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Long-term agrarian landscapes in the Troodos foothills, Cyprus

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ABSTRACT

We investigate the temporal and environmental relationships between the terraced hill slopes of Politiko-Koloikremmos and the adjacent Bronze Age settlement of Politiko-Troullia in foothills of the Troodos Mountains, central Cyprus. Mapping of 102 stone walls on Koloikremmos is compared with 66 walls farther afield on Cyprus to create a six-part terrace typology. Sherd counts from 174 2-m radius collection circles over approximately 20 ha on Troullia and Koloikremmos were used to create interpolated sherd density surfaces revealing distinctly different patterns of land use for four major archaeological eras between the Cypriot Bronze Age and Medieval Period. We compared sherd density patterns according to terrace types, length, slope and vegetation cover determined by SAVI (Soil-Adjusted Vegetation Index) from Ikonos and Quickbird satellite imagery.

The most robust sherd patterning indicates Prehistoric Bronze Age settlement at Troullia, as confirmed by soil resistivity and excavation, and multi-period land use on Koloikremmos immediately upslope of the village that may be associated with agricultural terracing. Scattered sherd concentrations indicate later use of this landscape as an agricultural hinterland for the Iron Age city of Tamassos. Sherds and a down slope spread of roof tiles from the Roman through Medieval periods suggest an isolated structure near the crest of Koloikremmos. Longer terraces correlate with greater vegetation cover and are interpreted as agricultural, while shorter terraces, apparently for erosion control and arboriculture, are significantly related to Prehistoric Bronze Age sherd patterns. Our results suggest that coordinated analysis of archaeological, geographical and remotely sensed environmental data associated with terraced landscapes can be used to infer long-term patterns of agricultural land use.

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1. Introduction

1.1. Research aims

The investigation of archaeological landscapes has become an intrinsic part of interpreting long-term changes in settlement and land use, especially among early agricultural societies (e.g., Alcock and Cherry, 2004; Barker, 2011). Agrarian landscapes implement constellations of built features to permit and sustain productive crop cultivation and animal husbandry. Terrace walls manage local geomorphology, especially on anthropogenic landscapes, by creating more stable topography for field plots, conserving down slope water flow, retaining arable sediments and minimizing soil erosion (Treacy and Denevan, 1994; Rackham and Moody, 1996,

140–142). Further, varying configurations of terraced fields provide a diversified risk reduction strategy for farmers in localities marked by seasonally or annually irregular rainfall (Sandor and Eash, 1991). As such, terrace systems play crucial roles in permitting long-term agricultural production in regions that may be agriculturally marginal due to limited water supply or pronounced topographic relief.

In southwestern Asia, one of the world's best-studied arid regions, the earliest terraced fields may date back five or more millennia (Spencer and Hale, 1961; Wilkinson, 2003, 135–136, 186–202). The southern Levant, marked by limited water availability and hilly topography, features extensive terracing and other evidence of arid land agriculture associated with Chalcolithic settlement in the fourth millennium B.C. (Levy and Alon, 1987), the advent of Bronze Age urbanism ca. 3000 B.C. (Finkelstein, 1988; Gibson et al., 1991), late Iron Age Israelite kingdoms in the first millennium B.C. (Hopkins, 1985) and long-term land use spanning the Neolithic through modern eras (Barker et al., 2007). Yet despite

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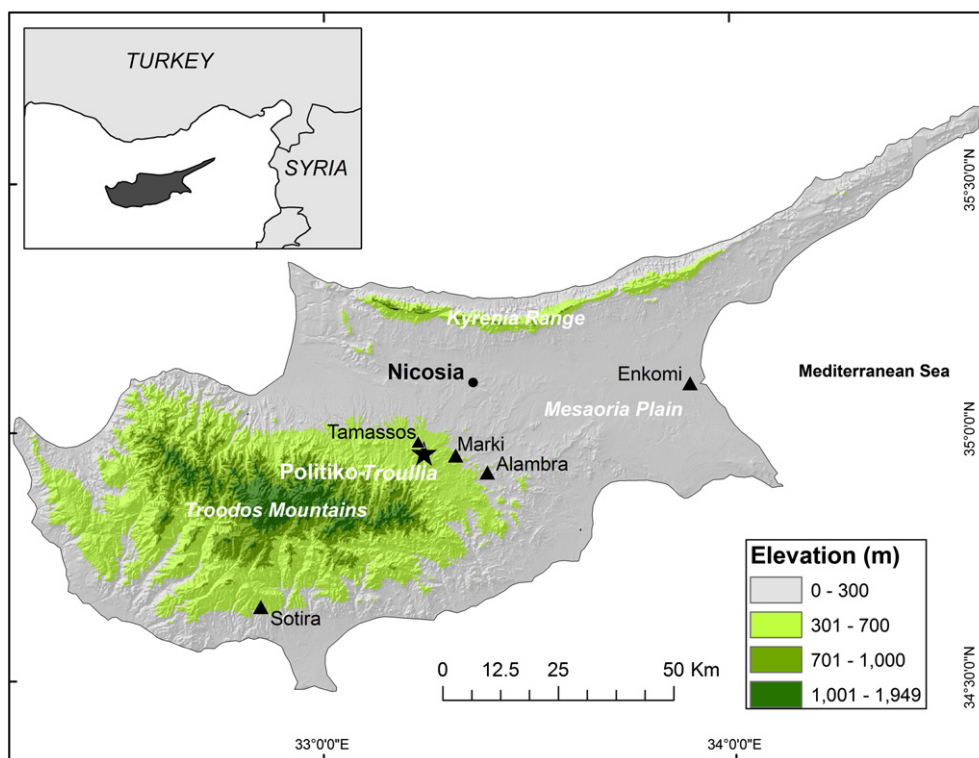


Fig. 1. Location of Politiko-Troullia in the foothills of the Troodos Mountains and other Bronze Age settlements. Early/Middle Bronze Age domestic evidence stems primarily from Sotira-Kaminoudhia (Swiny et al., 2003), Alambra-Mouttes (Coleman et al., 1996) and Marki-Alonia (Frankel and Webb, 1996, 2006); Late Bronze Age Enkomi (Courtois et al., 1986) and Iron Age Tamassos (Buchholz and Untiedt, 1996) also shown.

their prominent role in traditional dry land agriculture and their potential importance for agricultural development in early complex societies, terraced field systems remain challenging targets for dating and interpretation.

On Cyprus, marked by arid climate and the hilly topography of its interior, terrace walls date back at least several centuries (Given and Knapp, 2003, 306) and potentially much earlier, in light of the evidence from environmentally similar neighboring regions. This study was triggered by extensive hillside terraced fields, carpeted with archaeological ceramics, which lie in close proximity to the Bronze Age settlement of Politiko-Troullia¹. A variety of surveys around the Mediterranean (e.g., Bintliff et al., 1999; Cherry et al., 1991) argue that prehistoric archaeological evidence tends to be obscured by more abundant remains from later periods. Thus, the pronounced abundance of Bronze Age pottery on thoroughly terraced neighboring slopes, and the resulting potential for insights on the ancient agrarian landscape, invite detailed geographical and archaeological investigation. We examine the spatial relationships between archaeological material, terraced fields and environmental variables as they elucidate this long-term agrarian landscape in the Troodos foothills (Creighton et al., 2007 and Newson et al., 2007 apply a similar approach in the Wadi Feynan, Jordan).

1.2. Bronze Age settlement at Politiko-Troullia

The remains of Politiko-Troullia lie buried in the foothills of the Troodos Mountains, south of the fertile Mesaoria Plain

of central Cyprus (Fig. 1). Politiko-Troullia covers a saddle perched at 410 m above sea level (35° 1' 14" N; 33° 14' 50" E), bounded by deeply entrenched Kamaras Creek to the west and overlooking the streambed of the Pediaios River, the largest water course on Cyprus, to the east. Today, the Pediaios no longer flows below Tamassos Dam, 500 m to the southeast, but in antiquity the inhabitants of Politiko-Troullia would have enjoyed ready access to arable land, spring-fed stream flow just at the community's western edge along Kamaras Creek, the resources along the Pediaios, and easily-mined copper sources less than one km to the south in the pillow lavas of the Troodos. In concert, these factors no doubt encouraged the establishment of the agrarian community at Politiko-Troullia.

Bronze Age settlement at Politiko-Troullia was inferred originally from evidence of gaming stones to the south of the Iron Age ruins of Tamassos (Buchholz, 1982, 70–71). Subsequent reconnaissance along the eastern most transect of the Sydney Cyprus Survey Project noted abundant Red Polished Ware ceramics and eroded exposures of three stone walls (probably those still visible at the site's northwestern edge) that verified the settlement's location and Bronze Age occupation (Given, 2002, 44–45; Given and Knapp, 2003, 126, Appendix A). More systematic reconnaissance of the locality between 2004 and 2011 has revealed a multi-faceted archaeological landscape defined by a distribution of material culture, especially ceramics, over approximately 20 ha covering the modern fields of Politiko-Troullia and the adjacent hill slopes of Politiko-Koloikremmos (Falconer et al., 2005, in press; Fall et al., 2008) (Fig. 2). Just north of Troullia, the hill of Politiko-Lampertis east of Ayios Irakleidios Monastery features the remains of subterranean rock-cut tombs, and their associated Bronze Age pottery (Frankel, 1974a, 1974b; Karageorghis, 1965; Masson, 1964), which may have provided a final resting place for the occupants of the village of Politiko-Troullia.

¹ Cypriot archaeological sites are, by convention, named for the nearest modern village (Politiko) followed by an italicized toponym (Troullia), which refers to the plot of land that incorporates the site.

Initial field investigations in 2004 and 2005 focused on archaeological and soil resistivity survey of relatively flat fields covering approximately 2 ha (“*Troullia East*” and “*Troullia West*” in Fig. 2) that featured abundant surface material culture and thus suggested considerable sub-surface architecture (Falconer et al., 2005). Nine stone walls, in addition to the three reported by the Sydney Cyprus Survey, were exposed and mapped along the western edge of *Troullia West*. Test excavation immediately adjacent to one of these walls revealed at least 3 m of stratified archaeological sediments incorporating Bronze Age potsherds, chipped stone, animal bones and floral remains (Falconer et al., 2005; Fig. 4). Soil resistivity survey conducted over approximately 1 ha revealed a network of buried walls in southern *Troullia West*, at least one rectangular structure in northwestern *Troullia West*, a lengthy wall across the center of *Troullia East* and a multi-room structure at its northern end (Falconer et al., 2005; Fig. 3).

