plots with apparently higher number of species per unit area are more promising for digging. This, however, is only a first step, as we still do not fully understand the way in which buried remains affect vegetation characteristics. Therefore, distinguishing between anthropogenic features and natural patterns still requires complementary methods. The parameters we propose here may pave the way to understand vegetation patterns around archaeological sites. Moreover, in cases of highly heterogeneous landscape, such as the rubbles on top of mounds, the exploitation of vegetation characteristics may be more effective for high-resolution landscape analysis.

Despite the conclusive results obtained here, we should note that wider conclusions are currently limited, since this vegetation study was confined to one site of one dominant archaeological period, and sampling was conducted only once. Climatic conditions may vary in time and space, and thus result in fluctuations in vegetation characteristics. In addition, different types of archaeological remains (e.g. settlements of much shorter occupation time and lower intensity) may result in differences in species composition and richness. Thus, more test-cases are required in order to refine the implications and to better understand the influences of anthropogenicity on biodiversity.

**Summary and conclusions**

To the best of our knowledge, this is the first attempt of a systematic exploration of vegetation characteristics for the purpose of distinguishing between archaeological sites and natural areas in our region (and one of a few worldwide, e.g. Dambrine et al. 2007). We demonstrate how the above ground plant layer, especially
plant species richness and composition, can serve to identify past human activities. Specifically, we propose to utilize vegetation parameters of plant biodiversity to expose the buried cultural remains, to identify new loci of human activities, and to define the boundaries of already known archaeological sites. While the proposed method still requires validation and should be tested in other sites and archaeological periods, and while it is not perfectly accurate in differentiating between various archaeological loci, using vegetational characteristics may provide a powerful rapid and low cost tool for preliminary studies and field observations aimed to identify sites.

Acknowledgements
Ya.S. was supported by Presidential Scholarship for Outstanding PhD Students, Bar-Ilan University; This study is an offshoot of a JNF Grant on Archaeological Sites and the ‘Open’ Landscape – Tel ‘Eton’s Environments as a Test-Case to A. F. We thank Yamit Bar-Lev for technical laboratory support and to Sigal Rencus-Lazar for English editing. This paper is dedicated to the late Prof. Avi-noam Danin, who taught us the importance of plants as environmental indicators.

Author contributions

References