Our soil resistivity results guided the location and excavation of seven 4 × 4 m units (Areas A–G) in 2006 and 2007, which unearthed an architectural compound with roofed structures, storage bins, alleyways and out buildings (Fall et al., 2008, Figs. 12 and 13). These stone-built structures were founded on, or dug into, soft friable siltstone bedrock. Copper tongs, a carved limestone casting mold, ceramic crucible fragments, copper slag and chunks

of ore suggest a covered, exterior metallurgical work area (Fall et al., 2008, Figs. 14 and 15). Simultaneous excavation of Area L, near a lengthy wall running northwest-southeast, revealed architecture founded on bedrock and accompanied by shallow deposits with wall fall, material culture and animal bones. Settlement in *Troullia West*, as revealed first by soil resistivity, then by four seasons of excavation between 2008 and 2011, features a large rectangular courtyard surrounded by apparent domestic structures to the west, north and east (Falconer et al., in press; Fig. 4). The central courtyard is bounded on the south by an alley sloping down from east to west toward the streambed of Kamaras Creek at the site’s western edge. This architecture was rebuilt in at least four phases, as manifested most clearly by successive wall realignments and door blockage along the northern side of the *Troullia West* alley (Falconer et al., in press; Fig. 7). The ceramic assemblage from Politiko-*Troullia* places its occupation in the Middle Cypriot portion of the Prehistoric Bronze Age, based on abundant Red Polished Ware, especially Red Polished III, accompanied by more limited amounts of White Painted Ware (see discussions in Falconer et al., 2005, in press; Fall et al., 2008).

The bone evidence from Politiko-*Troullia* indicates animal husbandry emphasizing domesticated agrarian species, especially sheep (*Ovis aries*) and goat (*Capra hircus*) (Falconer et al., in press;

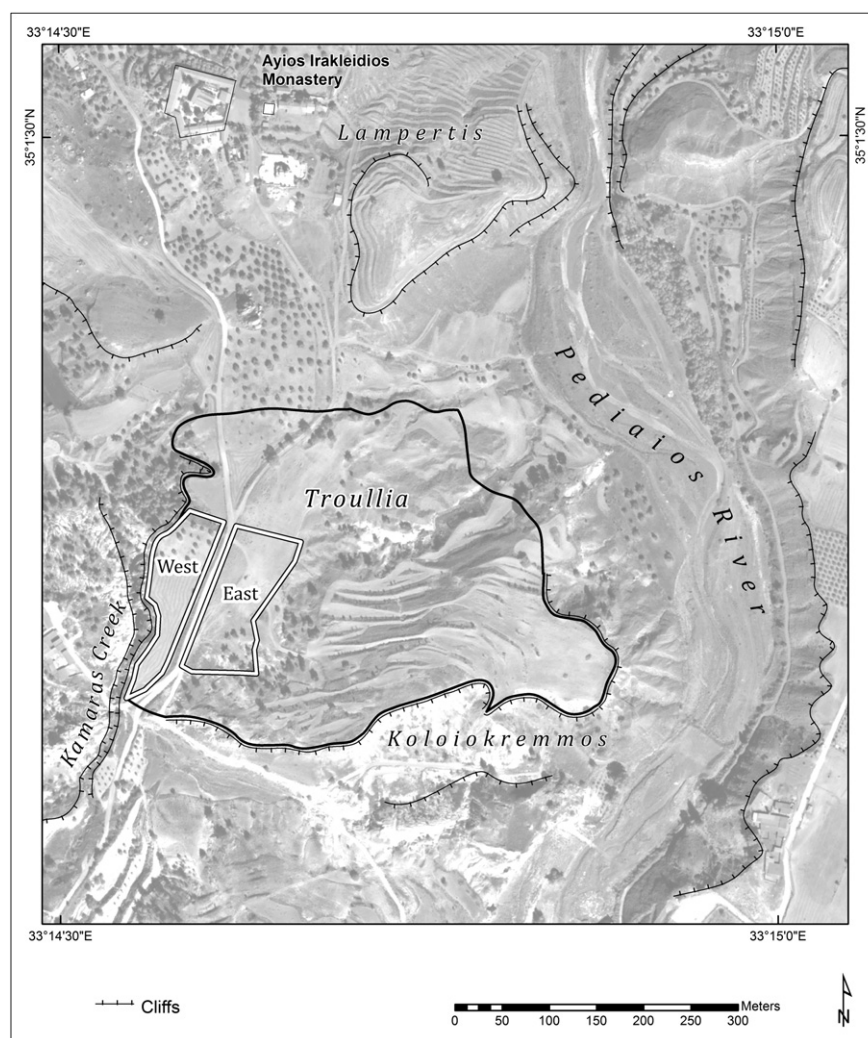


Fig. 2. Map of Politiko-*Troullia*, *Koloikremmos* and *Lampertis* between the *Pedaios River* and *Kamaras Creek*, noting Politiko-*Troullia West* and *East*. Map features overlaid on Quickbird satellite image from October 2003. Solid line indicates extent of material culture on surface.



Fig. 3. Photo of Politiko-Koloiokremmos showing north-facing terraced hillslope. Photo from northeast corner of Troullia with ravine in foreground (photo by Rachel Benkowski).

Fall et al., 2008; Table 1). Animal exploitation included hunting of forest species, like wild goat (*Capra aegagrus*) and especially Mesopotamian fallow deer (*Dama dama mesopotamica*), while management of farm animals included pig (*Sus scrofa*), cattle (*Bos taurus*) and equids (perhaps as traction animals). Systematic water flotation of almost 500 L of sediment from a variety of contexts at Politiko-Troullia produced botanical remains that feature substantial accumulations of wood charcoal. The major plant taxa in the Politiko-Troullia assemblage include olive (*Olea europaea*), grape (*Vitis vinifera*), fig (*Ficus carica*), pistacio (*Pistacia* sp.), cereals, and several wild taxa (e.g., Asteraceae, *Galium* and wild legumes). Clear evidence of multiple orchard species, especially carbonized olive seeds, suggests an emphasis on arboriculture at Troullia. Interestingly, cereal grains are very infrequent and pulses

are absent altogether from the Troullia plant assemblage, reinforcing the probable importance of meat, including venison, as a crucial protein source in the local diet. Analysis of seed:charcoal ratios in comparison to data from four Near Eastern Bronze Age towns and villages strongly suggests persistent woodlands and woodland resources (e.g., deer) in the Troullia hinterland, in contrast to the more deforested contemporaneous landscapes of the mainland (Klinge and Fall, 2010).

1.3. The land behind Troullia

Detailed mapping of the Politiko-Troullia locality reveals extensive distributions of archaeological material culture and agricultural features in Troullia's immediate hinterland, especially

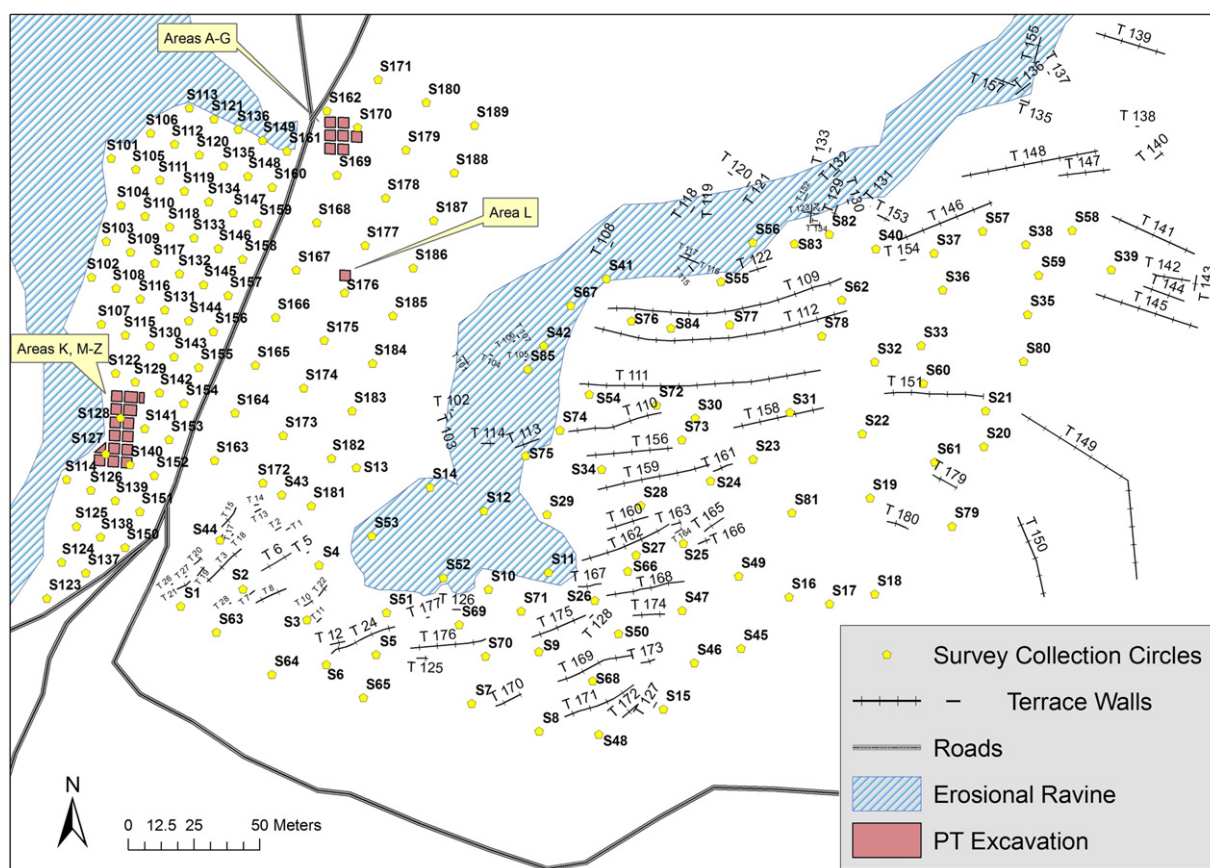


Fig. 4. Map showing location of 2 m radius survey collection circles (S1–85, S101–189), terrace walls (T), excavation units on Politiko-Troullia (PT), also indicating dirt roads and erosional ravines.

Table 1

Archaeological chronology, mean sherd densities, and ubiquity (% of samples in which sherds or tiles are present) for prehistoric and historic periods represented at Politiko-Troullia (village) and Koloikremmos (terraced fields); *n* = number of survey collection circles.

Cultural Period	Sherd Density (#/100 m ²)		
	Total <i>n</i> = 174	Troullia <i>n</i> = 91	Koloikremmos <i>n</i> = 83
Roman-Medieval (100 BC–AD 1571)	4.39 (26%)	2.80 (22%)	6.14 (31%)
(Roof Tiles)	13.82 (21%)	0.44 (1%)	28.49 (42%)
Iron Age-Hellenistic (1000–100 BC)	21.78 (66%)	16.10 (54%)	28.01 (78%)
Protohistoric Bronze Age (1700–1000 BC)	4.35 (22%)	8.14 (37%)	0.19 (2%)
Prehistoric Bronze Age (2500–1700 BC)	41.36 (76%)	51.53 (84%)	30.22 (67%)
All Time Periods (2500 BC – AD 1571)	111.14 (94%)	90.64 (93%)	133.62 (95%)

Chronology adapted from Given and Knapp (2003): Table 3.1. Roof tiles not included in the sherd density calculations.

on adjacent Politiko-Koloikremmos (see Fig. 2). Here we explore spatial patterns of material culture, topography and vegetation, as they reveal changing patterns of land use in association with stone-built terrace walls on the western, northern and eastern slopes of Koloikremmos (Fig. 3). These walls are particularly abundant on the northwestern slope overlooking Troullia West, and the northern and northeastern slopes that drain to the Pediaios River. Politiko-Troullia and the terraces on Koloikremmos have been plowed in the past and seeded with oats for hay. However, these field plots are not managed today. The nearby Ayios Irakleidos Monastery has no records of terrace farming or land ownership in the recent past, raising the distinct possibility that these terraces reflect multiple eras of pre-modern landscape management. Previous investigations of other Cypriot field systems (e.g., Deckers, 2003; Noller and Wells, 2003; Wagstaff, 1992) describe post-Bronze Age terraces. A survey around Sotira-Kaminoudhia, for example, found numerous local terraces associated with abundant Hellenistic and later ceramics (Held, 2003), accompanied by a notable absence of Middle or Late Bronze Age pottery. In contrast, the terrace walls of Koloikremmos lie amid a carpet of potsherds and roof tiles, which holds the potential to illuminate the land behind Troullia in the deep past.

Terrace walls are utilized throughout the Mediterranean to help redistribute sediment, increase root penetration of trees and vines, especially olives and grapes, to expand the land available for cultivation and to control erosion (Rackham and Moody, 1996). In antiquity, terraces may have been used to expand the cultivation of cereals, as well as for olive orchards and grape vines. Paleoethnobotanical data from excavations at Troullia contain relatively abundant olive pits and grape seeds suggesting that the landscape around this ancient settlement may have been used for arboriculture in addition to grain agriculture.

The importance of orchard product industry in the urbanization of Cyprus is demonstrated amply by a massive olive oil manufacturing center at Kalavassos-Ayios Dhimitrios, where a large Protohistoric Bronze Age central courtyard-style complex, with scores of pithos storejars, produced and stored up to 50,000 L of olive oil (South, 1992). Large-scale oil production in the Protohistoric Bronze Age is attested further by pressing floors found at Maroni-Vournes (Cadogen, 1984, 1986), Episkopi-Bamboula (Weinberg, 1983), Enkomi (Courtois et al., 1986) and Hala Sultan Teke (Astrom, 1985). However, as Hadjisavvas (1992, 2003) and Warnock (2007) document thoroughly, oil production often operates on a smaller, household scale involving the simple crushing of olives with

a mortar and pestle or in a shallow rectangular ground stone trough. Accordingly, Hadjisavvas (1992) notes that the most common archaeological evidence for oil production comes in the form of fragmentary crushing troughs, which are found in household contexts at the settlements above, and at Mrytou-Pighades (Taylor, 1957), Kition (Karageorghis, 1987) and Alassa-Pano Mandilaris (Hadjisavvas, 1988, 1989). The ground stone assemblage at Politiko-Troullia features large on-site and off-site mortars, as well as 16 shallow trough fragments arrayed primarily among the settlement's houses and the Troullia West alleyway. The combination of ground stone troughs, olive remains and local terracing forms a circumstantial case for arboriculture, including household-scale olive oil production, at Politiko-Troullia.

2. Methods

2.1. Archaeological survey

The first investigations of Politiko-Troullia included a systematic survey of surface material culture over Troullia West and East. This sampling identified concentrations of particularly dense material culture, and this patterning (in conjunction with our soil resistivity results) helped guide the location of the excavation areas noted above. Our sampling grid included 61 2-m circles on Troullia West and 30 2-m circles on Troullia East (Fig. 4). As a means of exploring the material culture associated with local terrace walls and integrating our assessment of village life at Politiko-Troullia with land use on its surrounding hillsides, we expanded this sampling procedure to include 83 2-m circles on the slopes of Koloikremmos. While approximating the 20-m sampling interval on the flat fields of Troullia East, the irregular topography of Koloikremmos required more purposeful placement of sample circles at locations that were unimpeded by particularly steep terrain or dense foliage. The locations of all 174 circles, as well as their surrounding topography and cultural features, were established digitally using a total station laser theodolite. Topography, sample circles, terrace walls, excavation areas, roads and erosional ravines were brought together as ArcGIS shapefiles for coordinated mapping.

Within each sampling circle all material culture, consisting overwhelmingly of pottery sherds and ceramic roof tiles, was collected for analysis. The sherds were identified according to the conventional ceramic “wares” of Cypriot prehistory when possible (especially for the Bronze Age sherds) and typed chronologically in four major time periods with distinct ceramics and roughly comparable lengths running from the Prehistoric Bronze Age through the Roman-Medieval era (Table 1). Roof tile fragments, which probably date to the Roman-Medieval era but may stretch over a longer span (e.g., Wright, 1992, 383–384) were identified and counted separately. No material culture emerged for periods prior to the Bronze Age or for the Ottoman Period, and modern remains were limited largely to shotgun shell casings. Surveyed material culture data were imported into ArcGIS shapefiles that included each sample's geographic coordinates, elevation, total sherd count, roof tile count and sherd counts categorized by period. Initial descriptive statistics include period-by-period mean sherd and tile densities, and ubiquity for samples collected from the village site of Politiko-Troullia and the hill slopes of Politiko-Koloikremmos.

Sherd and roof tile counts for all 174 circles were transformed into continuous surfaces to facilitate analysis of spatial patterns over Troullia and Koloikremmos. Archaeological spatial analyses increasingly employ a plethora of surface data to model landscape relationships (e.g., Bevan and Conolly, 2009). Our study utilizes an inverse distance weighting interpolation algorithm (e.g., Conolly and Lake, 2006, 94–97) to predict values for locations between

points with known data, thereby creating continuous surfaces of sherd or roof tile densities. In this procedure, known sample values are used to calculate unobserved values across intervening space using the principle of spatial autocorrelation, which posits that any value in space approximates nearby points more closely than more distant points (Tobler, 1970). Inverse distance weighting implements this principle by applying an increasing, penalized weight to known points as a function of their distance from an unknown point, thereby weighting interpolated values in favor of the nearest known points.

Interpolated surfaces were created at two resolutions, based on 12×12 m and 4×4 m pixel sizes, each utilizing a distance weighting parameter of 3 to give more weight to nearby neighbors. Interpolated values were based on known values from the four nearest sample points and in all cases these calculations exclude data from beyond 45 m. This fairly conservative approach to inverse distance weighting minimizes spurious interpolations, especially around the edges of our study area. Six maps were created at both resolutions to display continuous surfaces of densities for total sherds, Prehistoric Bronze Age sherds, Protohistoric Bronze Age sherds, Iron Age-Hellenistic sherds, Roman-Medieval sherds, and roof tiles. The two resolutions produced similar results, with use of a 4×4 m pixel size, not surprisingly, rendering maps with slightly more nuanced spatial patterns. The interpolated density values for total sherds were segregated into ten quantiles, which were then applied for depicting each of the six continuous sherd and tile density surfaces.

2.2. Agricultural terraces

Our study integrates these spatial patterns with detailed mapping of 102 terrace walls on Politiko-Koloikremmos. Because these walls varied in their state of preservation, the locations of wall faces and ends were plotted from well-preserved stone alignments in the field. Subsequent processing of digital map data using ArcGIS permitted judicious merging of partial or eroded wall segments based on shared alignments and base elevations. Each terrace wall was photographed (and evidence of erosion noted and sketched) to document its present condition and relationship to other terraces. Individual terraces were rendered as closed polygons using point coding in CAD, thereby providing measures of terrace wall width, top elevation, bottom elevation and orientation relative to natural contours.

These terrace walls share a number of general characteristics, but display several noteworthy systematic differences. All walls incorporate dry-stone, unmortared, and single-row construction. A layer of rubble behind many walls suggests the use of riser fill to separate the wall from upslope soil (see Frederick and Krahtopoulou, 2000). Only three walls on Koloikremmos show obvious signs of reinforcement or reconstruction. Secondary stone alignments are embedded behind walls T 161 and 168, while T 176 makes use of bedrock outcrops for structural support at its ends. A descriptive assessment of all 102 terraces on Koloikremmos, as well as 66 additional terraces on nearby hills farther afield on Cyprus, leads to a six-part qualitative typology based on terrace wall construction and associated evidence (Table 2). Wall Type 6 denotes unwallled terraces created by modern bulldozing, which often are planted with cereals, or active or abandoned orchards, including olive, almond and pine trees. Types 4 and 5 are built with fitted, stone-chinked limestone construction that lacks incorporated sherds or tile fragments. Type 5 walls lack sediment infilling between stones and, unlike Types 1–4, display minimal to no lichen cover. Some terrace plots bounded by Type 4 walls are planted with *Eucalyptus* trees, suggesting recent use. Type 3 walls utilize uncoursed, unfitted limestone boulder construction, again lacking

Table 2

Terrace types and associated construction and environmental data.

Type	Stone Work	Chinking	Sediment Infilling	Lichen Cover	Associated Archaeology
1	Unfitted	Yes	Yes	Yes	PreBA sherds Ground stone
<i>Description:</i> Terrace walls made from small rounded limestone and igneous cobbles, with small stone chinking and lichen-covered infilled sediment. Cobbles heavily covered with lichen. Red Polished Ware pottery sherds in terrace walls or in under-lying sediment. Some terraces include igneous ground stone artifacts and chert nodules.					
2	Unfitted	Yes	No	Yes	Roof tile fragments
<i>Description:</i> Terrace walls made from small rounded limestone and igneous cobbles with minimal stone chinking, some roof tile fragments included in construction of walls, no sediment infilling. Cobbles with moderate amount of lichen cover.					
3	Unfitted	No	Yes	Yes	None
<i>Description:</i> Terrace walls made from large weathered limestone boulders, built in courses and infilled with sediment, set on bedrock, some lichen cover on stones.					
4	Fitted	Yes	Yes	Yes	None
<i>Description:</i> Terrace walls made from cobbles and boulders, stones are fitted, sediment infilling, some lichen on stones. Some terraces planted with eucalyptus trees.					
5	Fitted	Yes	No	Little to none	None
<i>Description:</i> Terrace walls are uncoursed with fitted cobbles, without sediment infilling and very little lichen cover. Terrace form is braided (Rackham and Moody, 1996, Fig. 12.1).					
6	N/A	N/A	N/A	N/A	Modern
<i>Description:</i> Unwallled terraces created by modern bulldozing, sometimes retained by modern oil drums. Associated vegetation includes cereals and orchard trees.					

incorporated material culture. Wall types 1 and 2 are distinguished from the other types by their use of rounded limestone and igneous cobbles, chinked with stones and material culture. Type 2 walls lack sediment infilling, and include some examples of stone and roof tile fragment chinking. Type 1 walls feature heavy lichen cover on both constituent stones and infilled sediment, frequently associated with Red Polished sherds (Fig. 5). These walls may be founded on bedrock or on sediments containing Red Polished Ware. The terraces on Koloikremmos include examples of wall types 1 and 2, as well as a number of walls, often relatively short, fragmentary examples, that could not be categorized distinctly (Fig. 6).



Fig. 5. Photo of type 1 terrace wall on northwest slope of Koloikremmos overlooking Troullia excavation areas K, M–Z (photo by Rachel Benkowski).

2.3. Remote sensing

Elevation data from the ASTER satellite, at 30 m resolution, provided the basis for a digital elevation model. In association with this DEM, material culture distributions and terrace maps were coordinated with remotely sensed images from the Quickbird and Ikonos satellites, which have been used in other studies of terraces in the Mediterranean (e.g. Bevan and Conolly, 2011) and provide land cover data on vegetation, soil and sediment distribution, and erosional features. Data from Quickbird were acquired at 2.4 m resolution in October 2003, while Ikonos provided 3.2 m resolution data from April 2010, thereby capturing fall and spring biophysical attributes, respectively. We quantified vegetation by using the Soil-Adjusted Vegetation Index (SAVI; Huete, 1988), a modified version of the Normalized Difference Vegetation Index (NDVI) that dampens the influence of differential reflectance of red and near-infrared spectra when vegetation cover is sparse, as in our study area on Cyprus. Both the SAVI and NDVI provide indices of photosynthetic activity, based on the greater reflectance of near-infrared light and absorption of visual red light by “green” vegetation, which returns to typical reflection/absorption balance by dead or stressed vegetation.

As a means of exploring the relationships of terrace configurations with environmental and archaeological data, we conducted a sequence of linear and logistical regression analyses. In the field we surmised that variation in terrace wall characteristics, including wall type, might provide a window on differing wall functions and temporal patterns of land use. For example, we observed that longer terrace walls appeared to function as retaining walls for arable field plots on gentler, slightly lower elevation slopes, whereas shorter walls retained little sediment and appeared to function as erosion control features on steeper upper slopes. To test this exploratory hypothesis we employed linear regression (using

SPSS version 19) to consider the associations of terrace wall length with elevation, slope, and SAVI derived from both Quickbird and Ikonos data. Mean elevation was derived by averaging the elevation values along each terrace wall. Mean slope was calculated from interpolated values within a 4 m buffer around each terrace wall. Mean SAVI values were calculated for both satellite images by averaging the SAVI values within 4 m and 12 m buffers around each terrace wall. Soil-adjusted vegetation values provide direct measures of the living vegetation associated with each terrace, and therefore the ability of these walls to retain sediment and moisture. Subsequently, logistical regression was used to assess the environmental and archaeological variables that distinguish Type 1 from Type 2 terrace walls, again allowing us to explore variation in terrace form and function. Our logistical regressions consider only walls clearly defined as Type 1 or 2, and exclude walls shorter than 2 m in length. (Short length and fragmentary preservation characterize many unclassified walls.) This assessment builds on the results of our linear regressions and considers, from a slightly different analytical perspective, the possibility that different terrace wall types may be associated with temporal changes in land use. In particular, we wanted to assess the possibility that Type 1 walls relate more closely to Prehistoric Bronze Age land use (e.g., given their proximity to the south end of Politiko-Troullia), whereas Type 2 walls may relate to agrarian behavior in other time periods.

3. Results

3.1. Archaeological survey

Intensive survey of Politiko-Troullia and Koloikremmos reveals a discontinuous pattern of ceramic deposition across the Bronze Age settlement and its adjacent fields (data presented in Appendix A). Appreciable quantities of potsherds may be distributed across

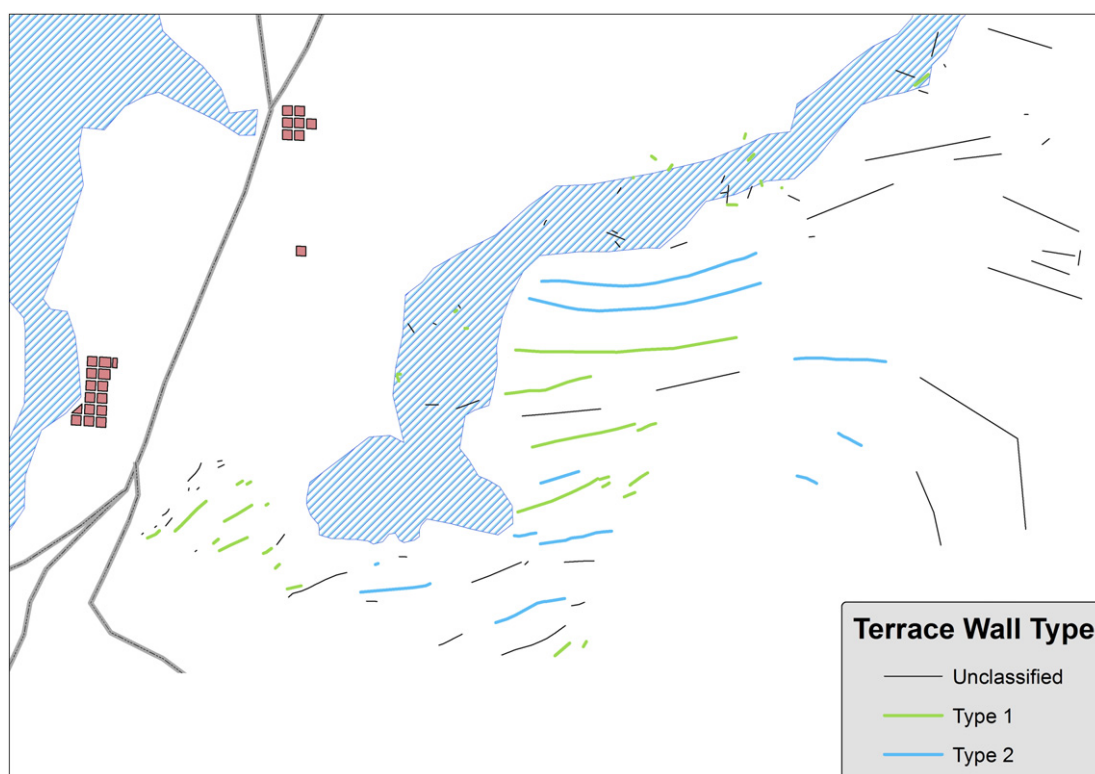


Fig. 6. Terrace walls on Politiko-Koloikremmos classified as Type 1, Type 2, or unclassified terraces (also shown are excavation units, dirt roads and erosional ravines).

agricultural landscapes through a variety of mechanisms, including “manuring” of fields (Alcock et al., 1994: 148–153; Astill and Davies, 1997: 28–32; Ault, 1999; Bakels, 1997; Gerrard, 1997: 69–70; Wilkinson, 1989), plowing of fertilized fields (Ammerman, 1985; Bintliff and Snodgrass, 1988; Yorson et al., 1990) and down slope erosion from dense sherd concentrations (Alcock et al., 1994, 164). All of these behaviors provide direct or indirect indications of human land use, in this case most likely related to agriculture. When compared to the survey evidence from *Troullia*, the higher mean total sherd density for *Koloiokremmos* and the similar ubiquity of sherds on its slopes (see Table 1) accentuate the probability of ancient utilization of its fields and terraces. High densities are particularly apparent on the lower slopes of *Koloiokremmos* and along either side of the ravine that drains off its northern slope down to the *Pediaios* riverbed (Fig. 7). Sherd distributions on *Troullia*'s margins also show high densities on the slopes immediately overlooking the settlement's southern end. The relatively high

sherd densities on *Koloiokremmos* do not appear to indicate a domestic settlement there. First indications of appreciable sherd densities on the eastern most portions of *Koloiokremmos* inspired a 20 m × 40 m soil resistivity transect plus three subsequent 1 m × 1 m test excavations in 2005, none of which revealed evidence of sub-surface architecture (see “*Troullia East of East*” shown on Fall et al., 2008; Fig. 4).

On the fields that cover the settlement at *Politiko-Troullia*, high sherd densities coincide with five areas of buried architecture revealed by soil resistivity: 1) the south end of *Troullia West*, where a matrix of buried walls has been excavated in Areas K and M–Z between 2008 and 2011 (Falconer et al., in press); 2) the south end of *Troullia East* along a lengthy buried wall alignment originally identified in 2004 (Falconer et al., 2005, 74, Fig. 3); 3) the north-western portion of *Troullia West* in which rectangular wall patterns are clearly visible (Falconer et al., 2005, 74, Fig. 3); 4) the northern end of *Troullia East*, where a rectilinear compound was identified

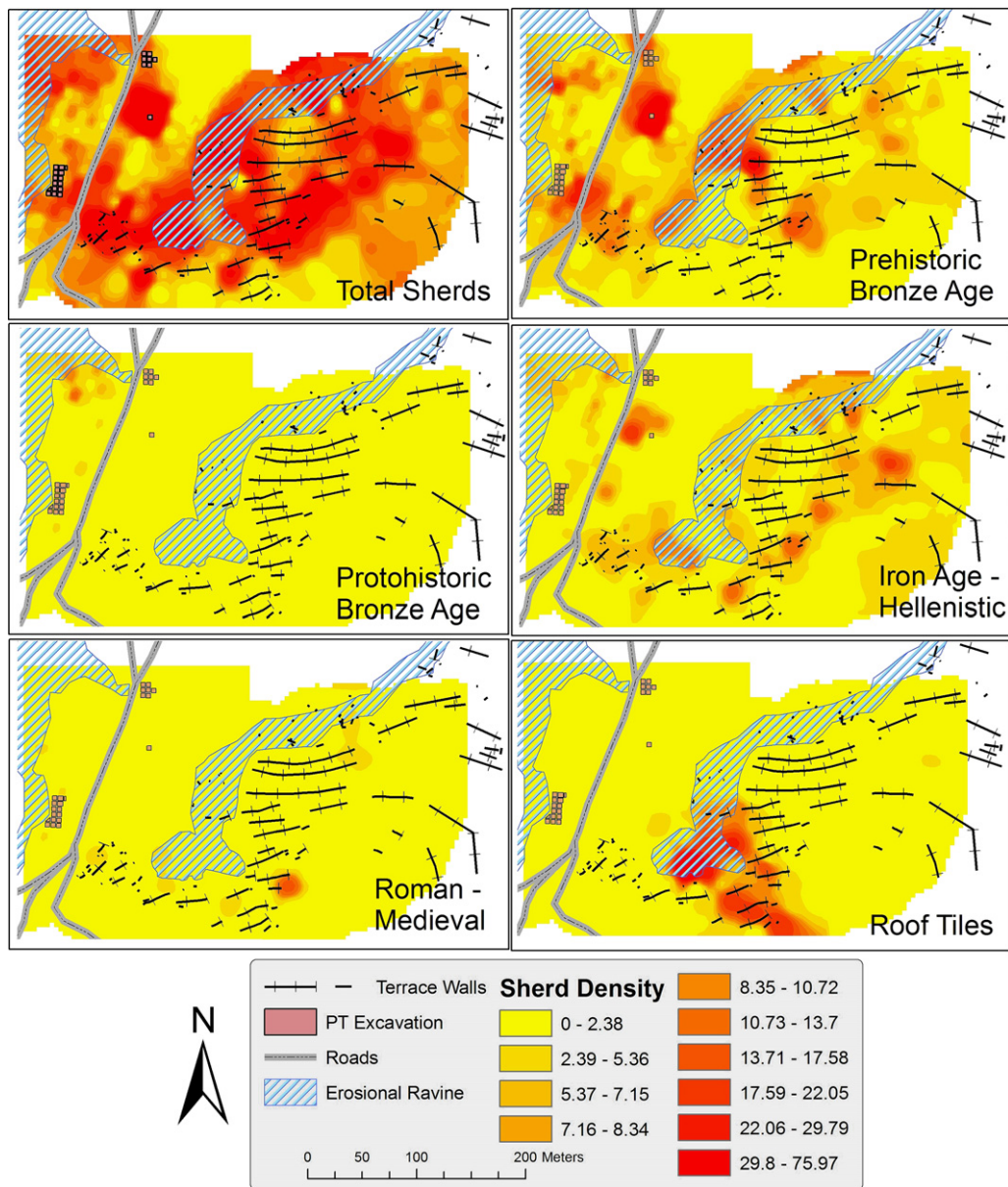


Fig. 7. Interpolated densities for total sherds, Prehistoric Bronze Age sherds, Protohistoric Bronze Age sherds, Iron Age – Hellenistic sherds, Roman – Medieval sherds and ceramic roof tile fragments. Density values are expressed in #/4 × 4 m pixel (#/16 m²).

through our original soil resistivity (Falconer et al., 2005, 74, Fig. 3), verified by follow-up resistivity (Fall et al., 2008, 188, Fig. 5) and excavated in Areas A–G in 2007 (Fall et al., 2008); and 5) the middle of *Troullia* East, which was sampled in excavation Area L in 2007 (Fall et al., 2008).

The mean densities for Prehistoric Bronze Age pottery on both *Troullia* and *Koloikremmos* are greater than for any other period considered in this study. The heaviest pottery density patterns (consisting primarily of Red Polished Ware) on Politiko-*Troullia* coincide once again with the five foci of buried architecture enumerated above. Unlike the mean densities for total sherds, Prehistoric Bronze Age sherds are more abundant and ubiquitous on the village of Politiko-*Troullia* than on *Koloikremmos*. A prominent “hotspot” on *Troullia* East surrounds excavation Area L and extends to Areas A–G, where high sherd densities reflect not only Bronze Age architectural remains, but also heavy plowing and possible sediment deflation. As with total sherd density, the northern portion of *Troullia* West and the vicinity of excavation Areas K and M–Z are marked by sherd concentrations. Away from the settlement, Prehistoric Bronze Age pottery is concentrated on slopes immediately overlooking the southern end of Politiko-*Troullia*, along the ravine banks below the site's eastern margin, and on the lower slopes of *Koloikremmos*. In general, Prehistoric Bronze Age pottery deposition on the fields of *Koloikremmos* is associated commonly with the margins of Politiko-*Troullia* East.

Protohistoric Bronze Age pottery also shows higher counts on *Troullia* than on *Koloikremmos*, where it was recovered in only two sample circles. Despite its 37% ubiquity on *Troullia*, Protohistoric Bronze Age sherds are notable only in small quantities from the northern end of *Troullia* West, and are virtually absent from its nearby hill slopes. Although the Protohistoric Bronze Age ushered in urbanized settlements and economies on Cyprus, this interval is marked by a hiatus in archaeological deposition at and around Politiko-*Troullia*.

The majority of sherds from the Iron Age through the Hellenistic Era pertain to the Geometric and Archaic periods of the Iron Age. On Politiko-*Troullia*, this evidence is notable near the high point of *Troullia* East, where the 2004 survey produced a ceramic Iron Age helmeted figurine (Falconer et al., 2005, Fig. 10). However, the excavation of nearby Area L in 2007 produced no stratified evidence of post-Bronze Age deposition or occupation. The spatial patterning of Iron Age-Hellenistic pottery also is noteworthy for its discontinuous hotspots on the slopes of *Koloikremmos*. Unlike Bronze Age patterns, the mean Iron Age-Hellenistic sherd density and its ubiquity are greater on Politiko-*Koloikremmos* than on *Troullia*. While the abundance of sherds on *Koloikremmos*' terraced fields approaches that for the Prehistoric Bronze Age, Iron Age-Hellenistic pottery is less than one-third as dense on Politiko-*Troullia*, is only about one-half as dense overall, and is not associated with any excavated evidence. However, sherds are more ubiquitous on *Koloikremmos* for this time range than for any other period.

Pottery from the Roman through Medieval periods (consisting primarily of Roman sherds) is distributed less densely and less ubiquitously than for the preceding Iron Age-Hellenistic Period. Although found in 26% of sample circles overall, only one circle (S47) produced more than five sherds, creating a plot that suggests a single location of concentrated Roman ceramic deposition. As seen in the Iron Age-Hellenistic evidence, pottery density and ubiquity are greater on *Koloikremmos* than on *Troullia*. Interestingly, although a buried medieval pipeline crossed Politiko-*Troullia* West (Falconer et al., in press), mean total sherd concentration for the Roman-Medieval timespan is nearly as low as that of the Protohistoric Bronze Age.

Ceramic roof tile fragments were recovered from only one collection circle on Politiko-*Troullia* (on its eastern edge).

Nonetheless, the mean tile concentration on *Koloikremmos* is comparable to those for Prehistoric Bronze Age and Iron Age-Hellenistic sherds, but in an extremely concentrated and confined spatial pattern, as reflected by the lower overall ubiquity of tile fragments. Roof tile remains describe a striking down slope flow from the top of *Koloikremmos* into the upper portions of the ravine that drains the hill's northern slopes.

3.2. Terrace types and environmental analyses

Our linear regressions began with simple exploratory scatterplots that related terrace wall length to elevation, slope, SAVI based on Ikonos 4 m and 12 m resolution, and SAVI based on Quickbird 4 m and 12 m resolution (Fig. 8). Initial scatterplots and regressions showed that the 4 m data for both satellites were slightly preferable, and that terrace wall length did not vary systematically with elevation. Our linear regression analyses continued by investigating the relationship between the dependent variable of terrace wall length and three independent variables: slope, Quickbird 4 m SAVI and Ikonos 4 m SAVI. This analysis produces a model that minimizes the squared error between the modeled regressions for the independent variables and the observed values of the dependent variable. We evaluated the regression model using backward selection of variables, a procedure that permits step-wise elimination of variables based on their lack of statistical significance (i.e., P values >0.05). Step 1 involves a multiple linear regression of terrace wall length on slope, Quickbird SAVI and Ikonos SAVI, in which only Ikonos SAVI produces a statistically significant result (Table 3). Elimination of the independent variable with the highest P value in step 1 (Quickbird SAVI) leads to Step 2, a regression of wall length on slope and Ikonos SAVI, in which Ikonos SAVI again emerges as a significant variable. Elimination of slope in Step 2 then produces a final regression that highlights the consistently significant relationship (note also the decreasing standard error with each step) in which higher SAVI values, indicative of greater spring vegetation, correlate with longer terrace walls. A scatterplot and linear regression of the lengths of Type 1 and 2 walls (≥ 2 m) on Ikonos SAVI reiterates the correlation of longer terrace walls with greater spring vegetation (Fig. 9). Interestingly, Type 2 terrace walls (median length = 29.5 m) commonly are longer than Type 1 walls (median length = 4.00 m). Jointly, these results raise the likelihood that longer terrace walls (including most Type 2 walls) more often serve to retain plant-bearing arable field plots, whereas less vegetated shorter terrace walls (usually Type 1) may have served primarily to control erosion.

Terrace wall configuration and land use may be considered further through logistic regression, which provides a means for assessing the independent environmental and archaeological variables that are most informative for predicting Type 2 terrace walls from Type 1 walls. Logistic regression, in contrast to linear regression, considers a dichotomous dependent variable (Hosmer and Lemeshow, 2000). In this case the dichotomous dependent variable is terrace wall type (Type 2 vs. Type 1). We used a maximum likelihood estimator to calculate regression coefficients for independent spatial and vegetation parameters, and period-by-period sherd and tile densities. These coefficients are incorporated in an odds ratio equation to calculate the likelihood of distinguishing a Type 2 terrace wall from a Type 1 wall on the basis of the independent variables. In a manner similar to the linear regression analysis above, we used backward elimination as a step-wise means to discard statistically insignificant independent variables. Previous studies (e.g., Flack and Chang, 1987; Freedman, 1983) suggest that too many variables may obscure meaningful analytic results. Therefore, we segregated our analysis into three parts, each with different combinations of independent variables.

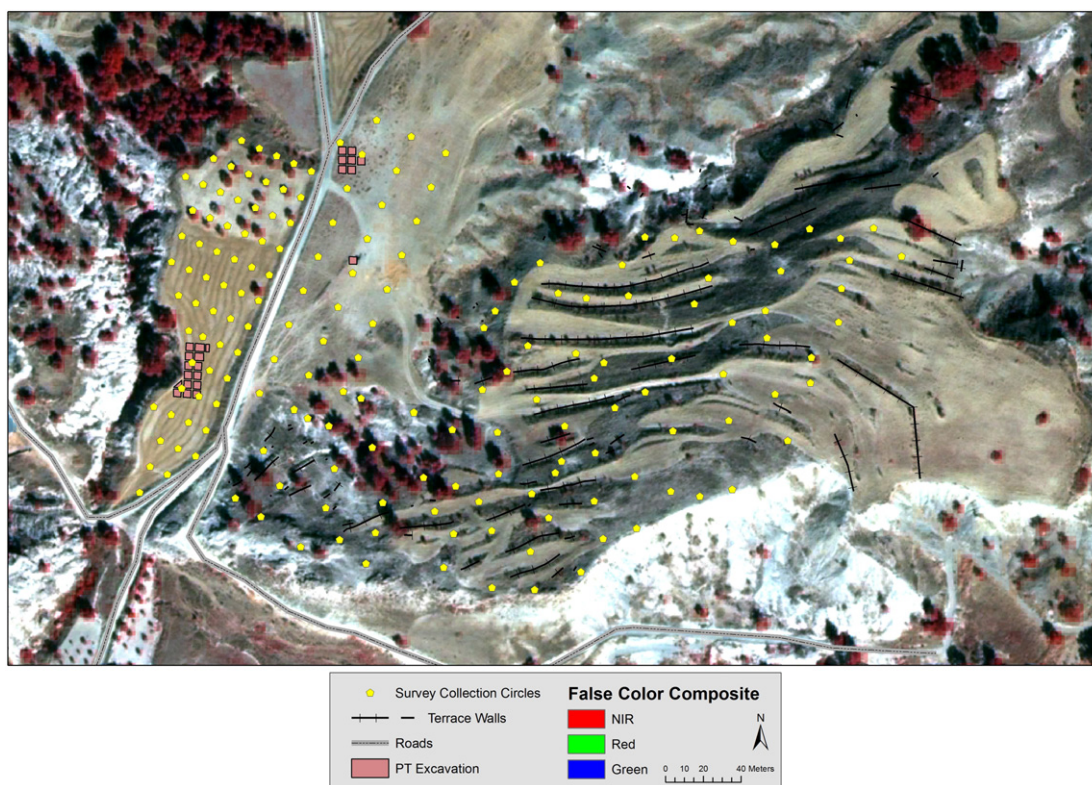


Fig. 8. Quickbird false color composite image (October 2003) of vegetation on Politiko-Troullia and surrounding landscape showing survey collection circles, terrace walls, and excavation units. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Part 1 considered the independent environmental variables of slope, Quickbird 4 m SAVI, Ikonos 4 m SAVI and terrace wall length. In this part, Step 1 eliminated Ikonos SAVI and Step 2 eliminated slope, leaving a significant negative regression based on Quickbird SAVI (Table 4). As with our linear regressions involving wall length, the significant independent variable (in this case Quickbird SAVI) provides P values < 0.05 through all three steps. This Part 1 logistical regression shows that, among environmental variables, Type 2 terrace walls (vs. Type 1 walls) can be predicted from lower mean Quickbird SAVI values. Conversely, higher Quickbird SAVI values are indicative of Type 1 walls and greater active fall vegetation, which consists primarily of trees (rather than shallow-rooted grasses that are dormant in the autumn months, see Fig. 8).

Our Part 2 logistical regression analysis considered independent variables that permit prediction of Type 2 vs. Type 1 terrace walls. These variables include mean sherd densities (based on interpolated values in a 4 m buffer around each terrace wall) for the Prehistoric Bronze Age, Protohistoric Bronze Age, Iron Age-Hellenistic Period and Roman-Medieval Era. In this part, Step 1 eliminated Protohistoric Bronze Age sherd density, Step 2 eliminated Iron Age-Hellenistic density, and Step 3 eliminated

Table 3
Stepwise linear regression of terrace wall length (for walls ≥ 2 m) on 4×4 m Quickbird SAVI, slope, and 4×4 m Ikonos SAVI.

Step	Ind. Variable	B	SE	P
1	QB SAVI	-0.463	0.315	0.145
	Slope	0.232	0.127	0.070
	IK SAVI	0.661	0.162	<0.0001
2	Slope	0.147	0.113	0.198
	IK SAVI	0.470	0.098	<0.0001
3	IK SAVI	0.564	0.066	<0.0001

P values < 0.05 in bold.

Roman-Medieval density, leaving Prehistoric Bronze Age sherd density as the sole significant archaeological variable for predicting Type 2 from Type 1 terrace walls (as shown in the last two steps in Table 5). In this instance, a negative regression reveals that lower

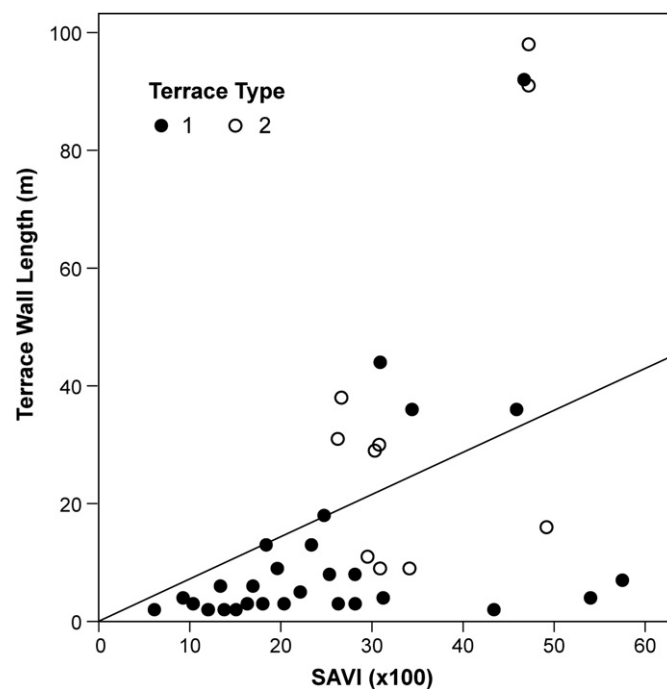


Fig. 9. Linear regression of terrace wall length on SAVI (soil-adjusted vegetation index) values, with Type 1 (median length = 4.00 m) and Type 2 (median length = 29.50 m) terrace walls indicated. Regression: $y = 0.716x$, $R^2 = 0.495$, $P < 0.0001$.

Table 4

Part 1 stepwise logistical regression distinguishing Type 2 from Type 1 terrace walls based on 4 × 4 m Ikonos SAVI, slope, and 4 × 4 m Quickbird SAVI.

Step	Ind. Variable	B	SE	P	Exp (B)
1	IK SAVI	0.044	0.033	0.179	1.045
	Slope	0.040	0.027	0.133	1.041
	QB SAVI	−0.192	0.092	0.038	0.826
2	Slope	0.028	0.023	0.228	1.029
	QB SAVI	−0.096	0.045	0.032	0.908
3	QB SAVI	−0.051	0.021	0.014	0.951

P values < 0.05 in bold.

Prehistoric Bronze Age sherd densities are indicative of Type 2 walls, and conversely that greater Prehistoric densities tend to indicate Type 1 walls.

Part 3 of our logistical regression analysis considers the significant variables identified by Parts 1 and 2: Quickbird 4 m SAVI and Prehistoric Bronze Age sherd density. This analysis eliminates Quickbird SAVI in Step 1, leaving Prehistoric Bronze Age sherd density as the most important independent variable, among all the environmental and archaeological variables considered in this study, for distinguishing Type 2 from Type 1 terrace walls (Table 6). Once again, lower sherd densities indicate Type 2 walls and, conversely, higher Prehistoric sherd densities indicate Type 1 walls.

4. Discussion

A variety of studies on Cyprus and elsewhere in the eastern Mediterranean (e.g., Cherry et al., 1991, 460–461; Cherry and Davis, 2001; Keswani, 1996; Knapp, 1997) propose Bronze Age settlement hierarchies with diversified coastal centers linked to inland towns that controlled rural villages and sanctuaries. The relatively scant Prehistoric Bronze Age ceramics and dispersed site locations reported by the Sydney Cyprus Survey (Given and Knapp, 2003, plate XLVII) suggest that the villagers of Politiko-Troullia inhabited a very sparsely populated countryside, in stark contrast to the later political and religious prominence of nearby Tamassos. In light of the rough mean of 20 sherds/100 m² suggested as agricultural background (Given and Knapp, 2003, 121), the densities of 30–50 sherds/100 m² on Koloikremmos and Troullia reveal an intensely utilized, but apparently isolated, agrarian locality. Linear and logistic regressions build an indirect case for local land use in which shorter Type 1 terrace walls are distinguished best by nearby or directly associated Prehistoric Bronze Age pottery and higher Quickbird SAVI values. Jointly, these results suggest the continued ability of Type 1 walls to restrain deep pockets of slope wash, which support some modern deep-rooted trees on small terraces, but otherwise gradually buried the settlement of Politiko-Troullia.

The subsequent urbanization of Cyprus in the Protohistoric Bronze Age is marked locally by notable sherd densities in the fields

Table 5

Part 2 stepwise logistical regression distinguishing Type 2 from Type 1 terrace walls based on sherd density by archaeological period (P values < 0.05 in bold).

Step	Ind. Variable	B	SE	P	Exp (B)
1	ProtoBA	−18.126	77.482	0.815	<0.0001
	IA-Hell	−0.188	0.210	0.370	0.829
	Rom-Med	0.716	0.477	0.134	2.045
	PreBA	−0.285	0.192	0.137	0.752
2	IA-Hell	−0.181	0.210	0.389	0.834
	Rom-Med	0.748	0.484	0.122	2.112
	PreBA	−0.330	0.179	0.065	0.719
3	Rom-Med	0.462	0.293	0.115	1.588
	PreBA	−0.428	0.148	0.004	0.652
4	PreBA	−0.325	0.108	0.003	0.723

Table 6

Part 3 stepwise logistical regression distinguishing Type 2 from Type 1 terrace walls based on 4 × 4 m Quickbird SAVI and Prehistoric Bronze Age (PreBA) sherd density (P values < 0.05 in bold).

Step	Ind. Variable	B	SE	P	Exp (B)
1	QB SAVI	0.047	0.036	0.189	1.048
	PreBA	−0.499	0.191	0.009	0.607
2	PreBA	−0.325	0.108	0.003	0.723

of the medieval monastery of Ayios Mnason, west of Tamassos and, to a lesser extent, elsewhere along the transects of the Sydney Cyprus Survey (Given and Knapp, 2003, plate XLVII). Among habitation sites, the Protohistoric Bronze Age villages of Aredhiou-Vouppes (Given and Knapp, 2003, 179) and Analiondas-Palioklichia (Webb and Frankel, 1994) lie several kilometers to the west and east, respectively. On the larger international stage of this era, the Amarna Letters mention a king of Alashiya, perhaps in reference to Cyprus or more likely its largest center at Enkomi (Malbran-Labat, 1999). In the midst of this local and island-wide political coalescence, our sherd densities, which are diminished by an order of magnitude or more, suggest that Politiko-Troullia stood abandoned, its adjacent fields apparently unused.

In contrast to modest and dispersed Bronze Age signatures, the Sydney Cyprus Survey reports abundant Iron Age and Classical Period remains, culminating in particularly high sherd densities along its eastern most transect, which runs nearest Politiko-Troullia (Given and Knapp, 2003, plates XXVI and XLVIII). This patterning around the city, sanctuary and tombs of ancient Tamassos (Politiko-Chomazoudhia) reflects the ascent of this community as one of ten island city-states by the seventh century B.C. (Buchholz and Untiedt, 1996). Our mean sherd densities approximating 20 sherds/100 m² and higher in the fields of Koloikremmos than on Troullia are consistent with manuring patterns. Alternatively, the low but discernible sherd peaks may indicate dispersed field structures or farmsteads, as found contemporaneously in southern Greece (Alcock, 1993: 48). During this era, particularly the Geometric and Archaic components of the Iron Age that provide the bulk of our evidence for this era, the fields of Koloikremmos and Troullia constituted part of the local agricultural hinterland for this emerging polity.

Roman through Medieval remains on and around Troullia and Koloikremmos reflect widespread and long-lived field systems beginning in the Late Roman Period, but historically more clearly associated with Medieval agrarian estates at Psimoloufou several kilometers to the north and around the nearby monasteries of Ayios Irakleidios and Ayios Mnason (Given, 2000). Sherd distributions, especially in the lower elevation coverage of the Sydney Cyprus Survey (Given and Knapp, 2003, plates XXVII, XXVIII, XLIX and L) are consistent with the development of peasant villages and manuring patterns on the broad lands below the ruins of abandoned Tamassos. The evidence from the higher elevation locale of Troullia and Koloikremmos now suggests very limited use, possibly involving only an isolated hilltop structure, as the most peripheral element in a landscape reoriented for extensive cultivation in a broadly spread manorial system.

5. Conclusions

Archaeological evidence, agricultural terraces and environmental parameters illuminate prehistoric and early historic agrarian landscapes in a locality marked by four millennia of settlement and agriculture on central Cyprus. Analysis of interpolated sherd distributions, modes of terrace wall construction, and remotely sensed data portray four eras of distinct agricultural land

use. Results suggest intensive utilization of terraced hill slopes adjacent to the Prehistoric Bronze Age settlement of Politiko-Troullia, and in association with the nearby Iron Age city of Tamassos. In contrast, a striking dearth of evidence suggests local abandonment during the initial urbanization of Cyprus in the Protohistoric Bronze Age. Land use during the Roman through Medieval periods leaves a restricted signature, most likely relating to an isolated structure on *Koloioikremmos*, as a peripheral element of monasteries and agrarian estates to the north. Coordinated geographical and archaeological analyses permit inference of shifting agricultural landscapes during the oscillations of Cypriot agrarian economy and society.

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Appendix. Supplementary material

Supplementary material related to this article can be found at doi:10.1016/j.jas.2012.02.010.

References

- Alcock, S.E., Cherry, J.F., 2004. Side-by-Side Survey: Comparative Regional Studies in the Mediterranean World. Oxbow Books, Oxford.
- Alcock, S.E., Cherry, J.F., Davis, J.L., 1994. Intensive survey, agricultural practice and the classical landscape of Greece. In: Morris, I. (Ed.), *Classical Greece: Ancient Histories and Modern Archaeologies*. Cambridge University Press, Cambridge, pp. 137–170.
- Alcock, S.E., 1993. *Graecia Capta: The Landscapes of Roman Greece*. Cambridge University Press, Cambridge.
- Ammerman, A.J., 1985. The Acconia Survey: Neolithic Settlement and the Obsidian Trade. University of London, Institute of Archaeology Occasional Paper 10. University College London Press, London.
- Astill, G., Davies, W., 1997. *A Breton Landscape*. University College London Press, London.
- Astrom, P., 1985. Hala Sultan Teke. In: Karageorghis, V. (Ed.), *Archaeology in Cyprus 1960–1985*. A.G. Leventis Foundation, Nicosia, pp. 173–181.
- Ault, B.A., 1999. Koprone and oil presses at Haliëis: interactions of town and country and the integration of domestic and rural economies. *Hesperia* 68, 549–573.
- Bakels, C.C., 1997. The beginnings of manuring in western Europe. *Antiquity* 71, 442–445.
- Barker, G., Gilbertson, D., Mattingly, D. (Eds.), 2007. *Archaeology and Desertification - The Wadi Faynan Landscape Survey*, Southern Jordan. Council for British Research in the Levant and Oxbow Books, Oxford.
- Barker, G., 2011. The desert and the sown: Nomad–farmer interactions in the Wadi Faynan, southern Jordan. *Journal of Arid Environments*. doi:10.1016/j.jaridenv.2011.11.023.
- Bevan, A., Conolly, J., 2009. Modelling spatial heterogeneity and nonstationarity in artifact-rich landscapes. *Journal of Archaeological Science* 36, 956–964.
- Bevan, A., Conolly, J., 2011. Terraced fields and Mediterranean landscape structure: an analytical case study from Antikythera, Greece. *Ecological Modelling* 222, 1303–1314.
- Bintliff, J., Snodgrass, A., 1988. Off-site pottery distributions: a regional and inter-regional perspective. *Current Anthropology* 29, 506–513.
- Bintliff, J., Howard, P., Snodgrass, A., 1999. The hidden landscape of prehistoric Greece. *Journal of Mediterranean Archaeology* 12, 139–168.
- Buchholz, H.-G., Untiedt, K., 1996. Tamassos. Ein Antikes Königreich auf Zypern. In: *Studies in Mediterranean Archaeology and Literature*, Pocketbook 136. P. Astrom Forlag, Jonsered.
- Buchholz, H.-G., 1982. Bronzezeitliche Brettspiele aus Zypern. *Acta Praehistorica et Archaeologica* 13/14, 67–73.
- Cadogen, G., 1984. Maroni and the Late Bronze Age of Cyprus. In: Karageorghis, V., Muhly, J.D. (Eds.), *Cyprus at the Close of the Late Bronze Age*. A.G. Leventis Foundation, Nicosia, pp. 1–10.
- Cadogen, G., 1986. Maroni II, Report of the Department of Antiquities, Cyprus 1986: 40–44 pp.
- Cherry, J.F., Davis, J.L., 2001. Under the scepter of Agamemnon: the view from the hinterlands of Mycenae. In: Branigan, K. (Ed.), *Urbanism in the Aegean Bronze Age*. Sheffield Academic Press, Sheffield, pp. 141–159.
- Cherry, J.F., Davis, J.L., Mantzourani, E., 1991. *Landscape Archaeology as Long-term History: The Keos Survey*. UCLA Institute of Archaeology, Los Angeles.
- Coleman, J.E., Barlow, J.A., Mogelonsky, M.K., Schaar, K.W., 1996. Alambra: a Middle Bronze Age Settlement in Cyprus. In: *Archaeological Investigations by Cornell University 1974–1985*. Studies in Mediterranean Archaeology 118. P. Astroms Forlag, Jonsered.
- Conolly, J., Lake, M., 2006. *Geographic Information Systems in Archaeology*. Cambridge University Press, Cambridge.
- Courtois, J.-C., Lagarce, J., Lagarce, E., 1986. *Enkomi et le Bronze Récent à Chypre*. A.G. Leventis Foundation, Nicosia.
- Creighton, O., Barker, G., Mattingly, D., 2007. Recording and classifying the archaeological record. In: Barker, G., Gilbertson, D., Mattingly, D. (Eds.), *Archaeology and Desertification - The Wadi Faynan Landscape Survey*, Southern Jordan, Levant Supplementary Series. Oxbow Books, Oxford, pp. 97–140.
- Deckers, K., 2003. The western Cyprus Geoarchaeological survey: some case studies. In: Brysbaert, A., de Bruijn, N., Gibson, E., Michael, A., Monaghan, M. (Eds.), *Symposium on Mediterranean Archaeology 2002*. British Archaeological Reports, International Series 1142, Oxford, pp. 27–34.
- Falconer, S.E., Fall, P.L., Horowitz, M.T., Hunt, J., 2005. Initial archaeological investigations at Politiko-Troullia, 2004, Report of the Department of Antiquities, Cyprus 2005: 69–85 pp.
- Falconer, S.E., Fall, P.L., Hunt, J., Metzger, M.C., in press. *Agrarian Settlement at Politiko-Troullia*, 2008. Report of the Department of Antiquities, Cyprus 2010.
- Fall, P.L., Falconer, S.E., Horowitz, M., Hunt, J., Metzger, M.C., Ryter, D., 2008. *Bronze Age Settlement and Landscape of Politiko-Troullia, 2005–2007*, Report of the Department of Antiquities, Cyprus 2008: 183–208 pp.
- Finkelstein, I., 1988. *The Archaeology of the Israelite Settlements*. Israel Exploration Society, Jerusalem.
- Flack, V.F., Chang, P.C., 1987. Frequency of selecting noise variables in subset regression analysis: a simulation study. *American Statistician* 41, 84–86.
- Frankel, D., Webb, J.M., 1996. Marki Alonia. An Early and Middle Bronze Age Town in Cyprus. Excavations 1990–1994. In: *Studies in Mediterranean Archaeology* 123: 1. P. Astroms Forlag, Jonsered.
- Frankel, D., Webb, J.M., 2006. Marki Alonia. An Early and Middle Bronze Age Settlement in Cyprus. Excavations 1995–2000. In: *Studies in Mediterranean Archaeology* 123: 2. P. Astroms Forlag, Jonsered.
- Frankel, D., 1974a. A Middle Cypriot Vessel with Modelled Figures from Politiko Lambertis, Report of the Department of Antiquities, Cyprus 1974: 43–50 pp.
- Frankel, D., 1974b. Middle Cypriot White Painted Pottery: An Analytical Study of the Decoration. In: *Studies in Mediterranean Archaeology* XLII. Göteborg.
- Frederick, C., Krahtopoulou, A., 2000. Deconstructing agricultural terraces: examining the influence of construction method on stratigraphy, dating and archaeological visibility. In: Halstead, P., Frederick, C. (Eds.), *Landscape and Landuse in Postglacial Greece*. Sheffield Academic Press, Sheffield, pp. 79–94.
- Freedman, D.A., 1983. A note on screening regression equations. *American Statistician* 37, 152–155.
- Gerrard, C., 1997. Misplaced faith? Medieval pottery and fieldwalking. *Medieval Ceramics* 21, 61–72.
- Gibson, S., Ibbs, B., Klöner, A., 1991. The Sataf Project of landscape archaeology in the Judean hills. *Levant* 23, 29–54.
- Given, M., Knapp, A.B., 2003. The Sydney Cyprus Survey Project: Social Approaches to Regional Archaeological Survey. The Cotsen Institute of Archaeology, University of California, Los Angeles.
- Given, M., 2000. Agriculture, settlement and landscape in Ottoman Cyprus. *Levant* 32, 215–236.
- Given, M., 2002. Sydney Cyprus Survey Project. *Gazetteer of Places of Special Interest*. Cyprus American Archaeological Research Institute, Cyprus.
- Hadjisavvas, S., 1988. Olive Oil Production in Ancient Cyprus, Report of the Department of Antiquities, Cyprus 1988: 111–120 pp.
- Hadjisavvas, S., 1989. A late Cypriot community at Alassa. In: Peltenberg, E. (Ed.), *Early Society in Cyprus*. University of Edinburgh, Edinburgh.
- Hadjisavvas, S., 1992. Olive Oil Processing in Cyprus From the Bronze Age to the Byzantine Period. *Studies in Mediterranean Archaeology* XCIX. Paul Astroms Forlag, Nicosia.
- Hadjisavvas, S., 2003. The production and diffusion of olive oil in the Mediterranean, ca. 1500–500 BC. In: Stampolidis, N.C., Karageorghis, V. (Eds.), *Interconnections in the Mediterranean, 16th–6th c. BC*. Athens: University of Crete, Leventis Foundation, Athens, pp. 117–123.
- Held, S.O., 2003. The regional archaeological survey. In: Swiny, S. (Ed.), *Sotira Kaminoudhia: An Early Bronze Age Site in Cyprus*. CAARI Monograph Series, vol. 4. ASOR Archaeological Reports number 8. Boston: American Schools of Oriental Research, Boston, pp. 467–474.
- Hopkins, D.C., 1985. *The Highlands of Canaan: Agricultural Life in the Early Iron Age*. Almond Press, Decatur, Georgia.
- Hosmer, D.W., Lemeshow, S., 2000. *Applied Logistical Regression*, second ed. Wiley, New York.
- Huete, A.R., 1988. A soil-adjusted vegetation index (SAVI). *Remote Sensing of Environment* 25, 295–309.

- Karageorghis, V., 1965. A Late Cypriot Tomb at Tamassos, Report of the Department of Antiquities, Cyprus 1965: 11–29 pp.
- Karageorghis, V., 1987. Excavations at Kition V. The Pre-Phoenician Levels. Part II. Department of Antiquities, Cyprus.
- Keswani, P.S., 1996. Hierarchies, heterarchies, and urbanization processes: the view from Bronze Age Cyprus. *Journal of Mediterranean Archaeology* 9, 211–249.
- Klinge, J., Fall, P.L., 2010. A paleoethnobotanical analysis of Bronze Age land use and land cover in the eastern Mediterranean. *Journal of Archaeological Science* 37, 2622–2629.
- Knapp, A.B., 1997. The Archaeology of Later Bronze Age Cypriot Society: The Study of Settlement, Survey and Landscape. Occasional Paper 4. Department of Archaeology, University of Glasgow, Glasgow.
- Levy, T.E., Alon, D., 1987. Settlement patterns along the Nahal Beersheva–Lower Nahal Besor: models of Subsistence in the northern Negev. In: Levy, T.E. (Ed.), *Shiqmim I*, British Archaeological Reports. International Series 356, Oxford, pp. 45–138.
- Malbran-Labat, F., 1999. Nouvelles Données Epigraphiques sur Chypre et Ougarit, Report of the Department of Antiquities, Cyprus 1999: 121–123 pp.
- Masson, O., 1964. Kypriaka I. Recherches sur les antiquites de Tamassos. *Bulletin de Correspondance Hellenique* 88, 199–238.
- Newson, P., Barker, G., Daly, P., Mattingly, D., Gilbertson, D., 2007. The Wadi Faynan field systems. In: Barker, G., Gilbertson, D., Mattingly, D. (Eds.), *Archaeology and Desertification - The Wadi Faynan Landscape Survey, Southern Jordan*. Levant Supplementary Series, Oxbow Books, Oxford, pp. 141–174.
- Noller, J., Wells, L., 2003. Mitsero Lambdhiotissa: check dams and Byzantine Church. In: Given, M., Knapp, A.B. (Eds.), *The Sydney Cyprus Survey Project. Social Approaches to Regional Archaeological Survey*. Monumenta Archaeologica 21. Los Angeles: Cotsen Institute of Archaeology, UCLA, Los Angeles, pp. 187–192.
- Rackham, O., Moody, J., 1996. *The Making of the Cretan Landscape*. Manchester University Press, New York.
- Sandor, J.A., Eash, N.S., 1991. Significance of ancient agricultural soils for long-term agronomic studies and sustainable agriculture research. *Agronomy Journal* 83, 29–37.
- South, A.K., 1992. Kalavassos–Ayios Dhimitrios 1991, Reports of the Department of Antiquities, Cyprus: 133–146 pp.
- Spencer, J.E., Hale, G.A., 1961. The origin, nature, and distribution of agricultural terracing. *Pacific Viewpoint* 2, 1–40.
- Swiny, S., Rapp, G., Herscher, E. (Eds.), 2003. *Sotira Kaminoudhia: An Early Bronze Age Site in Cyprus*. CAARI Monograph Series, vol. 4. ASOR Archaeological Reports number 8. American Schools of Oriental Research, Boston.
- Taylor, J., 1957. *Myrtou Pighades, A Late Bronze Age Sanctuary in Cyprus*. Ashmolean Museum, Oxford.
- Tobler, W., 1970. A computer movie simulating urban growth in the Detroit region. *Economic Geography* 46, 234–240.
- Treacy, J.M., Denevan, W.M., 1994. The creation of cultivable land through terracing. In: Miller, N.F., Gleason, K.L. (Eds.), *The Archaeology of Garden and Field*. University of Pennsylvania Press, Philadelphia.
- Wagstaff, M., 1992. Agricultural terraces: the Vasilikos Valley, Cyprus. In: Bell, M., Boardman, J. (Eds.), *Past and Present Soil Erosion: Archaeological and Geographical Perspectives*. Oxbow Books, Oxford, pp. 155–161.
- Warnock, P., 2007. Identification of Ancient Olive Oil Processing Methods Based on Olive Remains. *British Archaeological Reports, International Series 1635*, Oxford.
- Webb, J., Frankel, D., 1994. Making an impression: storage and surplus finance in late Bronze Age Cyprus. *Journal of Mediterranean Archaeology* 7, 5–26.
- Weinberg, S.S., 1983. *Bamboula at Kourion: The Architecture*. University of Pennsylvania Museum.
- Wilkinson, T.J., 1989. Extensive sherd scatters and land-use intensity: some recent results. *Journal of Field Archaeology* 16, 31–46.
- Wilkinson, T.J., 2003. *The Archaeological Landscape of the Near East*. University of Arizona Press, Tucson.
- Wright, G.R.H., 1992. *Ancient Building in Cyprus*. New York and Köln, Leiden.
- Yorson, R.M., Gaffney, V.L., Reynolds, P.J., 1990. Simulation of artifact movement due to cultivation. *Journal of Archaeological Science* 17, 67–83.